NOVA PBS



# MAKING STUFF WITH DAVID POGUE



# Outreach Toolkit

# Contents

# About MAKING STUFF

NOVA's exciting four-part documentary series, *Making Stuff*, takes viewers on a thrilling tour of the material world and presents dramatic stories about how the field of materials science has changed history and is shaping the future. Each episode—*Stronger*, *Smaller*, *Cleaner*, and *Smarter*—gives viewers a behind-the-scenes look at scientific innovations that are happening every day on the frontiers of scientific research and ushering in a new generation of materials. *Making Stuff* is hosted by respected journalist, *New York Times* technology columnist, and Emmy Award–winning CBS News correspondent David Pogue. *Making Stuff* premieres on PBS in January 2011 (check your local listings).

### *Making Stuff: Stronger*

The series begins with a quest for the world's strongest stuff. David Pogue helps viewers understand what defines strength by testing the world's strongest materials. He examines everything from mollusks, Kevlar®, and carbon nanotubes to the beak of the toucan and spider silk. He travels to the deck of a U.S. naval aircraft carrier, rides in a crash car in a demolition derby, and visits the country's top research labs to check in with the experts who are looking to nature to create the next generation of strong "stuff."

### *Making Stuff: Smaller*

In the current Information Age, the triumphs of tiny are seen all around us: smaller transistors and microchips used in ever-shrinking laptops and cell phones. Now, David Pogue takes viewers to an even smaller world, examining the latest in high-powered nanocircuits and microrobots that may one day hold the key to saving lives and creating materials from the ground up, atom by atom. He explores the star materials of small applications, including silicon—the stuff of computer chips, and carbon—the element now being manipulated at the atomic level to produce future technology.

### *Making Stuff: Cleaner*

Batteries grown from viruses, tires made from orange peel oil, and solar cells that cook up hydrogen—these are just a few of a new generation of clean materials that could power the devices of the future. In this episode, David Pogue explores the rapidly developing science and business of clean energy and the alternative ways to generate, store, and distribute it. He investigates the latest developments in bio-based fuels and in harnessing solar energy for our cars, homes, and industry in a fascinating exploration of the "stuff" of a sustainable future.

### *Making Stuff: Smarter*

This episode looks into the growing number of materials that can shape themselves—reacting, changing, and even learning. For inspiration and ideas, scientists are turning to nature and biology and producing innovative developments in materials science. The sticky feet of geckos have yielded an adhesive-less tape. David Pogue literally swims with the sharks to understand bacteria-resistant sharkskin, which is being used to develop an antibacterial film. He also visits a scientist who has created a material that can render objects invisible. The episode concludes with the ultimate in "life-like" stuff: programmable matter that could create a duplicate of a human.


***Making Stuff*** **premieres on PBS in January 2011 (check your local listings).**

# About the MAKING STUFF Outreach Campaign

WGBH, Boston's public television station and producer of NOVA and NOVA scienceNOW, is teaming up with the Materials Research Society (MRS) to create a national education outreach campaign that will encourage appreciation and better understanding of our material world in the young and old alike.

Working with partners in museums, schools, universities, labs, and businesses across the country, the national outreach campaign will coalesce with a month of *Making Stuff* events. Local and regional outreach coalitions will create opportunities for middle and high school youth, families, educators, and engineers and scientists to access a range of engaging educational activities that explore materials science, so that "viewers" become active "doers" in the process of science and engineering.

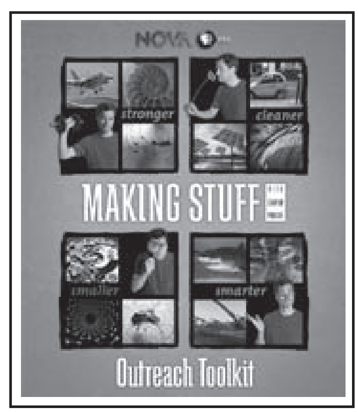
## Materials Research Society

MRS MATERIALS RESEARCH SOCIETY

*Advancing materials. Improving the quality of life.*

The Materials Research Society (MRS), a professional association of materials researchers from academia, industry, and government, has nearly 16,000 members around the world. As a professional organization for scientists, MRS is experienced at communicating complicated science topics to the public and finding new ways to engage them. To maximize the reach and impact of *Making Stuff*, MRS is drawing on its professional membership and its network of university student chapters and materials science and engineering departments, as well as expertise from the national laboratories and research centers of the National Science Foundation, the Department of Energy, the Nanoscale Informal Science Education Network, and other materials societies members. The goals of this collaboration are to enhance public engagement in and understanding of materials science, including appreciation of its effects on society; to promote sustainable collaboration among educators, scientists, and community-based organizations; and to create effective methods of expanding informal science learning.

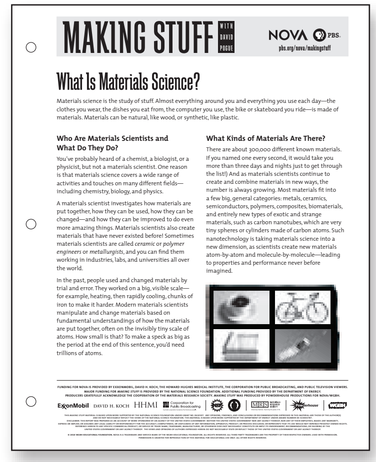
## About the MAKING STUFF Toolkit




This toolkit contains the information, guidelines, and resources needed to effectively plan and host a variety of community-based *Making Stuff* events. These materials can be adapted, expanded, shared, condensed, used, and reused. The *Making Stuff* toolkit blends print and multimedia educational resources to produce interactive events for all ages. You can use elements from any or all of these resources to customize activities that are suited to your particular audience. The *Making Stuff* toolkit includes:

- A description of the broadcast series (four one-hour documentary programs premiering nationally on PBS in January 2011)

- Guidelines for producing a variety of events, including a short presentation, materials science demonstrations, a large public event, an information table, a screening and panel discussion, a science café, training events, and youth activities, including hands-on activities and an online game
- Information sheet: *What Is Materials Science?*
- Four detailed scripts for materials science demonstrations
- An afterschool Activity Guide containing four episode-related activities
- Training presentations for scientists and educators
- *What's This Stuff? asks David Pogue* online game flyers
- Project logos that can be used to create local promotional, educational, and other collateral materials


MAKING STUFF WITH DAVID POGUE NOVA PBS pbs.org/nova/makingstuff

What Is Materials Science?

Materials science is the study of stuff. Almost everything around you and everything you use each day—the clothes you wear, the dishes you eat from, the computer you use, the bike or skateboard you ride—is made of materials. Materials can be natural, like wood, or synthetic, like plastic.

**Who Are Materials Scientists and What Do They Do?**

You've probably heard of a chemist, a biologist, or a physicist, but not a materials scientist. One reason is that materials science covers a wide range of activities and touches on many different fields—including chemistry, biology, and physics.

A materials scientist investigates how materials are put together, how they can be used, how they can be changed—and how they can be improved to do even more amazing things. Materials scientists also create materials that have never existed before! Sometimes materials scientists are called *ceramic* or *polymer engineers* or *metallurgists*, and you can find them working in industries, labs, and universities all over the world.

In the past, people used and changed materials by trial and error. They worked on a big, visible scale—for example, heating, then rapidly cooling, chunks of iron to make it harder. Modern materials scientists manipulate and change materials based on fundamental understandings of how the materials are put together, often on the invisibly tiny scale of atoms. How small is that? To make a speck as big as the period at the end of this sentence, you'd need trillions of atoms.

**What Kinds of Materials Are There?**

There are about 300,000 different known materials. If you named one every second, it would take you more than three days and nights just to get through the list!) And as materials scientists continue to create and combine materials in new ways, the number is always growing. Most materials fit into a few big, general categories: metals, ceramics, semiconductors, polymers, composites, biomaterials, and entirely new types of exotic and strange materials, such as carbon nanotubes, which are very tiny spheres or cylinders made of carbon atoms. Such nanotechnology is taking materials science into a new dimension, as scientists create new materials atom-by-atom and molecule-by-molecule—leading to properties and performance never before imagined.

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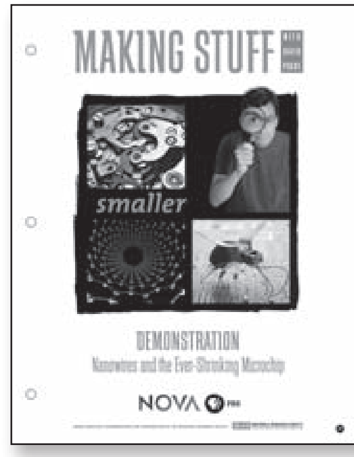
If you have any questions about *Making Stuff* or this toolkit, contact
Jennifer Larese, Outreach Coordinator, WGBH Educational Outreach,
One Guest Street, Boston, MA 02135; 617-300-4316; jennifer_larese@wgbh.org

# Resources at a Glance

These information sheets, signs, and other materials will support your efforts to host and promote successful *Making Stuff* events. These resources can be accessed online at pbs.org/nova/education/makingstuff.




### Educational Resources

- *Making Stuff* Activity Guide—This guide contains four hands-on materials science activities designed for use in afterschool programs serving students aged 10 to 12.
- *Making Stuff* Demonstrations—Four materials science demonstrations to be presented in a museum setting, or at a public event, for ages 12 and up. *Note: Most materials used in the demonstrations are readily available at hardware, home supply, or grocery stores. See the Demonstrations section for details.*
- General Resources—Reference these books, videos, and Web sites for further information on materials science.

### Information Sheets

- *What Is Materials Science?*—A brief description of materials science and materials scientists.
- *What's This Stuff? asks David Pogue* online game flyer—Solve the clues to identify the mystery material and then continue to play the game online.

### Promotional Resources

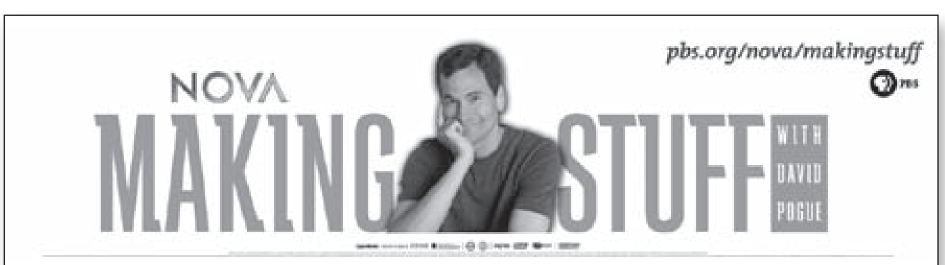
Use this resource to raise awareness about materials science at the community level as well as to promote specific *Making Stuff* events.

- *Making Stuff* customizable press release—Download and insert your own event information.

### Event Signage

Use these materials to support your efforts to host successful *Making Stuff* events.

- Demonstration signs.
- *Making Stuff* logo.



## Multimedia Resources

Use the following video clips and PowerPoint™ presentations as part of events, screenings, and educational outreach efforts.

- *Making Stuff* overview presentation
- Training Presentation for Scientists
- Training Presentation for Educators
- Screening video clip (a longer segment)
- Promotional video clip (a short series overview)
- Four video clips to accompany the four demonstrations (each segment highlights the materials science concepts related to that demonstration)

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DAVID H. KOCH HHMI Corporation for Public Broadcasting (A private corporation funded by the American people) NSF MRS MATERIALS RESEARCH SOCIETY (Advancing materials. Improving the quality of life.) Powderhouse WGBH

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# Press Release

**Contact**: ____________________  
**Phone**: ____________________

**FOR IMMEDIATE RELEASE**  
**Date**: ____________________

## ______________________________ Presents *MAKING STUFF* Event

______________________________ is partnering with WGBH/NOVA and the Materials Research Society and ____________________ to present ____________________ .

Almost everything around you—the clothes you wear, the dishes you eat from, the computer you use, the bike you ride or the car you drive—is made of stuff. Materials science is the study of stuff—what it's made of, how it works, and what we can do with it. For thousands of years, humans have been manipulating the elements and the world's raw materials. Now, scientists are generating new materials that function differently and are stronger, smaller, smarter, and cleaner than ever. Expected to revolutionize medicine and technology, these innovations are likely to result in an unprecedented trove of nifty new stuff that is sure to transform the way we live, work, and play.

Join us for ____________________ at ____________________ for ____________________. Doors open at ____________________. For further information contact ____________________

Airing in January 2011, NOVA's exciting four-part documentary series, *MAKING STUFF*, takes viewers on a thrilling tour of the material world and presents dramatic stories about how the field of materials science has changed history and is shaping the future. Each episode—*Stronger*, *Smaller*, *Cleaner,* and *Smarter*—gives viewers a behind-the-scenes look at scientific innovations that are happening every day on the frontiers of scientific research and ushering in a new generation of materials. *MAKING STUFF* is hosted by respected journalist, *New York Times* technology columnist, and Emmy Award-winning CBS News correspondent David Pogue.

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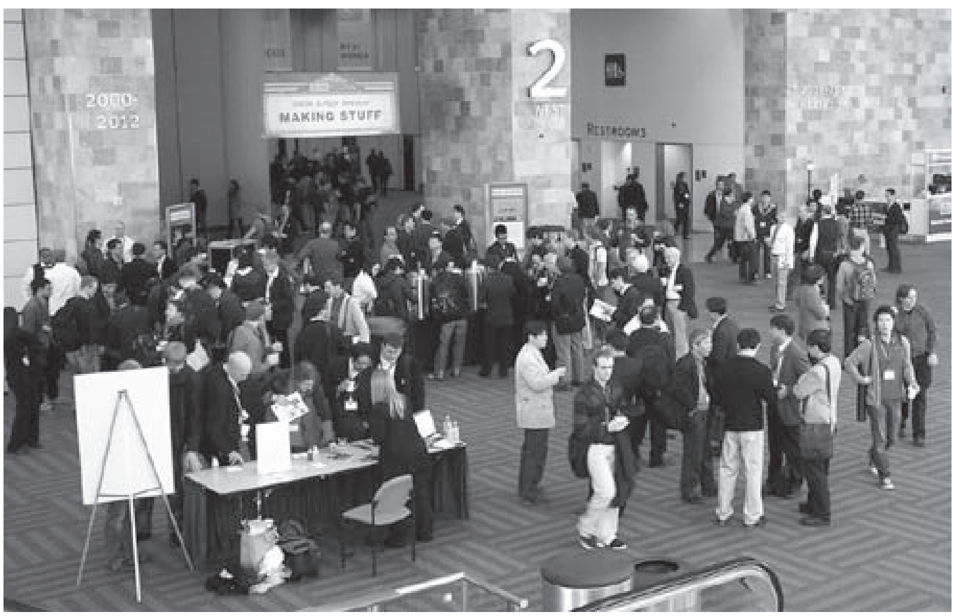
# MAKING STUFF Events & Activities at a Glance

You may be new to organizing events, or you may have years of experience. Whether you work with small groups or large ones; or in intimate settings or large venues, the step-by-step planning guidelines and resources provided here will assist you in making an event of any size a safe, rewarding, enjoyable experience for all. In addition to organizing your own event, consider finding groups in your community that are already hosting science programs and join their effort as well. Offer to host an information table, present a demonstration, furnish a video clip from the series, or coordinate a speaker for the event. Then, use the toolkit to prepare your portion of the event.

### Planning a *Making Stuff* Event

Convey the excitement and importance of materials science in our everyday lives. Reach and engage large numbers of people by joining an event—such as a community fair, festival, or professional society meeting—or by hosting one of your own.



### Hosting a *Making Stuff* Information Table

Use this versatile, flexible approach in a variety of high-traffic venues or as part of larger events to engage new audiences in materials science. Select some of the resources to display at your table and hand out to visitors.

### Giving a *Making Stuff* Presentation

Use the provided PowerPoint™ presentation, a demonstration or activity, and a video clip to engage your audience and spread the word about materials science.

## Holding a *Making Stuff* Screening and Panel Discussion

Gather a crowd, play a video clip from the *Making Stuff* program, and discuss. Or use a facilitated discussion with local materials scientists and others to introduce people to the excitement and relevance of materials science.

## Facilitating a *Making Stuff* Science Café

Invite a scientist to a bar, coffeehouse, or other venue to engage in a lively discussion about materials science. The informal setting and conversational tone help make the science accessible and engage a general audience.

## Training Educators and Scientists

Host effective communication workshops for scientists, and materials science workshops for educators. These hour-long trainings will cover project background as well as communication and engagement strategies.

## Presenting *Making Stuff* Activities & Demonstrations

Fascinate audiences with live materials science demonstrations linked to each episode. These scripted presentations demonstrate some of the principles, advances, and applications of materials science. Detailed instructions enable scientists, engineers, educators, and others to take center stage in a science center, afterschool setting, or other public venue to communicate their enthusiasm for materials science.

Partner with local afterschool or other youth groups to educate and involve young people in materials science. Choose from four activities in the *Making Stuff* Activity Guide. This inquiry-based Activity Guide engages 10- to 12-year-olds in hands-on activities to broaden their understanding of basic materials science principles and how they affect their daily lives.

At an event, distribute the *What's This Stuff? asks David Pogue* flyer. This online and in-person game will challenge participants to identify mystery materials. If possible, set up a station at an event for visitors to access the online portion of the game. See the Engaging Youth section of this toolkit, as well as the flyer, for further information.

# Planning a MAKING STUFF Event

Events can be large, multiple day affairs or smaller events that take place at a museum, university, community center, county fair, school, career fair, mall, or park. You can organize your own event or join one hosted by another group. If you decide to organize your own, the guide below provides logistical tips and strategies for running a successful event from start to finish. If you are joining someone else's event, select the planning tips that relate to your portion of the event.


## 1. Find partners for your event committee

Partners are key to developing a successful event. Recruit committee members from your coalition partners and other organizations with compatible goals. Partners can help with the planning and can often provide speakers, funding, volunteers, and publicity. Clearly define the roles and responsibilities of each participating organization to help the committee work effectively and stay on track throughout the process.

## 2. Hold a planning meeting

Below are some considerations you will want to discuss with your coalition partners.

- What is the event goal? How large a focus will there be on materials science, general science, and/or engineering?
- What is your budget for the event?
- Identify your target audience. Who will be attending the event? What is the age range?
- Estimate the size of your event. What is the ideal number of attendees?
- Select a date (and a rain date). Research other area events that may pose a conflict.
- Decide how long the event should last. Determine whether morning, afternoon, or evening is best or whether it will be a daylong event.
- Make a list of possible venues.
- Determine how many vendors, performers, speakers, and volunteers you will need and where you will find them.
- Develop a planning timeline, spelling out what needs to happen, when it needs to happen, and who is responsible for making it happen.

## 3. Select a venue

An event can be held just about anywhere, such as a museum, shopping mall, park, library, school, or youth and recreation center. When selecting a venue, consider the following:

- Is the location convenient and accessible by public transportation?
- Is it centrally located to attract passersby?
- How many people can it accommodate?

- Is it accessible to people with disabilities?
- Is there adequate parking? (Be prepared to make additional parking provisions.)
- Does the space lend itself to audience participation?
- Is there a reservation process to secure the location?
- Is there adequate access to electricity, water, and waste disposal?
- Do you need a quiet area for viewing the video clip?
- Does it have onsite audio-visual equipment and technical support, or do you need to provide this?
- Does it have restroom facilities?
- Are tables, chairs, stanchions, sign-holders, trash cans, and other furniture or equipment available for the event? Will these need to be rented from another source?
- Is a stage or other area available for a panel discussion or to present the demonstrations?
- Is a permit needed for your venue or vendors, or is it a public space?
- If insurance is required, will it be provided by you or by the venue?

## 4. Plan the agenda

Once you have identified an existing event to join or decided to create a new event, consider the following possibilities:

***Host an information table***

Showcase materials science and *Making Stuff* by hosting an information table. At your table, you can stimulate visitors' interest in materials science by showing a video clip, having them do an abbreviated activity, staging a demonstration or distributing *Making Stuff* giveaways, and engaging them in an exchange of ideas.

For more information, see the guidelines for Hosting a *Making Stuff* Information Table (page 19).

***Present Making Stuff demonstrations***

Bring the excitement of cutting-edge materials science to your audience with live, interactive demonstrations of the principles and applications of materials science. There are four to choose from:

*Making Stuff: Stronger—Breaking Point: Testing Tensile Strength*
Visitors learn that materials can be strong in different ways and that materials scientists test the strength of materials by stressing them to their breaking point.

*Making Stuff: Smaller—Nanowires and the Ever-Shrinking Microchip*
Visitors learn about extremely small, thin wires, called nanowires, that may help make computers and electronics even smaller in the future.

*Making Stuff: Cleaner—Instant Cheese Bioplastic*
Visitors learn about cleaner environmentally-friendly plastics made from biological materials.

*Making Stuff: Smarter—Shape Shifters: Shape-Memory Alloys & Polymers*
Visitors learn about two shape-memory materials that can be programmed to return to a previously set shape when exposed to heat.

For more information, see the section on Presenting *Making Stuff* Demonstrations (page 31).

***Facilitate Making Stuff activities***

Engage event attendees of all ages through *Making Stuff* activity stations. Select from the four activities in the *Making Stuff* Activity Guide.

When selecting activities, consider the following:

- What activity-to-attendee ratio do you want to provide?
- Which combination of activities best supports your event's goals?
- Have you included a variety of activities for visitors of different ages and interest levels?
- Who will organize and facilitate each activity?
- What materials do you need to collect, photocopy, or prepare before the activity?

The following is a short description of the four activities from the *Making Stuff* Activity Guide. Activities take about 45 minutes to an hour and are geared toward students aged 10 to 12, but can be enjoyed by adults as well:

*Making Stuff: Stronger—Spoon Drop Strength Test*
Participants test the strength of various readily available materials.

*Making Stuff: Smaller—Magnetic Microbot Models*
Participants build magnet-driven micro-"robots" and learn about magnetic materials and the challenges of building on the small scale.

*Making Stuff: Cleaner—Build a Cleaner Battery*
Participants build a saltwater battery and scale it up to run small electrical devices while learning about clean energy.

*Making Stuff: Smarter—Smart Glove*
Participants explore a non-Newtonian fluid, a "smart" material that thickens in response to an impact.

***Show a video clip from the Making Stuff series***

Video is a great way for attendees to visualize and understand materials science. If the event is small, propose that event organizers show a short *Making Stuff* video clip, followed by a brief presentation about materials science. For larger events, the longer video clip can be shown as a continuous loop in a designated quiet corner or separate viewing area. Pick one that meets your needs. (*Requires a video clip, laptop or DVD player, monitor, and extension cords*.) For more on ordering the *Making Stuff* series in its entirety, visit pbs.org/nova/makingstuff.

*Coordinate a speaker*

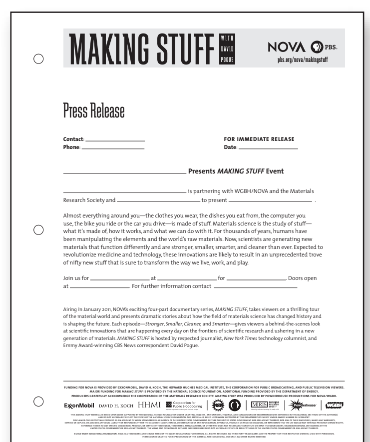
To highlight contributions of materials science to society, you may want to have one or two speakers kick off the event. Speakers may be representatives from your organization or from your event partners' organizations. Some things to consider when you have a speaker include:


- Is your potential speaker articulate and engaging?
- What are the key talking points you want the speaker to cover?
- What role do you want the speaker to play in finalizing the agenda and talking points?
- How long do you want the speaker to present?
- How will the speaker engage the audience? (A question-and-answer session? Small group discussions? Activities?)
- Who will introduce and thank the speaker?
- Where will the speaker stand?
- Can the space accommodate the expected audience?
- Do you need a podium or table?
- Does the speaker need a microphone and public address system? Props or audio-visual equipment?
- Will you hold a run-through before the actual presentation?
- Is it appropriate to include event signage or banners in this area?
- Does the speaker want to distribute handouts or do an activity with the audience?

(For a more complete set of recommendations, see the section on Holding a *Making Stuff* Screening and Panel Discussion—page 23.)

## 5. Promote and advertise the *Making Stuff* event

Promoting your event well in advance helps ensure that it is successful and that it achieves the attendance you want. To help you spread the word, use the *Making Stuff* Customizable Press Release in the *Making Stuff* Resources section to promote your event. Get the word out through:


MAKING STUFF WITH DAVID POGUE — NOVA PBS — pbs.org/nova/makingstuff

Press Release

**Contact**: ____________ **FOR IMMEDIATE RELEASE**
**Phone**: ____________ **Date**: ____________

____________ **Presents *MAKING STUFF* Event**

____________ is partnering with WGBH/NOVA and the Materials Research Society and ____________ to present ____________ .

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- TV (public service announcements, advertisements, newsletters, and member magazines)
- Radio (public service announcements, advertisements, newsletters, and member magazines)
- Community and daily newspapers (calendar listings and/or advertisements)
- Posters and flyers in the community (download a *Making Stuff* logo from pbs.org/nova/makingstuff and create your own flyer)
- Internet sites (Facebook® events, Twitter®, e-newsletters, meetup.com, craigslist.com, Classroom 2.0)
- Word of mouth: tell your friends and family
- Buttons or stickers

## 6. Recruit and coordinate volunteers

Your most valuable resources are your volunteers. Each staff member and volunteer should be assigned to a particular activity. For example:

- Welcome and information table
- Demonstrations and activity stations
- Technical support, such as audio-visual equipment and electricity

Here is a checklist of things to keep in mind as you plan for volunteers' participation:

- Appoint a volunteer manager to coordinate volunteer assignments. This person is responsible for assigning specific tasks to each volunteer, training volunteers, explaining the day's event(s) to the volunteers, answering questions, and troubleshooting.
- The number of volunteers you recruit will determine how many activities you can offer and vice versa. We recommend two volunteers to staff each activity station. Adults and responsible youths make good activity facilitators.
- If you anticipate high attendance, you may need volunteers to help with security and parking. You may also need additional volunteers at each activity station.
- Plan to provide volunteers with nametags and identifiable outfits.
- Create an event schedule that shows volunteers' assignments and break and meal times.
- Schedule volunteer training a week before the event. At the training, provide snacks and drinks (pizza is quick and easy), share the event goals and schedule, assign roles, and explain responsibilities. Have volunteers staffing the hands-on activity station do the activities themselves before the event.
- If you are able to host the training in the same location as the event itself, schedule a tour and show the volunteers where each station will be located.

## 7. Complete the on-site logistics

Whether you are planning a small event or an all-day affair, there are simple things that help traffic move smoothly, reduce overcrowding and lines, create a safe and secure environment, and help the event end on a high note for all.

***Prepare the event space***

- For large events, consider devoting multiple tables to the same activity to avoid crowding.
- Leave space between tables to prevent overcrowding.
- Arrange a U-shaped table (using three or four tables) to form a space where volunteers can work, interact with visitors, and restock supplies.
- Set up each activity in its own area with one or several six-foot tables, chairs, or stools for the activity facilitators, and at least one activity sign per table.

- Depending on the event size, you may want to set up stanchions around the demonstrations and activity areas, so as not to overwhelm the facilitators and visitors.
- Cover tables with colorful cloths. For activities involving water, use plastic tablecloths. Secure cloths with tape or clips so that they don't move while participants are working.
- Store extra supplies under the table so that they will be readily available but not in the way.
- Supply each activity area with materials and instructions. Placing instructions in a clear acrylic frame helps make them more visible.
- Place a trash container under each table.

***Post signs and photos***

Signage is a key factor in getting people to and around your event. Signs at all venue entrances should mention the event name and room location. Download the logo and create signs for the Welcome and Information tables and the podium. To display the images and signs, set them in clear acrylic table stands or mount them on foam core.

***Coordinate the volunteers***

- Schedule a day-of-event orientation at least one hour before your event opens. At this orientation, give volunteers an overview of the day, remind them of their assignments, give them their schedules, and review restroom locations and venue-specific information.
- Designate some volunteers as floaters. They can cover stations during assigned breaks and lunch.

***Clean up***

At the end of an event, the staff and volunteers are tired and there is generally a big mess. Make things easier by having lots of large trash bins, recycling boxes, dustpans, and brooms.

***Send thank you notes and debrief the event (share lessons learned)***

Whatever your event's size and scope, take the time to thank everyone involved. From the smallest task to the grandest, a thank you is greatly appreciated and garners good will.

An informal gathering with food and drink held shortly after the event is a great way to celebrate in a friendly, relaxed atmosphere. You can also use it as an opportunity to evaluate the event and learn how to improve future ones.

**Please let us know how your event went!**

Contact: Jennifer Larese
Outreach Coordinator
WGBH Educational Outreach
One Guest Street
Boston, MA 02135
617-300-4316
jennifer_larese@wgbh.org

# Hosting a MAKING STUFF Information Table

An information table is a versatile way to introduce large numbers of people to materials science and to encourage their participation in the *Making Stuff* outreach activities. You can set up a table in a variety of high-traffic venues (e.g., museums, libraries, malls, schools, universities, and faith-based organizations) or as part of larger events (e.g., fairs, professional societies, and other community-wide activities).

For many people who stop at your table, it may be the first time they have heard about materials science. When you talk with them, describe some ways that materials science impacts their daily lives.

## Setting Up Your Information Table

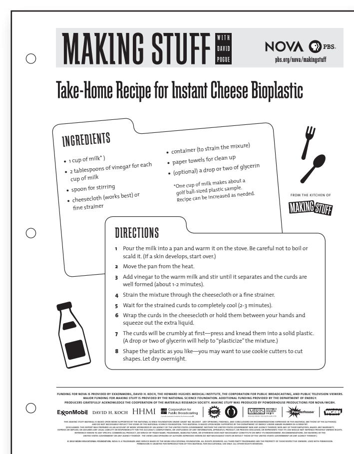
### 1. Recruit and train volunteers to staff the table

Generally, it is advisable to have two people at a table—one person to facilitate the activity and another to talk to people and replenish the table resources. In advance of the event, have them read the information sheet (*What Is Materials Science?*), watch the *Making Stuff* promotional video clip, and try any of the activities or demonstrations you choose to use. Encourage the volunteers to contact you with any questions.

### 2. Set up the table

Use the provided files or the logo to make signs for your table. Download, print, and photocopy a combination of the toolkit resources to display and distribute at your table and set out any items you plan to distribute. For example:

- Information sheet: *What Is Materials Science?*
- Recipe for instant cheese bioplastic from *Making Stuff: Cleaner* demonstration
- *Making Stuff* online game flyer: *What's This Stuff? asks David Pogue*
- An activity from the *Making Stuff* Activity Guide to do at home


MAKING STUFF WITH DAVID POGUE
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Take-Home Recipe for Instant Cheese Bioplastic

INGREDIENTS
- 1 cup of milk* )
- 2 tablespoons of vinegar for each cup of milk
- spoon for stirring
- cheesecloth (works best) or fine strainer
- container (to strain the mixure)
- paper towels for clean up
- (optional) a drop or two of glycerin

*One cup of milk makes about a golf ball-sized plastic sample. Recipe can be increased as needed.

FROM THE KITCHEN OF MAKING STUFF

DIRECTIONS
1 Pour the milk into a pan and warm it on the stove. Be careful not to boil or scald it. (If a skin develops, start over.)
2 Move the pan from the heat.
3 Add vinegar to the warm milk and stir until it separates and the curds are well formed (about 1-2 minutes).
4 Strain the mixture through the cheesecloth or a fine strainer.
5 Wait for the strained curds to completely cool (2-3 minutes).
6 Wrap the curds in the cheesecloth or hold them between your hands and squeeze out the extra liquid.
7 The curds will be crumbly at first—press and knead them into a solid plastic. (A drop or two of glycerin will help to "plasticize" the mixture.)
8 Shape the plastic as you like—you may want to use cookie cutters to cut shapes. Let dry overnight.

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### 3. Do a short demonstration or activity

Activities engage people and help them learn about materials science. See the *Making Stuff* Demonstrations section for ideas, or consider presenting a shortened version of one of the activities from the *Making Stuff* Activity Guide. (Bring enough materials for the number of people you think may visit your table.)

## 4. Show a *Making Stuff* video

A *Making Stuff* video is another way to convey information about materials science. The promotional clip provides a short introduction to the show, whereas the screening segment is longer and more detailed. Either can be played on a loop. Designate space on your table for a monitor (or computer). Make sure there is an electrical source.

## 5. Miscellaneous materials


You've established the message points you want to convey, copied the information sheets, collected materials for your activities, chosen the video clip, printed and posted the signs, and trained your staff. What's left? Make sure you have:

- Pens and pencils
- Nametags (Wear a nametag with your first name in large letters to make visitors feel comfortable.)
- Table and chairs
- Trash can

# Giving a MAKING STUFF Presentation

An effective way to spread the word about materials science is to make a short presentation to civic, educational, professional, and community-based groups. Engage your audience with a PowerPoint™ presentation, an activity or demonstration, and a video clip. These resources communicate the idea that materials science is important and has an impact on everyday life—a key message of the *Making Stuff* outreach campaign.

## Planning a Presentation


### 1. Find partners and make connections

The community organizations listed below are examples of groups that may be interested in having you present about materials science. Contact them and offer to make a presentation.

- Science and technology museums
- Major employers and businesses
- Newspaper reporters and public TV and radio station producers
- Civic organizations (e.g., Rotary, the Kiwanis, Lions Club, etc.)
- Chambers of Commerce
- Youth groups (Girl Scouts, Boy Scouts, 4-H)
- Local schools
- Education groups and teacher associations
- Local science, math, engineering, or technology conferences
- National Science Foundation Research Centers (Materials Research Science and Engineering Centers/Nanoscience Science and Engineering Centers [MRSECs/NSECs])
- Materials Research Society (MRS) university student chapters
- Nanoscale Informal Science Education (NISE) Network hubs and partners
- University materials science and engineering departments
- Department of Energy research labs
- Local science cafés

### 2. Plan your presentation

Following the steps below to educate your guests about materials science can motivate them to learn more. Mix and match the elements to suit your audience and your objectives.

***Show the Making Stuff presentation***

Use the *Making Stuff* PowerPoint™ overview presentation, which helps audiences engage and learn about materials science. It highlights the contribution of materials science in everyday life.

### *Conduct a demonstration*

Give your presentation an interactive component by having your audience participate in a hands-on demo. See the *Making Stuff* Demonstrations section of the toolkit (page 33). For other activity ideas, see the *Making Stuff* Activity Guide.

### *Show a video clip from Making Stuff*

Video can be a powerful tool for helping people visualize and understand materials science. Show the shorter promotional video clip that gives an overview of the *Making Stuff* series.

### *Distribute handouts*

Photocopy and distribute the information sheet on materials science found in the Resources section of the toolkit at pbs.org/nova/education/makingstuff.

# Holding a MAKING STUFF Screening and Panel Discussion

Screening a video clip from *Making Stuff* and following it with a facilitated discussion is an effective way to promote awareness of the relevance of materials science in your audience's daily lives. This strategy can inspire them to learn more and share their knowledge with others.

## Planning Your Screening and Panel Discussion

### 1. Find partners and make connections

For more detailed information on finding partners and making community connections, and suggestions of materials science partners, refer to the Giving a *Making Stuff* Presentation section (page 21). When making the initial contact with a group, explain who you are and that you are organizing an event in conjunction with *Making Stuff*. Before calling, review the *Making Stuff* overview PowerPoint™ presentation and be prepared to give a brief overview of the project. Consider showing potential partners the short promotional clip of the show.

### 2. Select a venue

There are many possible locations to host your event—local colleges or universities, libraries, museums, town or city halls, educational or professional organizations, or a public radio or television studio. Refer to the Planning a *Making Stuff* Event section in this toolkit (page 13) and review the questions to consider when selecting a venue. Also consider whether:

- the venue is centrally located to attract passersby,
- the space lends itself to audience participation, and
- there are facilities to allow phone-in questions and comments if the event is being broadcast.

### 3. Create an agenda

Below is a sample agenda of what your event might look like:

- Welcome and introduction of the event's materials science topic(s)
- Introduce the *Making Stuff* program and/or outreach campaign
- Introduce speaker(s)
- *Making Stuff* overview PowerPoint™ presentation
- Show the *Making Stuff* screening video clip
- Panel discussion
- Question-and-answer session
- Distribute the information sheet (*What Is Materials Science?*)

## 4. Secure presenters/facilitators

Work with your event partners to identify possible speakers, facilitators, and/or panelists. Consider tapping professional societies, such as the Materials Research Society (MRS). Also, contact universities and colleges, state and local research labs, and local MRS student chapters. Your speaker may want to use some or all of the *Making Stuff* overview presentation. When considering potential speakers and their needs, you may want to ask the following questions:

- Are your potential speakers articulate and engaging?
- What are the key talking points you want your speakers to cover?
- What role do you want the speakers to play in finalizing the agenda and talking points?
- How long do you want each presenter to speak?
- Will you hold a run-through before the actual presentation?
- How will the speakers engage the audience? (Questions and answers? Small group discussions? Activities?)
- Do the speakers want to distribute handouts or facilitate activities with the audience?
- Do the speakers need a microphone and a public address system?
- Will the speakers use props or audio-visual equipment?

For further details on promoting and advertising your event, recruiting and coordinating volunteers, and completing the onsite logistics, see the Planning a *Making Stuff* Event section of this toolkit (page 13).

MATERIALS RESEARCH SOCIETY
Advancing materials. Improving the quality of life.

# Facilitating a MAKING STUFF Science Café

## What is a Science Café?

A science café's casual meeting place, plain language, and inclusive conversation create a welcoming and comfortable atmosphere for people with a limited science background. Each meeting is organized around an interesting topic of conversation, such as plastics, nanotechnology, or alternative uses for Kevlar®. Ideally, a materials scientist will give a brief presentation and show a short video clip from *Making Stuff* to kick off the discussion.

### 1. Know your audience

A good understanding of your audience will inform every decision you make about your café. Choosing a target audience is not about whom you will let in, but rather whom you are trying to attract and make comfortable. Leveraging your coalition partners, you might want to feature multiple cafés—each café could focus on a slightly different topic that is tailored to a different audience: for example, a "junior" science café for young adults, college students, and even families.

### 2. Choose a time and place

The choice of meeting time and venue plays a large role in determining who will feel comfortable attending a café. It also affects how attendees act when they get there.


- Science cafés have been held in pubs, coffeehouses, bookstores, restaurants, art galleries, malls, and even bowling alleys. The point is to go where your audience already congregates naturally—even if it seems unconventional at first.
- Think about logistical issues, such as parking, acoustics, line of sight, reserving a block of time, flexible seating arrangements, public accessibility, and food and drink.
- Many venues have in-house audio-visual equipment, making it easy to show videos, such as the *Making Stuff* promotional video clip, and provide microphones if necessary.
- Most cafés do not pay fees to use the venue. Point out to the owner that the event will introduce the venue to many new people, and bring in new business.

### 3. Choose a moderator

The moderator can play an essential part in a café meeting. The café organizer often serve as the moderator, but this is not always the case. Either way, be clear about that role.

- A good moderator moves the event along and ensures that no one dominates the conversation (including the scientist!).

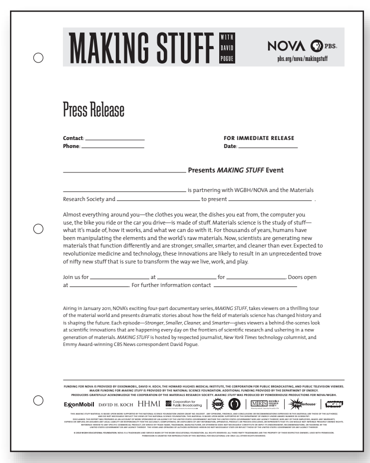
- The moderator typically introduces the scientist at the beginning of the café and keeps track of time. During the discussion, the moderator often helps the scientist keep track of who speaks next.
- The moderator may facilitate clear communication. For example, he or she may ask individuals who use technical jargon to rephrase what they want to say.
- The moderator can play a role in shaping conversation. If a particularly interesting topic is raised, the moderator may break from the routine of calling on people in the order they raised their hands to allow the room to explore a theme further.
- A group conversation that includes everyone in a room rarely happens naturally. It is up to the moderator to find ways to get as many people involved in the conversation as possible.

## 4. Choose a scientist

There are many resources beyond the local university for finding guest scientists to speak at your café. Within your coalition, ask around to find scientists and engineers who may be researching or working on a very interesting topic related to materials science.

## 5. Prepare the guest scientist

The guest scientist gets a meeting's conversation going in the right direction and helps set the overall tone of the event. Do not be shy about coaching the scientist on the audience and goals of your café. When inviting scientists to participate, be clear about their role and the atmosphere you are trying to create. Let the scientists know that you are not asking them for a speech or lecture, but for a short conversation starter. Have them consider what questions they would like to ask the audience about the topic. Help the moderator and scientist establish a rapport. If possible, introduce them to each other before a café and buy them a meal or drink. If you are using video in your café, give the scientist the opportunity to view it in advance.


MAKING STUFF WITH DAVID POGUE

NOVA PBS
pbs.org/nova/makingstuff

Press Release

**Contact**: ____________ **FOR IMMEDIATE RELEASE**
**Phone**: ____________ **Date**: ____________

____________ **Presents *MAKING STUFF* Event**

____________ is partnering with WGBH/NOVA and the Materials Research Society and ____________ to present ____________ .

Almost everything around you—the clothes you wear, the dishes you eat from, the computer you use, the bike you ride or the car you drive—is made of stuff. Materials science is the study of stuff—what it's made of, how it works, and what we can do with it. For thousands of years, humans have been manipulating the elements and the world's raw materials. Now, scientists are generating new materials that function differently and are stronger, smaller, smarter, and cleaner than ever. Expected to revolutionize medicine and technology, these innovations are likely to result in an unprecedented trove of nifty new stuff that is sure to transform the way we live, work, and play.

Join us for ____________ at ____________ for ____________. Doors open at ____________. For further information contact ____________

Airing in January 2011, NOVA's exciting four-part documentary series, *MAKING STUFF*, takes viewers on a thrilling tour of the material world and presents dramatic stories about how the field of materials science has changed history and is shaping the future. Each episode—*Stronger*, *Smaller*, *Cleaner*, and *Smarter*—gives viewers a behind-the-scenes look at scientific innovations that are happening every day on the frontiers of scientific research and ushering in a new generation of materials. *MAKING STUFF* is hosted by respected journalist, *New York Times* technology columnist, and Emmy Award-winning CBS News correspondent David Pogue.

FUNDING FOR NOVA IS PROVIDED BY EXXONMOBIL, DAVID H. KOCH, THE HOWARD HUGHES MEDICAL INSTITUTE, THE CORPORATION FOR PUBLIC BROADCASTING, AND PUBLIC TELEVISION VIEWERS. MAJOR FUNDING FOR *MAKING STUFF* IS PROVIDED BY THE NATIONAL SCIENCE FOUNDATION. ADDITIONAL FUNDING PROVIDED BY THE DEPARTMENT OF ENERGY. PRODUCERS GRATEFULLY ACKNOWLEDGE THE COOPERATION OF THE MATERIALS RESEARCH SOCIETY. *MAKING STUFF* WAS PRODUCED BY POWDERHOUSE PRODUCTIONS FOR NOVA/WGBH.

## 6. Promote your café

Word of mouth and e-mail are the most effective ways to draw people to your event. To capitalize on this, choose a catchy name, come up with intriguing descriptions for topics, think about your audience, and pick a venue that people are excited to visit and invite their friends to.

- Send notices to local calendar listings (both in print and at internet sites like craigslist.org and meetup.com).
- Many local newspapers and TV stations will list events for free.
- Post flyers in areas that are popular with your audience. (See sciencecafes.org/organizers.html for a sample flyer.)

- Choose promotional partners who will help you reach your audience. For example, if you are trying to reach people who are not already science enthusiasts, you may not want to advertise at other science events. Consider using student groups, community organizations, and local businesses as promotional partners.
- Specific topics let you reach out to groups that are not used to talking about science. For example, a science café on materials science may be an opportunity to partner with a group of green entrepreneurs or an engineering society.

## 7. Fine tune the café experience

- Mind the gap. Have you ever noticed that your café audience is the most animated during breaks? Tap into this energy by giving everyone a few minutes to socialize after a scientist has finished a presentation and before starting group discussion.
- Go beyond Q & A. A group conversation that includes everyone in a room rarely happens naturally. It is up to a café's moderator and guest scientist to find ways to get as many people involved as possible.
- Go on tour. Are people sticking around after your event is "over" to keep discussions going on their own? Having the scientist go from table to table at this point can lead to the best conversations of the event.
- Trivia. As people are arriving for a café, trivia questions can get them talking together and thinking about a topic. Or distribute the online game flyer and play *What's This Stuff? asks David Pogue*.
- Keep the momentum going. Circulate an e-mail sign-up list for future cafés in your area.
- *Making Stuff* resources that could be used at a science café include the online game flyer and the materials science information sheet.

For more information and additional resources, please visit sciencecafes.org. Feel free to contact WGBH directly for science café–related questions at: getinvolved@wgbh.org

# Training Educators and Scientists

Two PowerPoint™ training presentations found at pbs.org/nova/education/makingstuff can help your organization host effective communication workshops for scientists and materials science workshops for educators. These hour-long trainings will cover project background and communication and engagement strategies. The presentations can then be used by participants to train other teachers and scientists on how to communicate materials science to a variety of audiences.

## Educator Training


The training presentation for educators provides teachers with the information and science content they need to integrate materials science topics into their classrooms. The presentation also provides talking points and ideas for discussion while highlighting the day-to-day contributions that materials science has made to our lives, as well as discussing the science behind the headlines.

Consider a short discussion about science cafés tailored to a younger audience. A "junior" science café, in an age-appropriate venue, could be an opportunity to talk about materials science with middle and high school students.

### 1. Find educators and make connections

The educational organizations listed below are samples of those that may be interested in having you present about materials science. Contact them and offer to schedule a materials science workshop using the Training Presentation for Educators.

- Local schools (K–12)
- Informal educators at afterschool programs, science and technology museums, and children's museums
- Education groups and teacher associations
- Youth group leaders (Girl Scouts, Boy Scouts, 4-H)

### 2. Review the Training Presentation for Educators

Mix and match the elements to suit your audience and your objectives.
In addition to the training presentation, perhaps:

***Present a demonstration***

Give your presentation an interactive component by having your audience participate in a hands-on demonstration. See the *Making Stuff* Demonstrations section of the toolkit (page 33). For other activity ideas, see the *Making Stuff* Activity Guide.

***Show a video clip from* Making Stuff**

Video can be a powerful tool for helping people visualize and understand materials science.

# Scientist Training

For those who know the science, but are not sure how to talk to a lay or young audience in an engaging way about the ideas and theories behind it, this presentation will help guide them. The training presentation for scientists will highlight the main topics of materials science that align with the *Making Stuff* content, as well as offer tips on how to present the ideas in engaging and meaningful ways to your audience. Whether you are visiting a junior science café to present to high school students or talking about materials science to local teachers, the presentation will cover the what to say about materials science and how to say it for a variety of audiences.


## 1. Find scientists and make connections

The scientific organizations listed below are examples of those that may be interested in a presentation about communicating materials science to the public. Contact them and offer to schedule a workshop using the Training Presentation for Scientists.

- Science museums and technology centers
- Local science, math, engineering, or technology conferences
- National Science Foundation Research Centers (Materials Research Science and Engineering Centers/Nanoscience Science and Engineering Centers [MRSECs/NSECs])
- Materials Research Society (MRS) university student chapters
- Nanoscale Informal Science Education (NISE) Network hubs and partners
- University materials science and engineering departments
- Department of Energy research labs

## 2. Review the Training Presentation for Scientists

Mix and match the elements from the toolkit to suit the audience and objectives. In addition to the training presentation, perhaps:

***Present a demonstration***

Give your presentation an interactive component by having your audience participate in a hands-on demo. See the *Making Stuff* Demonstrations section of the toolkit (page 33). For other activity ideas, see the *Making Stuff* Activity Guide.

***Show a video clip from* Making Stuff**

Video can be a powerful tool for helping people visualize and understand materials science.

Encourage workshop participants to further spread the word about *Making Stuff* and materials science. Participating scientists may be interested in presenting the *Making Stuff* overview PowerPoint™ presentation and the *Making Stuff* promotional video clip at various events. See Giving a *Making Stuff* Presentation (page 21) for further details.

# Engaging Youth in MAKING STUFF Activities

Materials science isn't just for adults. At events, use activities from the *Making Stuff* Activity Guide to engage younger attendees at activity stations. The activities can be used as a follow-up to a demonstration or as stand-alone explorations in a variety of settings. The *Making Stuff* Activity Guide is geared toward ages 10 to 12, but the activities can be enjoyed by families and adults as well. The activities take about 45 minutes and are designed for small groups, working at or near a table. The materials are inexpensive and readily available at grocery, hardware, and home supply stores. We recommend that you collect all of the necessary materials in advance and ask the volunteers who will be facilitating the activity to practice it before the day of the event. The following is a short description of the four activities from the *Making Stuff* Activity Guide.

***Making Stuff: Stronger***
Spoon Drop Strength Test: Participants test the strength of various readily available materials, such as aluminum foil, plastic wrap, newspaper, and waxed paper.

***Making Stuff: Smaller***
Magnetic Microbot Models: Participants build small magnet-driven model "robots" and learn about magnetic materials and the challenges of building on the small scale.

***Making Stuff: Cleaner***
Build a Cleaner Battery: Participants build a saltwater battery and scale it up to run small electrical devices while learning about clean energy.

***Making Stuff: Smarter***
Smart Glove: Participants explore a non-Newtonian fluid, a "smart" material that thickens in response to an impact.

# Online Game: WHAT'S THIS STUFF? ASKS DAVID POGUE

The *What's This Stuff? asks David Pogue* online game challenges players to reveal the identity of a set of mystery materials by deciphering clues that the materials "themselves" reveal. *What's This Stuff? asks David Pogue* will engage players as they play at home or in informal educational settings. The game will launch on the NOVA Web site in conjunction with the series broadcast. See the flyer for more information and to engage visitors in an enjoyable online and in-person game.

## Extension Activities

- Consider presenting a "junior" science café in an age-appropriate venue. See Facilitating a *Making Stuff* Science Café (page 25) for further details.
- Organize an afterschool materials science club to investigate the materials all around us.

# Presenting MAKING STUFF Demonstrations

Bring the excitement of cutting-edge materials science to your audience with live, interactive demonstrations of the principles and applications of materials science with one or more of the following demonstrations, and video clips from *Making Stuff*.

***Making Stuff: Stronger—Breaking Point: Testing Tensile Strength*** (page 33)
The audience participates to test and compare the tensile strength and elasticity of Kevlar®, Nylon, and cotton thread by lifting weighted buckets with wooden dowels and then comparing the Kevlar® to steel wire. Visitors learn that materials can be strong in different ways and that materials scientists test the strength of materials by stressing them to their breaking point.

***Making Stuff: Smaller—Nanowires and the Ever-Shrinking Microchip*** (page 43)
Visitors use a Styrofoam® block and pipe cleaners to demonstrate the challenge of working on the nanoscale (placing millions of wires and transistors onto tiny chips) to produce smaller but more powerful computing and electronic devices. Visitors learn how difficult it is to work on the small scale and that materials scientists are developing extremely small, thin wires, called nanowires, that may help make computers and electronics even smaller in the future.

***Making Stuff: Cleaner—Instant Cheese Bioplastic*** (page 54)
In this two-part demonstration, visitors learn about bioplastic, a material made of plant or animal matter that is cleaner because it breaks down more easily in the environment than petroleum-based synthetic plastics. Visitors learn how to make and explore a simple bioplastic by curdling milk with vinegar in a process similar to cheese making.

***Making Stuff: Smarter—Shape Shifters: Shape-Memory Alloys & Polymers*** (page 63)
In this two-part demonstration, visitors learn about two shape-memory materials that can be programmed to return to a previously set shape when exposed to heat. Visitors also learn about exciting new smart products that materials scientists are developing to help solve problems in engineering, medicine, and everyday life.

When planning demonstrations, consider the following:

*How many attendees do you expect?*
The demonstrations can be presented at a cart, table, or stage for any number of visitors; however, an audience of 5 to 15 is recommended to ensure the highest degree of participation. Some demonstrations, such as the tensile strength test, are ideal for a larger audience, as up to 10 volunteers can participate directly in the demonstration. Others, such as the nanowire demonstration, are better suited for smaller groups, as it involves more discussion with visitors.

*Have you included a variety of activities for visitors of different ages and interest levels?*
The scientific content of the demonstrations is geared toward ages 12 and up; however, younger children can participate and remain engaged by the demonstrations. For example, in the nanowire demonstration volunteers engage in a hands-on activity involving a foam block and pipe cleaners, which younger children can do. In the instant bioplastic demonstration, participants mold a simple milk-based bioplastic into a preferred shape. In the shape-memory demonstration, volunteers bend plastic strips into shapes, straighten them out, and watch as they re-form when dropped into warm water. In the tensile strength demonstration, younger volunteers can participate by loading the water bottles into the buckets or by teaming up with another volunteer to hold a lighter bucket.

*Who will organize and present each demonstration?*
The presenter can be a museum educator or materials scientist or anyone with an enthusiasm for science and science education and the desire to share it. The detailed step-by-step scripts are accessible to those without previous demonstration experience. Demonstrators should practice in advance to ensure the best result.

*What materials do you need to collect, photocopy, or prepare before the demonstration?*
For further details on each of the demonstrations, see the scripts (found in the *Making Stuff* Demonstrations section). Each demonstration contains the following sections: Overview, Science Background, Materials List, Showing Video Clips from *Making Stuff*, Advance Preparation, Demonstration Script, Applications, Glossary, and Safety Notes. Frequently asked questions about the topics are answered in easy-to-reference sidebars, and any reproducible handouts are included at the end of the section. Don't forget to bring any equipment you will need to show video clips at the site of the demonstration.

*WGBH/NOVA would like to extend our deepest appreciation and thanks to the Museum of Science, Boston, particularly museum educator Karine Thate, who helped develop the four demonstrations and tested them live for museum audiences and evaluators.*

# MAKING STUFF
WITH DAVID POGUE


# DEMONSTRATION
## Breaking Point: Testing Tensile Strength

NOVA PBS

WGBH GRATEFULLY ACKNOWLEDGES THE CONTRIBUTION OF THE MATERIALS RESEARCH SOCIETY. MRS MATERIALS RESEARCH SOCIETY Advancing materials. Improving the quality of life.

# MAKING STUFF STRONGER Demonstration

## Overview

**TITLE**
Breaking Point: Testing Tensile Strength

**SHOW**
*Making Stuff: Stronger*

**DESCRIPTION**
The audience will participate to test and compare the tensile strength and elasticity of Kevlar®, Nylon, and cotton thread by lifting weighted buckets with wooden dowels. Visitors will then compare the tensile strength of Kevlar® to steel wire. In both rounds, Kevlar® wins handily.

**OBJECTIVE**
Visitors will learn:

- that materials can be strong in different ways; for example, some possess high tensile strength while others are more elastic
- that materials scientists test the strength of materials by stressing them to their breaking point

**OTHER KEY TALKING POINTS**

- materials scientists have invented synthetic polymers, such as Kevlar®, that are stronger than natural polymers (and in this case, steel).
- the strength of a material is determined by its molecular structure.

**AUDIENCE**
General public, ages 10 and up

**TIME**
Set-up: 10 minutes
Presentation: 20 minutes

"Strong as steel" is a familiar saying, and it's an apt one. Steel, an iron alloy, is one of the strongest and most versatile materials around. But, as host David Pogue discovers in NOVA's *Making Stuff: Stronger*, scientists are creating new materials that push the idea of *strong* to extraordinary new limits.

In *Making Stuff: Stronger,* materials scientists demonstrate the latest breakthroughs in strengthening old materials and developing new, stronger ones. Some of these include:

- Kevlar® (a registered trademark of DuPont)—a unique polymer fiber tough enough to stop the impact force of a bullet with a few layers of fabric, each only millimeters thick
- Spider silk—a natural protein polymer similar to Nylon that, pound for pound, has more tensile strength than either Kevlar® or steel. Scientists have genetically engineered goats to produce this protein in their milk
- Carbon nanotubes—hollow pipelines just a few atoms thick that may be the strongest material yet discovered and could one day be used to build many things, including a 200-mile-long cable to lift things into orbit

Materials scientists are asking:

- How can we make materials stronger?
- How can stronger materials be lighter, cheaper, or better in other ways?
- How can we develop new strong materials for specific applications?

## Science Background

### TENSILE STRENGTH AND ELASTICITY

The word *strong* actually refers to a range of properties, each defined by the ability to stand up to a different type of force. **Strength** is a measure of how well a material can resist a force (or load) before failing. The load is distributed over an area and is more accurately defined as **stress** (force per unit area). There are different kinds of stresses, including tension (pulling), compression (squeezing), impact (a sharp blow), torsion (twisting), and shearing (surfaces sliding past one another). We apply these stresses in our daily lives when we pull open a door, push a cart, or twist the cap off a bottle.

Materials scientists test the strength of materials by stressing them to the breaking point, called **failure**, at which point the material ruptures and cannot rebound to its original condition or shape.

**Tensile strength** is how much stress a material can withstand while being pulled in opposite directions. This stress causes the material to temporarily lengthen. If the stress is low enough, when you release the force, the material will return to its original length—this ability for the thread to stretch and rebound is a property called **elasticity.** The amount the material lengthens is called the **elongation**. (If you divide the elongation by the original length you get what is called **strain.**)

If you continue to pull, the bonds between atoms in the material will start to break, eventually reaching the point at which the material will not rebound when the stress is released; the deformation is permanent, or **plastic.** When enough bonds break, the material snaps apart. The amount of stress the material can endure at the time of failure is the strength of a material.

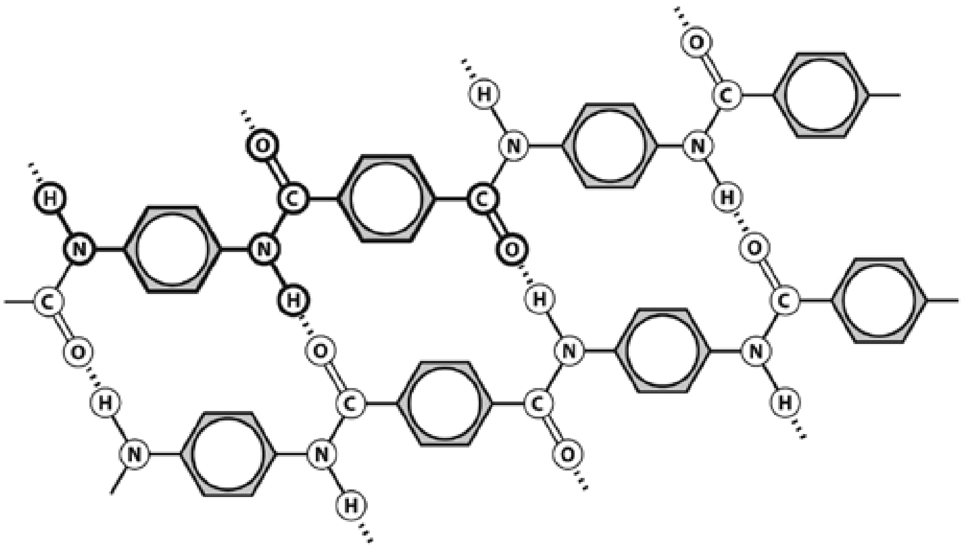
## COTTON, NYLON, KEVLAR®, AND STEEL

This demonstration investigates and compares the tensile strength of cotton, Nylon, Kevlar®, and steel, and shows that different materials can be strong in different ways.

**Cotton** is a natural polymer, or plastic, composed of long chains of cellulose molecules. These small units of cellulose are formed through side-by-side hydrogen bonding. However, because its molecules are randomly arranged, it has low tensile strength, which means it will break under relatively low stress. Cotton will stretch 8–10 percent before breaking. Size 35 cotton thread (an equivalent gauge to size 46 Nylon and Kevlar® thread) has a tensile strength of approximately 2 pounds (0.9 kilograms).

**Nylon** is a lightweight synthetic polymer that also has long strands and hydrogen bonds, but it has a more ordered molecular structure than the cellulose in cotton, which gives it higher tensile strength. Like rungs of a ladder, the hydrogen bonds lock the rigid molecules into a tight formation. In addition, Nylon will stretch 30–40 percent of its length before breaking, which makes it an ideal material for parachute cords, for example. Size 46 Nylon thread has a tensile strength of approximately 8 pounds (3.6 kilograms).

**Kevlar®** is a lightweight synthetic polymer with a highly ordered molecular structure that gives it the highest tensile strength of the four materials. Like Nylon and cotton, it also has hydrogen bonds between strands. And like Nylon, it has ordered polymer strands, which increase the strength. On top of that, however, Kevlar® has rigid ring structures within the polymer strands, which further increases the strength. Polymers with ring structures have high tensile strengths.




**Molecular Structure of Kevlar®**

Kevlar® molecules are composed of long chains of repeating units (in bold at right). These chains of rigid rings run parallel to the fibers and are bonded to each other by strong hydrogen bonds. Like rungs of a ladder, the hydrogen bonds lock the rigid rings into a tight formation giving Kevlar® its superior tensile strength.

Size 46 Kevlar® thread has a tensile strength of approximately 18 pounds (8 kilograms). However, larger sizes of Kevlar® thread will hold 400 pounds or more. Also, Kevlar® fibers will only stretch 3–5 percent before breaking. So it is much less elastic than Nylon of the same gauge, but possesses much higher tensile strength. **That is, Kevlar® doesn't stretch much before breaking, but it can withstand a much greater force before it breaks.**

**Steel** is an alloy of iron and carbon that, like all metals, has a crystalline structure, which means the atoms are arranged in an ordered pattern. The addition of carbon hardens the iron by locking the layers of iron atoms into a strong, rigid structure. In general, metals have higher tensile strengths than polymers. In the case of Kevlar® the rigid ring structures give it superior strength for a polymer, especially such a lightweight one. Pound for pound, Kevlar® is five times stronger than steel.

| Material | Tensile Strength (What's the maximum stress it can withstand before breaking?) | Elasticity (How much does it stretch before breaking?) |
|---|---|---|
| Cotton Thread size 35 | 2 lbs (0.9 kg) | 8–10% |
| Nylon Thread size 46 | 8 lbs (3.6 kg) | 30–40% |
| Steel Wire size 28 | 10 lbs (4.5 kg) | 8–15% |
| Kevlar® Thread size 46 | 18 lbs (8 kg) | 3–5% |

**A bulletproof plastic? Give me a break!** Kevlar® has a rigid structure and does not stretch much. When a bullet strikes a vest, it hits the layers of Kevlar® and acts to pull them apart. The Kevlar® fabric in a bulletproof vest is made of several very thin layers of fibers. The fibers are woven perpendicular to each other to help distribute the force of an impact. When Kevlar® is struck, it responds by stretching individual fibers a small amount. This serves to dissipate the energy of the bullet. Some of the fibers break and also absorb the energy. The total amount of energy a material can absorb is its **toughness,** and Kevlar® fabric is one of the toughest materials ever created.

# Materials List

- 1 case of 24 plastic bottles of water, 16.9 oz/0.5 L each, *unopened* (to use as uniform weights, 1 bottle = 1.16 lbs/0.525 kg)
- 4 identical 5-gallon buckets with firmly attached handles
- 5 metal S-hooks large enough to latch onto the bucket handles
- 5 wooden dowels, ⅞" x 48"
- 10 pairs of safety glasses (clean after each use)
- cotton thread, size 35 (equivalent diameter to size 46 Nylon and Kevlar®)
- Kevlar® filament thread, size 46
- Kevlar® fabric swatches
- Nylon thread, size 46
- steel picture-hanging wire, 28-gauge (twice the diameter of the threads)
- tape (vinyl electrical tape works well for securing the thread to the dowels and hooks)
- wipes, to clean safety glasses
- wire cutters
- bucket labels (see Resources)
- Demonstration Title Sign and applications collage (see Resources) –mount on foam core or insert into a clear plastic display rack
- (optional) Nylon sample (e.g., pantyhose)
- (optional) NOVA *Making Stuff: Stronger* video clip (see Resources) and video display equipment
- (optional) photo of Kevlar® bulletproof vest or real vest if possible

For Resources, visit **pbs.org/nova/education/makingstuff**

Materials and supplies for this demonstration can be found at most hardware and home improvement stores. The specific thread types and gauges are available online at **thethreadexchange.com**. Kevlar® fabric samples or tape can be obtained from several online vendors including **fibreglast.com**, **jamestowndistributors.com**, and **fiberglasssupply.com**.

# Showing Video Clips from MAKING STUFF: STRONGER

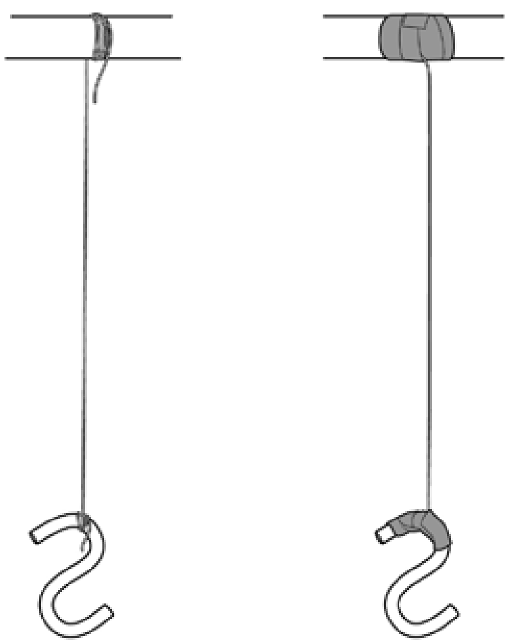
If you are able to show video at the demonstration site, the video clip from NOVA's *Making Stuff: Stronger* can be used either as an introduction or as a follow-up to your demonstration. The clip can also be played on a continuous loop nearby to draw visitors into the demonstration area.

# Advance Preparation

1. **Test the demonstration before presenting it to an audience.**

2. **Assemble three dowels,** each with a different type of thread (cotton, Nylon, Kevlar®). For each dowel, cut a piece of thread 48 inches long (the same as the length of the dowel).

   Wrap one end of the thread **around the center** of the dowel 10 times and tape it firmly in place with several layers of electrical tape. Wrap the other end of the thread around the top of an S-hook 10 times and tape it firmly in place with several layers of electrical tape. Do not knot the thread, as a knot forms a point of weakness in the thread. This should leave about 12 inches of thread exposed.



**How to Attach the Thread and Wire to the Dowel and S-Hook**
Wrap the ends of the thread and wire around the center of the dowel and the top of the S-hook and tape firmly in place.

3. **Assemble two more dowels,** another dowel with Kevlar® thread set up as above, and one set up with the steel wire. Cut a piece of wire about 24 inches in length (half the length of the dowel). Wrap one end around the center of the dowel and the other end around the top of an S-hook, five times each, and secure it with electrical tape. Be careful not to bend the wire more than necessary, as bends, like knots, can create points of weakness. This should leave about 12 inches of wire exposed.

4. **Place the labels on the four buckets.** A standard plastic 5-gallon bucket, available at most hardware or home improvement stores, weighs a little over 1.5 pounds. The weight of the bucket alone may be enough to break the cotton thread.

5. **Set the stage.** Just before the demonstration:
   - Set out the Nylon and Kevlar® samples.
   - Place the first three labeled buckets (*cotton*, *Nylon*, and *Kevlar®*) and three threaded dowels side-by-side on the floor with eight water bottles next to each one.
   - Set the other two dowels (Kevlar® and steel) and the bucket labeled *steel* out of view for the first part of the demonstration.
   - Cue up the NOVA video clip, if you are using it.
   - Keep the threads, scissors, wire, and tape on hand to re-thread the dowels in between demonstrations. Or, if the demonstration is to be repeated, consider two sets of dowels and hooks to limit set-up time in between demonstrations.
   - Put on your safety glasses and the bulletproof vest, if available. (Or ask a volunteer to wear it.)
   - Post the Demonstration Title Sign on the cart/table.

**SAFETY NOTES**

- Have your volunteers put on safety goggles.
- Buckets can be lifted by single volunteers or a pair of volunteers (see photo, left). Assign two lifters per bucket, one on each end of the dowel. Assign children to the cotton thread first, then the Nylon as they will be lighter loads to lift. Steer adult volunteers first toward the Kevlar®.
- Ensure that volunteers hold the dowels and buckets at a safe distance from their faces and other visitors to avoid rebound or dropping the bucket on toes.


6. **Note:** Due to the very low tensile strength of the cotton, the line may break immediately, under just the weight of the bucket. After each line breaks, the water bottles from that bucket can be used to continue the test. The likely outcome of the test is shown at right.

| Thread Type | Water Bottles |
|---|---|
| Cotton | 0–1 |
| Nylon | 4–5 |
| Kevlar® | 11–12 |

# Demonstration Script

1. **Welcome visitors** to the demonstration and briefly introduce the show. *"Welcome to this* Making Stuff *demonstration.* Making Stuff: Stronger, Smaller, Cleaner, Smarter *is a four-part NOVA series on materials science that will air on PBS in January 2011. This demonstration accompanies the* Making Stuff: Stronger *episode."*

2. **Engage your visitors.** *"What are some strong materials?* (steel, concrete, etc. Accept all answers.) *Those are good examples, but what does it really mean for a material to be 'strong'?" (Accept all answers.)*

3. **Introduce materials science.** *"Well, it turns out there is an entire field of science dedicated to answering that question. These scientists are called materials scientists and some of them develop and test materials by breaking them to see how strong they are. Wouldn't that be a fun job, to break things for a living? You may be familiar with some of the tests already."*
   - *Perhaps you've seen video of car crash tests where a car is hooked onto a cable and slammed into a wall—that's an **impact test** to see how much force the materials can withstand before breaking.*
   - *There are also machines that pull materials apart with more and more force until they stretch out and break—that kind of test tells materials scientists how much **tensile strength**, which is **how much stress**, or **pulling**, the materials can withstand before breaking.*

4. **Introduce the challenge.** *"Well, we don't have a machine like that here but we can do a simple test to investigate **tensile strength** and **elasticity**, which is how much **something can stretch before breaking**."*

5. **Get volunteers.** Solicit three to six volunteers to lift the dowels and one to three other volunteers to load the buckets. Distribute the safety glasses and instruct the volunteers to put them on.

6. **Describe the procedure.** While the volunteers hook the S-hooks to the bucket handles, say: *"We're going to test the tensile strength and elasticity of three different materials. All three materials are polymers, which are materials whose molecules are made up of long chains of repeating atoms."*
   - ***Cotton**: a lightweight natural fiber that some of you might be wearing right now*
   - ***Nylon**: the very first synthetic, or human-made, fiber, which was invented by materials scientists in 1935*
   - ***Kevlar®**: a lightweight synthetic fiber that was invented by materials scientists in 1965 and is used in bulletproof vests, tires, and firefighting gear*

7. **Ask for predictions.** *"All three of these threads are the same diameter so it is a fair test of the strength of the thread. Which material do you think will be the strongest? How many think it will be the cotton?...the Nylon?... the Kevlar®?"*

8. **Load the buckets.** With the buckets on the floor, ask the loader(s) to add one water bottle to each bucket and step back. Then ask the lifters to *gradually*

**Presentation tips**

- Encourage participation by having the audience members count in unison as the water bottles are added to the buckets.
- Use hand signals to help volunteers raise the buckets at a steady pace. Slowly raise your hand, palm up to signal lifting and a flat outward palm to signal stop.
- Have volunteers set the bucket down on the floor before adding each water bottle.

hoist the three buckets at the same time. **Caution** the lifters not to jerk or yank the dowels as that could snap a line and is a different kind of stress than the one being tested.

9. **Continue the test** lowering the buckets, adding water bottles and lifting the buckets, until each thread breaks.
   - When the cotton breaks, say: *"Okay, so we just saw that the tensile strength of cotton is very low, just a few pounds. And how much did it stretch?"* (A little bit. Cotton stretches, or elongates, 8–10 percent.) *But what about the other two?*
   - When the Nylon breaks, say: *"Okay, so now we see that Nylon has greater tensile strength than cotton. And how much did it stretch?"* (A lot more. Nylon stretches 30–40 percent.)
   - When the Kevlar® breaks, review the final bottle counts and say: *"Okay, so we've just seen that this material has more **than twice the tensile strength of Nylon and almost 10 times as much as cotton**. And how much did it stretch?"* (Not very much. Kevlar® stretches only 3–5 percent.)

10. **Compare Kevlar® to steel.** "*But how do you think **Kevlar®** would stand up to steel?"* Bring out the steel and Kevlar® dowels and say: *"Here we have a steel wire that is **twice the diameter** of the Kevlar® thread. Which do you think will have the greater tensile strength?"* (Accept all answers. Many in the audience will expect the steel to be stronger.)

11. **Repeat** the test, testing Kevlar® versus steel, using two bottles of water per lift. The steel should break first, at about 6–8 bottles. If time permits, keep going until the Kevlar® again breaks at about 10–12 bottles.

12. **Summarize.** *"So we've seen that Kevlar® has **greater tensile strength** than the other materials, including steel, but is **less elastic**."*

13. **Pass around the Kevlar® fabric samples** and ask: *"Can anyone guess why those properties make Kevlar® good for bulletproof vests?"* (Kevlar® fibers can absorb a lot of force while stretching very little, which stops the bullet. If it were more elastic, like Nylon [hold up the Nylon pantyhose and stretch them] it would allow the bullet's force to impact the wearer. Also, the fibers are woven perpendicular to each other to create a net that further dissipates the force of the bullet. This protects the wearer from receiving its full impact.)

14. **Wrap up.** *"So what does the word* strong *really mean?"* (Accept all answers.) Then reiterate: *"As this demonstration shows, a material can be strong in one respect (tensile strength) and weak in another (elasticity). However, materials scientists can turn those different properties into advantages when designing new materials and products. For example, Nylon, which has greater elasticity than Kevlar® is used more often for parachute cords, where the stretchy fibers decrease the jerking motion when the chute is deployed."*

15. **Conclude the demo.** Ask if anyone has any questions, and share some other applications of Kevlar® (see page 42).

### How to Gauge Elasticity

- Ask audience members to pay attention to how much each line stretches before the bucket lifts off the floor. For example, the Nylon thread will stretch for some time before the bucket finally lifts off the floor, but the Kevlar® bucket will rise almost immediately after the volunteer begins lifting.
- Ask the lifters how much they feel the lines stretching when they lift the buckets.
- Visually compare the lengths of the line while the buckets are raised in the air.

**Q Why is the Kevlar® thread so strong?**

**A** Failure happens when the stress overcomes the force of the atomic bonds that hold the material together. The stronger the bonds, the more force it takes to make the material fail. Also, bonds are stronger when the molecules form a rigid, regular pattern. All three of the polymers have hydrogen bonds, but cotton molecules are randomly arranged, while Nylon molecules have a more ordered structure making it stronger. Steel has a highly ordered crystalline structure that makes it very strong. Kevlar® molecules are also highly ordered, but they have additional rigid ring structures that give Kevlar® superior tensile strength.

# Applications

Materials scientists often combine materials to produce composites that have unique properties (flexibility, stiffness, elasticity, etc.). These are a few applications of Kevlar® and composites containing Kevlar®:

**Applications of Kevlar®**

- bicycle helmets
- protective suits for motorcyclists
- the hulls of sailboats, yachts, canoes, and kayaks
- the strings of tennis rackets
- snowboards and skis
- baseball bats and hockey sticks
- industrial gloves for workers who handle glass, sharp metals, etc.
- hoses and pipes on deep-ocean oil rigs
- protective shields for satellites and spacecraft
- strong, fire-resistant mattresses
- firefighting clothing and gear
- inside-the-home storm rooms that can stand up to tornados.

# Glossary

- **elastic deformation**–change that is non-permanent; when the stress is released the material returns to its previous shape
- **elasticity**–the ability for a material to lengthen under stress and then return to its original shape when the stress is removed
- **elongation**–the amount the material lengthens while undergoing elastic deformation
- **failure**–the rupture or breaking of a material, with no chance of returning to the way it was
- **plastic deformation**–deformation, or change, that is permanent; when the stress is released the material does not return to its previous shape
- **polymer**–large molecules made of long chains of repeating atoms; can be synthetic or natural
- **strain**–the elongation divided by the original length
- **strength**–a measure of how well a material can resist a force (or load) before failing
- **stress**–force per unit area; types of stress include tension (pulling), compression (squeezing), impact (a sharp blow), torsion (twisting), and shearing (surfaces sliding past one another).
- **tensile strength**–how much stress a material can withstand while being pulled apart
- **toughness**–the total amount of energy a material can absorb at fracture or failure

# MAKING STUFF WITH DAVID POGUE


# DEMONSTRATION

## Nanowires and the Ever-Shrinking Microchip

NOVA PBS

WGBH GRATEFULLY ACKNOWLEDGES THE CONTRIBUTION OF THE MATERIALS RESEARCH SOCIETY. MRS MATERIALS RESEARCH SOCIETY Advancing materials. Improving the quality of life.

# MAKING STUFF SMALLER Demonstration

## Overview

**TITLE**
Nanowires and the Ever-Shrinking Microchip

**SHOW**
*Making Stuff: Smaller*

**DESCRIPTION**
Visitors will use a Styrofoam® block and pipe cleaners to demonstrate the challenge of working on the nanoscale (placing millions of wires and transistors onto tiny chips) to produce smaller but more powerful computing and electronic devices.

**OBJECTIVE**
Visitors will learn:

- how challenging it is to work on the small scale
- that materials scientists are developing extremely small, thin wires, called nanowires, that may help make computers and electronics even smaller in the future

**OTHER KEY TALKING POINTS**

- the nanoscale is too small to see
- scientists are discovering how to build small materials—objects measured in nanometers, or billionths of a meter—to create amazing new technologies. This is called nanotechnology.

**AUDIENCE**
General public, ages 10 and up

**TIME**
10-15 minutes

Yesterday's room-sized supercomputers are today's miniature microchips. Today's smaller devices are more portable, cost less to make, consume less power, and have longer-lasting batteries. But how small can we go? How much power and performance can we squeeze out of ever-shrinking microchips?

A nanometer is one-billionth of a meter, which is thousands of times smaller than the width of a human hair. The nanochip does not yet exist, but materials scientists and engineers are steadily advancing toward nanocomputing. Creating materials at that scale raises unique challenges—electrons that jump their wires, circuits that overheat, and the need for super-tiny tools and innovative manufacturing techniques to create nanoscale objects.

Materials scientists are asking:

- How can we make stuff even smaller and more powerful?
- How can new materials push beyond our current limits?

## Science Background

### NANOTECHNOLOGY AND THE NANOSCALE

The components of today's electronics are measured on the macroscale (visible to the naked eye) and microscopic (visible using a microscope) scale. But to push the limits of "smaller," materials scientists are investigating how to build and work on the **nanoscale** (one billionth of a meter). Nanoscale objects are billions of times smaller than everyday objects measured on the macroscale.

- **Macroscale**: Objects on this scale are measured in kilometers/miles, meters/yards, centimeters (one hundredth of a meter)/inches and millimeters (one thousandth of a meter)/fractions of an inch. Examples include:
  - Meter: height of a two-year-old child, medium-sized dog, poster, or some plants and shrubs
  - Millimeter: width of a pin head, thickness of a dime, thickness of some cardboard
- **Microscale**: Objects on this scale are measured in millionths of a meter. Examples include:
  - Micrometer: human hairs (about 200 micrometers), pollen, red blood cells, baker's yeast, some bacteria

- **Nanoscale**: Objects less than 100 nanometers (billionths of a meter). Examples include:
  - Nanometer: viruses, width of strands of DNA and RNA, thickness of a cell membrane

**Nanotechnology** involves engineering new materials out of individual atoms and molecules. When you build things on such a small scale, things act differently than on our scale. For example:

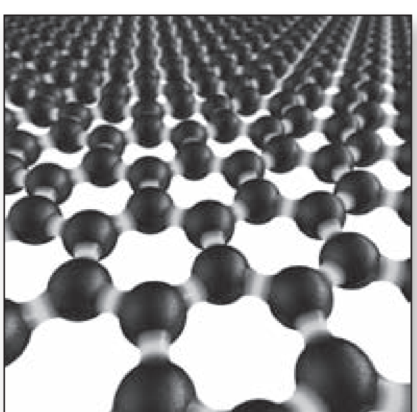
- Electrons jump from their extremely tiny wires to neighboring wires, rather than smoothly flowing the course laid out for them (called current leakage).
- Tightly packed, tiny components overheat more easily.
- Building tiny components requires very tiny tools.

One area of nanotechnology is the development of **nanowires**, which are wires thinner than 100 nanometers in diameter. Nanowires are so thin compared to their length that they are considered to be one-dimensional objects.

They can be made from metals, such as titanium or molybdenum, or non-metals, such as silica, which is the most common component of sand. One way nanowires are made is by dragging a thicker wire through a very hot flame using the tip of a tiny probe to thin it. They can also be made "from scratch" by combining atoms using several common laboratory techniques.

Materials scientists are designing some nanowires that conduct light instead of electrons, which will eliminate the problems with overheating circuits. Replacing silicon with a newly discovered form of carbon called graphene, which is a single-atom thick layer of carbon, may make possible new computer chips that allow electrons to move 1,000 times faster, making computers even more powerful.

The promise of nanotechnology goes beyond smaller, more powerful computers. Picture a TV screen that's a flexible film that you could roll up and put in your pocket. Or e-paper embedded with invisible nanowires that has the appearance of natural paper but is digital. Or new medical procedures to remove tumors without surgery or deliver medicine only where it is needed.



**Graphene** is a single-atom thick layer of carbon. The 2010 Nobel Prize in Physics was awarded for the discovery of this new form of carbon and its amazing physical properties.

# Materials List

- a collection of outdated electronics and computer equipment, plus any other items whose functions are now available on a smart phone. Select five or six from the below list*:

  atlas/map, calculator, calendar, camera (digital or film), CD, CD player, computer (desktop or laptop), cookbook, dictionary, DVD, DVD player, phone book, radio (desktop or portable), tape recorder, television, videocassettes, VCR player, video camera (digital or VHS), video games, video game unit
- 12 pipe cleaners, silver or gold tinsel, cut to 4" lengths
- 1 block** of green floral Styrofoam®, 4" wide x 4" long x 2" high
- 2 smaller green floral Styrofoam® blocks (e.g., 2" x 2", and 1" x 1")
- 1 dime
- Photos (see Resources)

  #1—circuit board

  #2—inside of microchip

  #3—microscopic image of wires on a microchip

  #4—microchip on a fingertip

  #5—a nanowire compared to a human hair
- Demonstration Title Sign and applications collage (see Resources)—mount on foam core or insert into a clear plastic display rack
- (optional) NOVA *Making Stuff: Smaller* video clip (see Resources) and video display equipment
- (optional) a real circuit board (e.g., from an old computer) in place of photo #1

For Resources, visit **pbs.org/nova/education/makingstuff**

*To obtain examples of outdated technology, ask neighbors and friends or inquire at IT departments, schools, and recycling centers, etc.

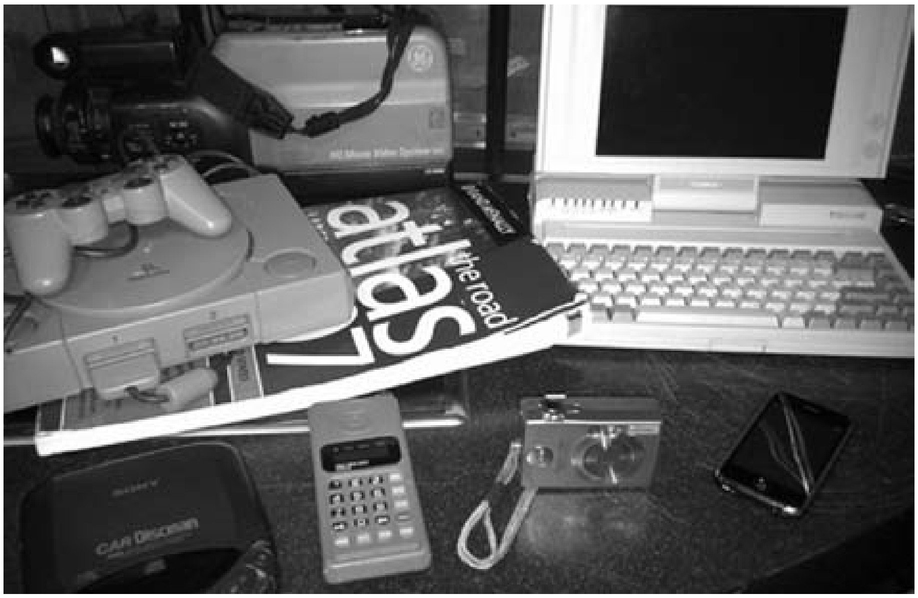
**The larger Styrofoam® block may be damaged during the demo, so have several on hand if the demonstration is to be repeated.

# Showing Video Clips from MAKING STUFF: SMALLER

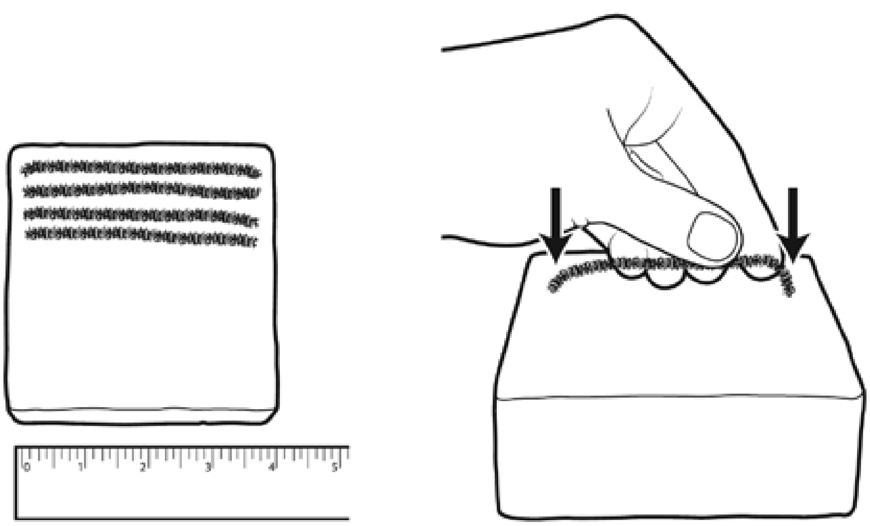
If you are able to show video at the site of the demonstration, the video clip from NOVA's *Making Stuff: Smaller* can be used either as an introduction or as a follow-up to your demonstration. The clips can also be played on a continuous loop nearby to draw visitors into the demonstration area or before or after the demonstration.

# Advance Preparation

1. Test the demonstration in its entirety before performing it for an audience the first time.
2. Set out in one group the collection of outdated technology, computing and electronic devices, and other items whose functions have been replaced by smart phones.




3. Insert several “starter” pipe cleaners in the 4" x 4" Styrofoam® block as an example as shown here.
4. Arrange the photos in the order they will be shown.
5. Post the Demonstration Title Sign on the cart/table.



**How to Insert the Pipe Cleaners on the Foam Block**

Insert five or six of the tinsel pipe cleaners into the block so visitors will have an example to follow. Bend the ends and punch them into the foam. Line them up and make sure they are not touching each other.

# Demonstration Script

1. **Welcome visitors** to the demonstration and briefly introduce the show. *"Welcome to this* Making Stuff *demonstration.* Making Stuff: Stronger, Smaller, Cleaner, Smarter *is a four-part NOVA series on materials science that will air on PBS in January 2011. This demonstration accompanies the* Making Stuff: Smaller *episode."*

2. **Engage your visitors.** Point out and name the outdated computers, electronics, and other items. *"So here we have a variety of items...."* **Ask**: *"Would all of this technology fit in your pocket?"* If someone says no, ask: *"Does anyone have a smart phone—a small device that has all of these functions and more?"*

3. **Think "small."** *"What are some advantages to having small electronics and computers, like the smart phone in your pocket?"* [Some answers: Smaller devices are more portable and less expensive to make; they consume less power, so batteries last longer.] *"You've probably noticed that electronics and computers keep getting smaller and smaller, while at the same time doing more, but how did that happen?"*

4. **Introduce the circuit board.** Hold up the real circuit board or photo #1 (circuit board) and say:
   - *"This is a circuit board, sometimes called a motherboard, which is found inside computers and other electronic devices.*
   - *It has many microchips—these small black squares and rectangles—that are the "brains" of the computer.*
   - *These are macroscale, or visible with the naked eye."*

### About the History of Computers

- The "brains" of computers weren't always so small. One of the first computers, called Eniac, used vacuum tubes as switches. Eniac weighed 30 tons, took up 1,800 square feet, and cost half a million dollars (a lot of money in the 1940s), yet it had only the same computing capacity as a modern inexpensive calculator.
- Vacuum tubes were eventually replaced by transistors, the first of which were half an inch long (1.27 cm).
- Today, more than two billion transistors can fit on a chip that is one-centimeter square (0.15-inches square), or about half the size of a dime.

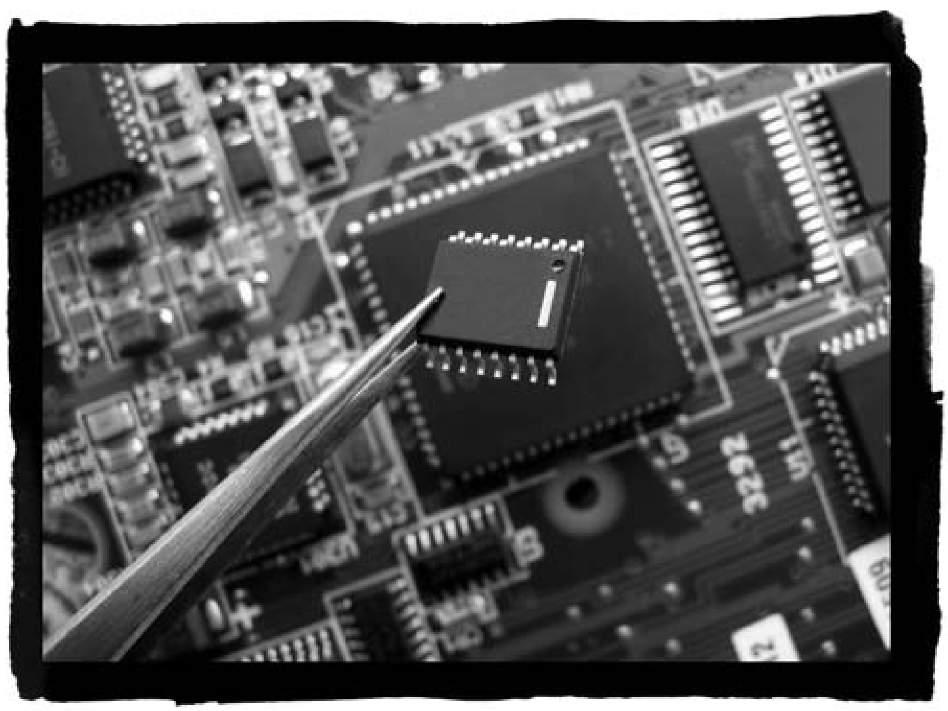


**Photo #1: Circuit Board**

Microchips and circuit board

5. **Introduce the microchip and transistor.** Hold up photo #2 of the inside of a microchip and say:
   - *"The inside of this microchip is an example of the **microscale**. This photo is magnified 40 times.*
   - *A **microchip** is a silicon wafer etched with extremely tiny metal wires and switches called transistors that make up miniaturized electrical circuits that process information.*
   - ***Transistors** are switches that turn a flow of electrons on and off. All electronics work by controlling the flow of electrons. In the last 60 years transistors became smaller, faster, and cheaper.*
   - *The more transistors you can fit on a chip, the greater the computing power and processing speed. Today, more than two billion transistors (that's 2,000 million) can fit on a chip that is about half the size of a dime (1 centimeter square/0.15 inches square)."* **Hold up the dime**.

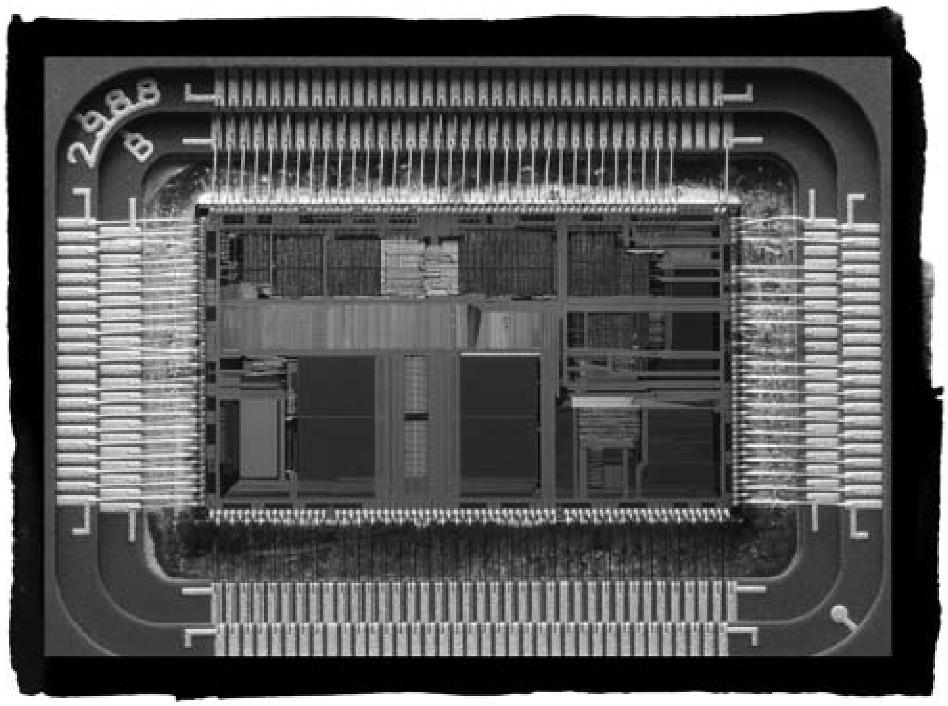



**Photo #2: A Microchip with the Cover Removed**

- This is a photo of the Intel 486 chip introduced in the early 1990s.
- It was the first chip to have **more than a million transistors.**
- The actual chip is only about **½-inch** by **¼-inch.**
- This photo is magnified **40 times.**
- However, even at that magnification it is difficult to see the tiny wires on the chip, which is the rectangle in the center.
- The outer edges are the packaging and the large wires connect the chip to the pins that attach to the motherboard.

6. **Discuss scale.** *"Although the components of today's electronics are very small, they are still visible with the naked eye (**macroscale**) or with a microscope (**microscale**).*
   - *But there is an even smaller scale called the **nanoscale**. Nano is 1,000 times smaller than the micro. It is named after a unit of measurement called the **nanometer**, which is one billionth of a meter. That's 25-millionths of an inch.*
   - *Nanoscale objects are too small to be seen with a microscope, although they can be imaged with special, very powerful tools."*

7. **Introduce nanotechnology.** *"Materials scientists and engineers now are discovering how to work on this scale to build small materials—mere clusters of atoms—to create amazing new technologies. This is called **nanotechnology**."*

8. **Describe the challenges of nanotechnology.** *"However, there are challenges to making things even smaller. For example*:

   - *It is difficult to work on such a small scale—new tools and materials are needed.*
   - *As more and more electronic components are placed in a small area, heat builds up due to the friction of the electrons flowing in the wires.*
   - **Hold up photo #3.** *"And, as the tiny wires get closer together, electrons can jump from one wire to another, making the circuit less efficient."*

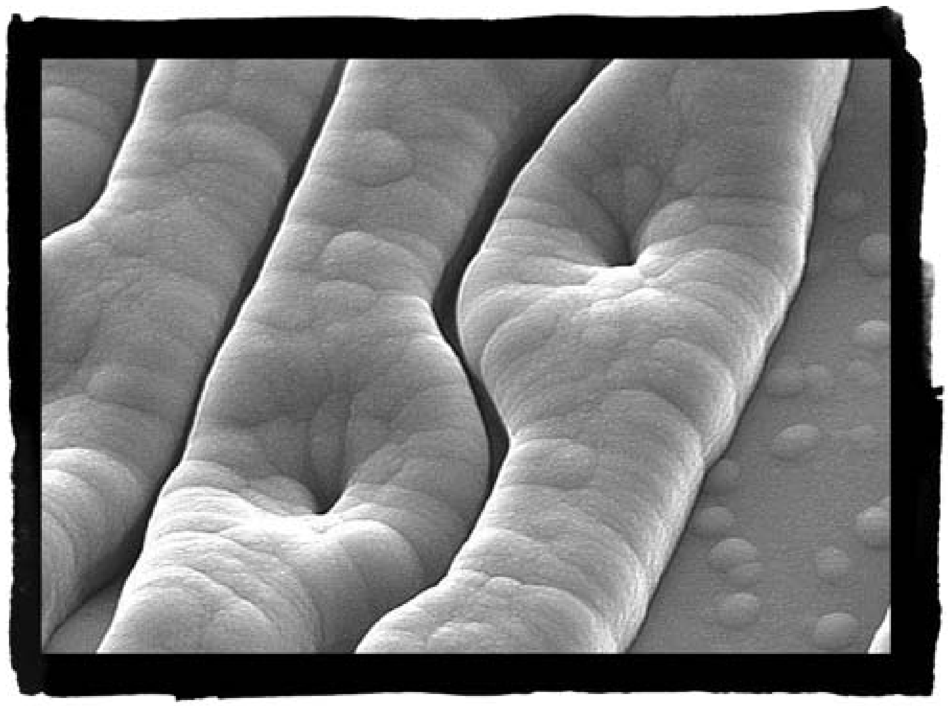


**Photo #3: A Scanning Electron Micrograph Image of Wires on a Microchip**

- This image shows the wires or connectors on a microchip magnified about **400 times.**
- When these wires get too close, the electrons can jump from one wire to the next.
- This makes the circuit much less efficient.

9. **Introduce the hands-on component.** Introduce the Styrofoam chip model as a way for visitors to see why working on the small scale is so challenging. The green block of Styrofoam represents a microchip and the pipe cleaners represent wires and transistors. Pass out one or two pipe cleaners to each visitor as you explain the goal of the exercise is to place as many wires onto the green block of Styrofoam as possible, following these rules:

   - Wires must lay flat with each end stuck firmly in the foam.
   - None of the wires can touch each other.

   [**Note**: Either keep the block at the cart and have the audience members approach one at a time to add their wires, or pass the block around the group, with members adding wires in turn.]

10. **Scale down and compare.** It will be difficult to get more than a dozen onto the block without touching. After the last wire has been added to the Styrofoam block, say: *"So you can see how challenging it is to work at this scale, the macroscale."* Hold up the successively smaller blocks of foam as you ask: *"Do you think it would be possible to fit the same number of components onto a chip this size? What about this size?"*

**11. Make the real-world connection.** Show photo #4 of the real microchip on the fingertip and ask: *"What if we were trying to fit even more components in an even smaller space?"* Solicit answers to the question: *"Does anyone have any ideas about how that could be done?"* Someone will likely say the obvious and key answer: Make the wires smaller.

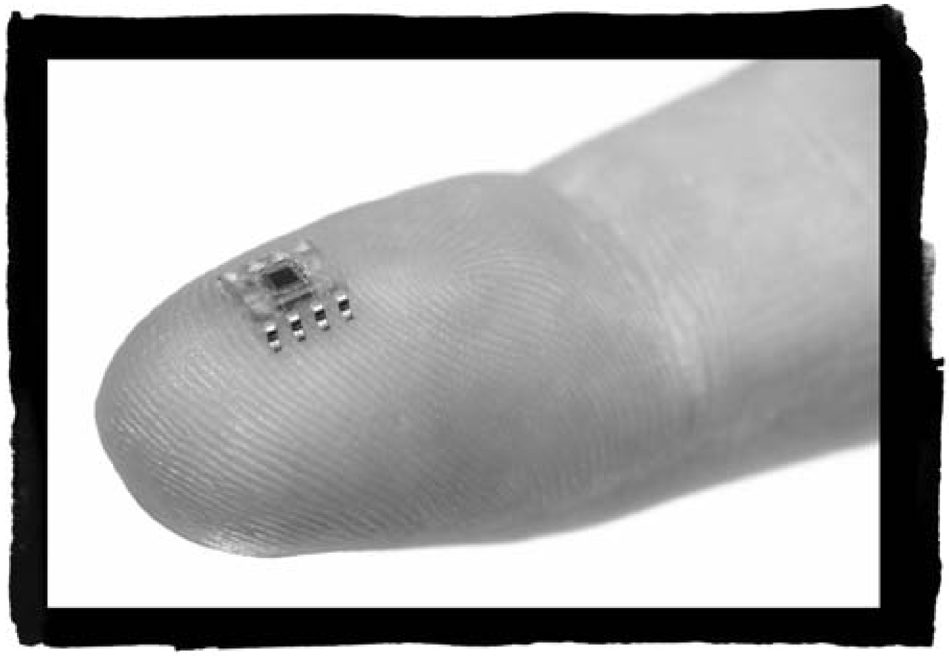


**Photo #4: A Microchip on a Fingertip for Scale**

**12. Introduce the concept of nanowires.** Say: *"Materials scientists and engineers are now developing **nanowires**, which are wires that have a thickness of about 100 nanometers or less."* Show photo #5 of the nanowire next to the human hair. Emphasize that it is a real photo, taken through a special microscope, and explain: *"The tiny, looped filament you see is just 50 nanometers wide. That's 1,000 times thinner than the single strand of human hair behind it."*

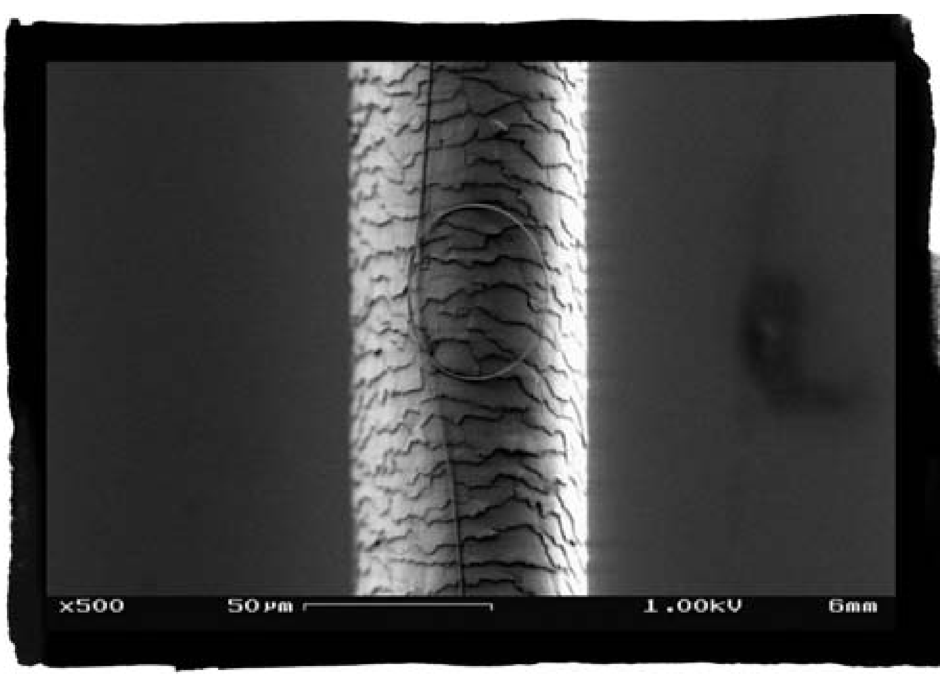



**Photo #5: A Nanowire Compared to a Human Hair**

- This is an image of a **nanowire** taken at **500 times** magnification.
- The **nanowire** is just 50 nanometers wide.
- The single strand of **hair** shown behind it is **1,000 times thicker.**

13. **Pass around the image** so everyone can get a closer view and explain: *"Nanowires could be used to make extremely tiny wires and transistors, resulting in smaller and more powerful computers and electronics as well as some of the other applications, including wearable computers and bendable TV screens."*

14. **Ask** if there are any questions and **share** some of the other applications below.

# Applications

**Potential Applications of Nanowires**

- A **television screen** so small, thin, and flexible that you could roll it up and carry it with you.
- A wearable **computer** with a bendable screen that could be mounted on your forearm.
- **E-paper** embedded with nanowires that could mimic real paper but is digital.
- Wires embedded in the windshield of your car (so small they are invisible) that, when activated, could create a **pop-up interactive display**.
- **Smart clothes** that generate electricity when you move.
- **Artificial skin** for prosthetics or robots.

# Frequently Asked Questions

**Q What does silicon have to do with computers?**

**A** The story of smaller, faster, cheaper computers began with the discovery of semiconductors. Silicon, the element that makes up most sand, has had a profound impact on our culture and the development of nanotechnology—despite being the sixth worst conductor in the periodic table of elements. In the 1940s and 1950s, scientists at Bell Labs discovered how to change the conductivity in semiconductors to make them work as switches. This made the miniaturization of transistors possible. Today, another element, carbon, is being manipulated at the atomic level to produce the next generation of small technology.

**Q What are some other uses of nanotechnology?**

**A** Some examples of products that currently use nanotechnology are sunscreens containing titanium particles that absorb harmful ultraviolet rays, socks containing silver particles that kill bacteria, and certain stain-resistant additives in fabrics. The applications of nanotechnology may change the future of not only computers and electronics but also medicine with the invention of exciting new applications such as pills that know what medicine to release into the body or tiny robots that repair damaged body parts.

# Glossary

- **macroscale**–objects on this scale are measured in kilometers or miles, meters or yards, centimeters (one hundredth of a meter) or inches, and millimeters (one thousandth of a meter) or fractions of an inch
- **microchip**–a silicon wafer etched with extremely tiny metal wires and switches called transistors that make up miniaturized electrical circuits that process information
- **microscale**–objects on this scale are measured in millionths of a meter
- **nanometer**–one-billionth of a meter
- **nanoscale**–objects on this scale are measured in billionths of a meter
- **nanotechnology**–technology involving objects usually less than 100 nanometers wide
- **nanowire**–a wire less than 100 nanometers wide; made of metals or non-metals
- **semiconductor**–a material that has more electrical conductivity than an insulator and less than a conductor, which makes it ideal for use in transistors
- **transistor**–a device made out of a semiconducting material that acts as a switch, controlling the flow of electrons, allowing information processing in electrical devices and computers

# MAKING STUFF WITH DAVID POGUE


## DEMONSTRATION

### Instant Cheese Bioplastic

NOVA PBS

WGBH GRATEFULLY ACKNOWLEDGES THE CONTRIBUTION OF THE MATERIALS RESEARCH SOCIETY. MRS MATERIALS RESEARCH SOCIETY *Advancing materials. Improving the quality of life.*

# MAKING STUFF CLEANER Demonstration

## Overview

**TITLE**
Instant Cheese Bioplastic

**SHOW**
*Making Stuff: Cleaner*

**DESCRIPTION**
In this two-part demonstration, visitors will learn about **bioplastic** and see a simple bioplastic made by curdling milk with vinegar in a process similar to cheese making.

**OBJECTIVE**
Visitors will learn about bioplastic, a material made of plant or animal matter that is cleaner because it breaks down more easily in the environment than petroleum-based synthetic plastics.

**OTHER KEY TALKING POINTS**
Materials scientists are developing new cleaner materials that are safer for the environment.

**AUDIENCE**
General public, ages 10 and up

**TIME**
Set-up: 10 minutes
Presentation: 20 minutes

Each year, we extract some 30 trillion tons of raw materials from the Earth. We turn iron ore into steel cars, petroleum products into plastics, and metals into batteries. What happens to all those raw materials when the useful life of our stuff ends? Many end up in landfills or at the bottom of rivers, lakes, and oceans.

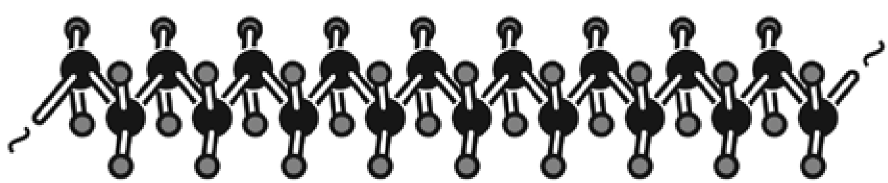
NOVA's *Making Stuff: Cleaner* explores the rapidly developing science and business of clean energy and clean materials. The show follows innovative materials scientists as they work to invent cleaner materials to help solve environmental problems created by the production and use of automobiles, plastics, and batteries. These new materials—including plastics made from sugar instead of petroleum and tires made from orange peel oil—could provide the energy and materials we need without polluting the Earth.

Materials scientists are asking:

- What if we lived in a zero-waste world where every product could be recycled, reused, or composted?
- How can we replace dirty materials with cleaner biomaterials?

## Science Background

The word ***plastic*** has many meanings. In everyday language, it means a material or object that can be molded or shaped. Such materials have the property of **plasticity**. Scientifically, however, a plastic is a type of **polymer**, a substance made of long chains of molecules. The properties of a plastic—whether it bends or stretches, remains soft or hardens into a solid—depend on how those long chains are arranged.



**Molecular Structure of a Polymer**
Polyethylene (PE), the most widely-used plastic, is made of long chains of carbon and hydrogen atoms. Polyethylene bags and bottles, which are not biodegradable, often end up in landfills and the ocean. Materials scientists are working to develop polyethylene made from sugars and grain, which are biodegradable and cleaner for the environment.

Polymers, including plastics, can be synthetic or natural. Today most plastics are synthetic and made from petroleum. It can take hundreds of years or more for light, heat, or moisture to break them down in the environment. When they do degrade, some can leach harmful substances into the water or soil. However, bioplastics are usually **biodegradable**, which means they will decay as microbes eat them.

This presents a challenge to materials scientists who must design materials that are strong and durable enough to be useful—but not so strong and durable that they remain in the environment long after they are no longer needed.

One type of bioplastic is made from the protein found in milk, called casein (pronunciation: \ˈkā-ˌsēn, "*kay-seen*"). Casein plastic, invented in 1899, is made by a process similar to cheese making in which an acid (in this case, vinegar) is added to milk. This causes the casein proteins to unfold and reorganize into long chains of molecules forming a polymer. This process is called **polymerization**.

In the early 20th century, before petroleum-based plastics became widespread and relatively inexpensive to produce, casein plastic was used to make jewelry, buttons, door handles, and acrylic paints. Today it is a component of some glues. Another, harder form of casein plastic, called *galalith*, which means "milkstone" in Greek, is produced by adding formaldehyde, which is a toxic chemical.

**Q Can petroleum-based plastics be made biodegradable?**

**A** Yes. So-called "superbugs" are microbes developed specifically to break down petroleum or petroleum products in a process called *bioremediation*—but it's not common, cheap, or easy.

**Q What are some other uses of casein?**

**A** Casein is also made into white glue—just add extra vinegar (about 1/3 cup to 1 cup of milk) and a teaspoon of baking soda. Though Elmer's® glue features a cow on the bottle and belongs to a dairy company (Borden®), it's no longer a milk product. It's a synthetic plastic.

Examples of objects made from casein (milk protein) plastic. For commercial use, casein was often mixed with formaldehyde to make galalith, which is stronger than milk plastic made with vinegar.

# Materials List

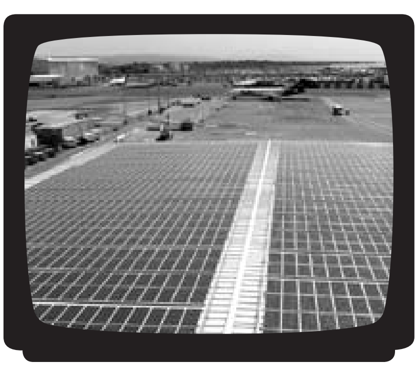
- cheese cubes in a plastic baggie
- cheesecloth or fine strainer
- clear glass cooking pot* or large, glass Pyrex® measuring cup
- container to catch the whey liquid
- copies of the cheese bioplastic recipe (p. 62) for audience to take home
- examples of biodegradable plastics, if available
- examples of casein plastics, if available
- hand wipes for visitors who volunteer to mold the bioplastic
- hot plate, microwave, or other heat source (or preheat the milk to more than 37°C/98°F—do not boil or scald—and keep it in a Thermos)
- large spoon for stirring
- milk, 1 cup**
- paper towels
- safety goggles
- scissors (to cut cheesecloth, if using)
- thermometer
- vinegar, 2 tablespoons per cup of milk
- waste bucket for disposing of vinegar solution
- waste basket for disposing of paper towels/hand wipes
- wax paper
- Demonstration Title Sign and applications collage (see Resources)—mount on foam core or insert into a clear plastic display rack
- (optional) NOVA *Making Stuff: Cleaner* video clip (see Resources) and video display equipment

For Resources, visit **pbs.org/nova/education/makingstuff**

* A glass or Pyrex® cooking pot will allow the audience to better see the curdling.

** A cup of milk will yield about a golf-ball sized batch of casein plastic. Adjust the volume of ingredients to the size of your audience using two tablespoons of vinegar per cup of milk.

# Showing Video Clips from MAKING STUFF: CLEANER



If you are able to show video at the site of the demonstration, the video clip from NOVA's *Making Stuff: Cleaner* can be used either as an introduction or as a follow-up to your demonstration. The segment could also be played on a continuous loop nearby to draw visitors into the demonstration area.

# Advance Preparation

1. At least a day before the demonstration, follow the recipe (p. 67) to **make several casein plastic samples**—or keep samples from previous demonstrations.

2. Before the demonstration, **warm the milk** to at least 37°C/98°F so that it's ready to be used. Don't boil or scald it. If doing multiple demonstrations throughout the day in a venue where no heat source is available, a large batch of milk (at least 2 cups/demo) can be microwaved and kept in a Thermos. Heat the milk for five minutes at 50 percent power and it should remain above 37°C/98°F for several hours.

3. If using cheesecloth rather than a fine strainer, **cut the cheesecloth** into squares large enough to be affixed with rubber bands over the mouth of the container that you will use to strain the mixture, separating the curds from the whey.

4. (optional) **Locate pictures** or samples of casein plastic products—vintage jewelry, buttons, doorknobs, or acrylic paints. Either create a display on a side table or use as visual aids when discussing casein plastic during the demonstration.

5. (optional) **Locate examples** of biodegradable products—such as the new biodegradable plastic bags used for certain kinds of snack chips, compostable soup bowls containing polylactic acid (PLA) plastic, or other PLA products if available in your area. Either create a display on a side table or use as visual aids when discussing biodegradable materials during the demonstration.

6. (optional) If screening a video clip, **set up a monitor** and DVD player at the demonstration site.

7. **Post** the Demonstration Title Sign on the cart/table.


**SAFETY NOTES**

- Stress that cheese is safe to eat because it's made of 100 percent food products. Commercial bioplastics (containers, bags, etc.) often also contain non-bio materials. ***DO NOT*** eat them.
- Keep pure vinegar and any heat source at a safe distance from visitors.
- Make sure your curds cool completely before handling, about three minutes.
- Because the take-home recipe requires heat, children should only use it under the direct supervision of an adult.
- Vinegar can sting eyes on contact, and so should only be handled by an adult.

# Demonstration Script

## PART 1 – DEFINE BIOPLASTIC

1. **Welcome visitors** to the demonstration and briefly introduce the show. "*Welcome to this* Making Stuff *demonstration*. Making Stuff: Stronger, Smaller, Cleaner, Smarter *is a four-part NOVA series on materials science that will air on PBS in January 2011. This demonstration accompanies the Making Stuff: Cleaner episode*."

2. **Define plastic.** *"What is plastic?"* Solicit some answers and then say: *"The word plastic has many meanings. It can describe anything that is molded or shaped. But scientifically, a plastic is a type of polymer, a substance made of long chains of molecules. Polymers can be natural or artificial (synthetic)."*

3. **Discuss plastic's origin.** *"Where does plastic come from?"* Most will know it is artificial or synthetic but many may not know it is petroleum-based. Solicit some answers and then say: *"Most plastics today are synthetic (or artificial) plastics made from petroleum (just like oil and gas)."*

4. **Define bioplastic.** Hold up the plastic bag containing the cheese and say: *"What I have here is a bioplastic."* (Don't define the word yet or reveal that it is cheese.) Demonstrate how plastic it is. Bend it, squeeze it, roll it into a ball. Let visitors handle the bag. Ask: "*What does* bio *mean*?" Maybe someone is learning *bio*logy? Or writing a *bio*graphy? Explain that *bio* means "life" and this bioplastic (hold up the plastic baggie containing the cheese) came from a living thing—a plant or animal. Ask: *"Any guesses where it came from?"* Announce: *"This bioplastic is—guess what, folks?—ordinary cheese, which is made from milk that came from cows. Cheese is a natural polymer, a bioplastic."*

5. **Expand the scope of inquiry.** *"Why would a plastic made from plant or animal materials be good?"* Some answers are:
   - A plastic made from natural materials will break down more easily in the environment (if you can eat it, so can bacteria and other microbes that break down living things, which is why we refrigerate cheeses to slow down this process).
   - Also cows keep making milk, so this bioplastic is a renewable resource.

6. **Sum up.** Field any other questions and then say: *"Now let's make a bioplastic."*

**Q How is synthetic plastic made?**

**A** Most synthetic plastics are chemically derived from petroleum. Hard plastics are molded during a semi-liquid state and then hardened. Non-bioplastics can remain buried in landfills for hundreds or thousands of years and are generally not biodegradable (microbes do not break them down).

## PART 2 – MAKE INSTANT CHEESE BIOPLASTIC

1. **Engage the audience** by holding up containers of milk and vinegar and announcing: *"I'm about to turn these two ordinary liquids, milk and vinegar, into a solid bioplastic—in an instant!"* See who believes you.

2. **Introduce vinegar.** Explain that vinegar is an acid. Don the safety goggles and **explain** that you are wearing safety goggles because pure vinegar is an acid, which is a powerful chemical that can sting your eyeballs.

3. **Introduce milk.** Hold up the milk and explain: *"Milk is a kind of liquid that has solids suspended in it, including fats and proteins that a human body needs. The protein found in milk is called casein."* (*Casein* is pronounced "kay-seen".)

4. **Ask for predictions.** The curdling really will happen in a flash, and you don't want a single onlooker to miss it. **Ask**: *"What do you think will happen when we mix the two liquids?"*

5. **Curdle the milk.** Add the vinegar with a flourish and stir for a minute or two until the curds are well formed. (This happens at about pH 4.7; milk's normal acidity is pH 6.5.) Hold up the container to show the result.

6. **Explain the science.** Say: *"What just happened was that the vinegar caused the casein proteins in the milk to unfold and reorganize into long chains of molecules called a polymer. So this is an example of a natural polymer—a bioplastic."*

7. **Strain the mixture.** Pour the mixture through the strainer or cheesecloth, allowing the whey to collect in a container; squeeze the vinegar out of the curds and let the curds cool (about 2-3 minutes).

8. **Share the casein samples.** While the newly made bioplastic cools, pass around your pre-made sample(s), field questions, and share the below facts:
   - The vinegar, with a boost from heat, causes proteins called caseins to drop out of the liquid and clump together. It does this by dissolving the calcium that binds casein proteins, which then join together in very long and strong chains (polymers).
   - The fact that bacteria eat milk makes this plastic *biodegradable*—microbes break it down.

9. **Hands-on bioplastic.** Invite a volunteer to take a handful of the *fully cooled* curds and press and shape it into a figure—which you can use for the next demonstration. Point out that the plastic will harden, like your casein artwork, in a couple of days. Offer the visitors who handled the material some wet hand wipes to clean the vinegar smell.

10. **Conclude the demo.** Emphasize that this is just one example of a simple, homemade bioplastic. Not all bioplastics are milk-based; others are made from cellulose, soy protein, hemp fiber, or flax fiber and commercial production is much more complicated. Share some applications of bioplastic including utensils, plates, cups, bowls, and packaging such as snack chip bags. Remind visitors to pick up a take-home recipe and to use it with adult supervision.

When vinegar is added to milk, a bioplastic forms.

**Q** **Can you eat this bioplastic?**

**A** Yes, but it wouldn't taste very good. This substance is a precursor to cheese. A cheese called paneer is made by adding acid to hot milk. The curds are squeezed, drained, or soaked in cold water for hours to change their texture. Other cheeses are formed by rennet—an enzyme from the stomachs of cows and sheep that curdles milk.

# Applications

**Applications of Bioplastic**

- packaging
- disposable food service items such as cups, plates, containers, and cutlery
- bags
- water bottles
- diapers
- carpet
- car interiors

# Glossary

- **biodegradable**–able to be broken down safely in the environment by microbes or natural processes
- **bioplastic**–a plastic made from plant or animal material that is biodegradable
- **casein**–a protein found in milk that can be used to make bioplastic
- **plastic**–the common term for a polymer; plastics can be natural or synthetic
- **plasticity**–the ability to be molded or shaped
- **polymer**–long chains of molecules
- **polymerization**–the process by which a polymer is formed

# Take-Home Recipe for Instant Cheese Bioplastic

## INGREDIENTS

- 1 cup of milk*
- 2 tablespoons of vinegar for each cup of milk
- spoon for stirring
- cheesecloth (works best) or fine strainer
- container (to strain the mixture)
- paper towels for clean up
- (optional) a drop or two of glycerin

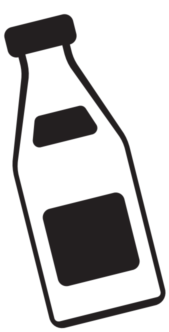
*One cup of milk makes about a golf ball-sized plastic sample. Recipe can be increased as needed.

FROM THE KITCHEN OF

MAKING STUFF

## DIRECTIONS

1. Pour the milk into a pan and warm it on the stove. Be careful not to boil or scald it. (If a skin develops, start over.)
2. Move the pan from the heat.
3. Add vinegar to the warm milk and stir until it separates and the curds are well formed (about 1–2 minutes).
4. Strain the mixture through the cheesecloth or a fine strainer.
5. Wait for the strained curds to completely cool (2–3 minutes).
6. Wrap the curds in the cheesecloth or hold them between your hands and squeeze out the extra liquid.
7. The curds will be crumbly at first—press and knead them into a solid plastic. (A drop or two of glycerin will help to "plasticize" the mixture.)
8. Shape the plastic as you like—you may want to use cookie cutters to cut shapes. Let dry overnight.



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# MAKING STUFF WITH DAVID POGUE


## DEMONSTRATION

## Shape Shifters: Shape-Memory Alloys & Polymers



WGBH GRATEFULLY ACKNOWLEDGES THE CONTRIBUTION OF THE MATERIALS RESEARCH SOCIETY.

# MAKING STUFF SMARTER Demonstration

## Overview

**TITLE**
Shape Shifters: Shape-Memory Alloys & Polymers

**SHOW**
*Making Stuff: Smarter*

**DESCRIPTION**
In this two-part demonstration, visitors will explore two shape-memory materials (a metal and a plastic) that can be programmed to return to a previously set shape when exposed to heat.

**OBJECTIVE**
Visitors will learn about:
- "smart" materials that can sense and respond to their environments
- shape-memory materials, which are smart materials that can be programmed to remember specific shapes

**OTHER KEY TALKING POINTS**
Materials scientists are developing new smart materials to help solve problems in engineering, medicine, and everyday life.

**AUDIENCE**
General public, ages 10 and up

**TIME**
Set-up: 10 minutes
Presentation: 20 minutes. (Each part can stand alone but the two are best presented together, with the shape-memory wire first.)

All materials change in response to their environment. Most expand when heated, for example. **Smart materials** are designed by materials scientists and engineers to respond to changes in their environments—often in unusual or dramatic ways to achieve a specific purpose. NOVA's *Making Stuff: Smarter* features scientists developing new airplane wings that will one day be able to change their shape smoothly in mid-flight, as birds do. (Nature, a master of response and change, inspires the design of many smart materials.)

A **shape-memory material** is a type of smart material that can be programmed to return to a previously set shape when exposed to certain change in its environment. The materials in this demonstration display their shape-shifting properties when exposed to heat. Other shape-memory materials respond to certain wavelengths of light, changes in the magnetic field, electrical currents, or chemical solutions.

Shape-memory and other smart materials are revolutionizing medicine, manufacturing, construction, and energy. Researchers are working to develop a smart fabric that senses the presence of blood and sends a signal to a handheld computer, alerting doctors that an unconscious combat soldier may be injured. Another potential application is a **piezoelectric** city sidewalk that senses the pressure of footsteps and converts that kinetic energy into electric current that can power streetlights and buildings.

Materials scientists are asking:

- How can we design materials that respond to changes in their environment?
- How can we use those materials to make smarter stuff?

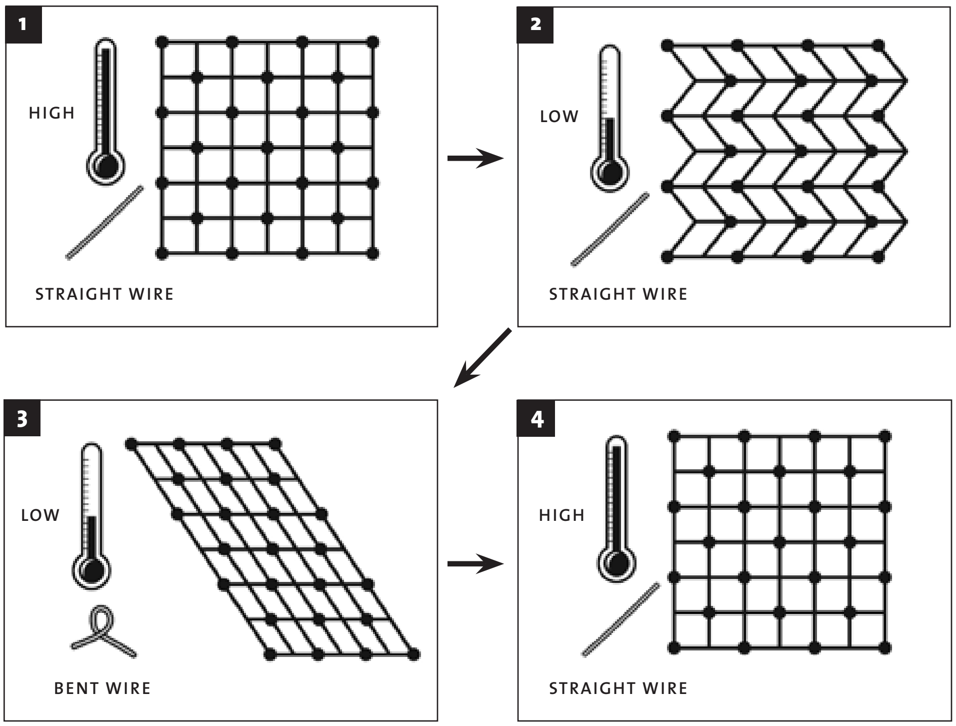
## Science Background

### Shape-Memory Alloys & Polymers

This two-part demonstration focuses on two **shape-memory** materials, an alloy and a polymer.

#### SHAPE-MEMORY ALLOY

An **alloy** is a blend of metals. The alloy in the first part of this demonstration is a nickel (Ni) and titanium (Ti) alloy named Nitinol (pronounced "*night-in-all*") whose shape-memory properties were discovered at the Naval Ordnance Laboratory (NOL) in White Oak, Maryland, in 1961 (hence the name NiTiNOL). It has a crystal structure, meaning the molecules are arranged in a rigid and regular structure, like a military marching band locked in formation. Most common materials undergo a **phase change** at specific transition temperatures. For example, they change from solid to liquid at their melting points, like ice to water, or from liquid to gas at their boiling points, like water to steam. Nitinol, however, when heated, undergoes a phase change while remaining solid. This causes its atoms to shift to a new arrangement, changing its outward shape, while remaining solid.




### How Do Shape-Memory Alloys Work?

A shape-memory alloy has two structures or phases, which it can transition between while remaining solid. In the high temperature phase, called austenite, the atoms arrange themselves in their "memorized" or permanent shape. In this case, the wire is set straight **(1)**. As the alloy cools and enters the low temperature phase, called martensite, the cubic structure becomes folded or twinned **(2)**. In this state, the wire can be deformed, skewing the cubic structure **(3)**. The alloy will hold that deformed shape until it is heated back above the transition temperature, at which point the atoms revert to their austenite state and the wire "remembers" its previous shape and straightens **(4)**.

Below that transition temperature, the wire can be deformed because atoms shear past each other. It will hold that deformed shape until it is heated back above the transition temperature, at which point the molecules revert to their previous state. Training the wire to a new memorized shape requires a blast of thermal energy on the order of 500°C (about 900°F) and for the new shape to be temporarily maintained with applied force (such as pliers) until the wire sets and relaxes. Cooling the material ensures that the new shape becomes fixed.

Some other shape-memory alloys are copper-aluminum-nickel, copper-zinc-aluminum, and iron-manganese-silicon.

## SHAPE-MEMORY POLYMER

All plastics are **polymers**, which are long chains of molecules. Shape-memory polymers, however, are combinations of two polymers, each of which has a different melting point.  One polymer sets the permanent memorized shape at the polymer's melting point while the other polymer creates the temporary shape at a different, transition temperature. Heat softens this temporary shape (by breaking the crosslinks between polymer strands), and the shape-memory polymer reverts to its permanent shape. Some shape-memory polymers have up to three memorized shapes, each triggered at a different temperature.

# Materials List

*Part 1: Shape-Memory Alloy (Nitinol)*

- Nitinol wires set straight
- straight, flexible, ordinary wire segments about the same length as the Nitinol (e.g., straightened paper clips)

*Part 2: Shape-Memory Polymer*

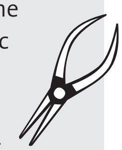
- clear container of cold water to cool shape-memory polymer
- clear container of warm water (85°F/30°C or warmer, not hot) to reset the shape
- paper towels
- samples of ordinary plastic such as polyethylene (#1 plastic, e.g., plastic soda bottles or pint-size fruit containers) or polystyrene (#6 plastic, e.g., plastic drink cups or clamshell deli containers)
- shape-memory plastic strips
- Thermos of hot water (to refresh the warm water throughout the day)
- overhead projector on which to place the clear container (for large audiences) and projection screen or wall (optional)

*Both*

- heat gun (also called a hot air gun) needle-nose pliers to hold material in front of the heat gun
- (optional) NOVA *Making Stuff:Smarter* video clip (see Resources) and video display equipment
- Demonstration Title Sign and applications collage (see Resources)—mount on foam core or insert into a clear plastic display rack

For Resources, visit **pbs.org/nova/education/makingstuff**

Materials and supplies for this demonstration can be found at most hardware, home improvement or office supply stores. The Nitinol wire can be found online at **teachersource.com**, and **imagesco.com**. The shape-memory plastic can be purchased at **bendableplastic.com** and **inventables.com**.



# Showing Video Clips from MAKING STUFF: SMARTER

If you are able to show video at the site of the demonstration, the video clip from NOVA's *Making Stuff: Smarter* can be used either as an introduction or as a follow-up to your demonstration. The clip can also be played on a continuous loop nearby to draw visitors into the demonstration area.

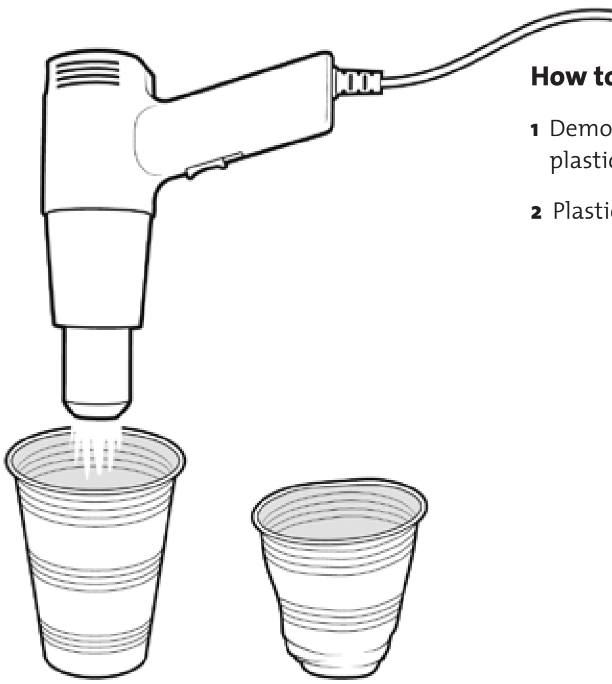
# Advance Preparation

## PART 1: ALLOY

1. The transition temperature for Nitinol wires varies, so bend and then test the shape-memory properties of your samples with the heat gun several times to make sure you're providing enough thermal energy.

## PART 2: POLYMER

1. Test your heat gun on a common plastic sample (#1 polyethylene or #6 polystyrene) to make sure it's hot enough to shrink the plastic. Directing the heat gun down into the mouth of a plastic cup (as below) works well to quickly shrink it. Hold the cup still with the needle-nose pliers or up for better visibility.



**How to Heat Common Plastic**

1 Demonstrator heats common plastic with heat gun

2 Plastic will shrink but not melt

2. Cut the shape-memory sheets into several strips. Long thin strips make for easier manipulation and viewing.

3. Practice the demonstration several times before performing it for a live audience.

4. Prior to starting the demonstration, set up the materials for both parts, to make for a smoother transition. Have the containers of cold and warm water off to the side. Have a Thermos of hot water ready to use throughout the day to refresh the warm water container.

5. Post the Demonstration Title Sign on the cart/table.

# Demonstration Script

## PART 1: SHAPE-MEMORY ALLOY—NITINOL WIRE

1. **Welcome visitors** to the demonstration and briefly introduce the show. *"Welcome to this* Making Stuff *demonstration.* Making Stuff: Stronger, Smaller, Cleaner, Smarter *is a four-part NOVA series on materials science that will air on PBS in January 2011. This demonstration accompanies the* Making Stuff: Smarter *episode."*

2. **Engage your audience.** Announce that you're about to demonstrate some "smart materials" that can do some amazing things. Point to the wires lying on the cart and ask your audience: "*Do these wires look 'smart'?*"

3. **Set up the challenge.** "*Well, we're going to investigate to find out if they are smart materials.*"

4. **Introduce smart materials.** "*A smart material is something that can sense a change and respond to it in a way that makes it very useful.*"

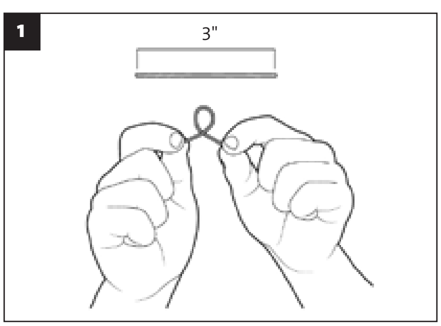
5. **Get volunteers.** Ask the audience: "*What happens to a metal when you heat it?*" As you solicit answers, pass out one or two normal wires and one or two Nitinol wires to volunteers. In answer to your question, science-savvy listeners will likely respond that metal expands or melts. Someone may incorrectly suggest it burns. Or, perhaps just note that it gets hot.

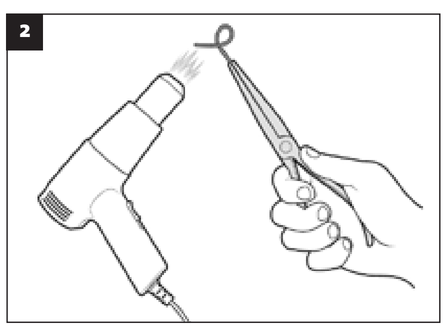
6. **Bend the wires.** Ask the volunteers to bend their wires into any shape—perhaps coils, springs, curlicues, zigzags, etc.

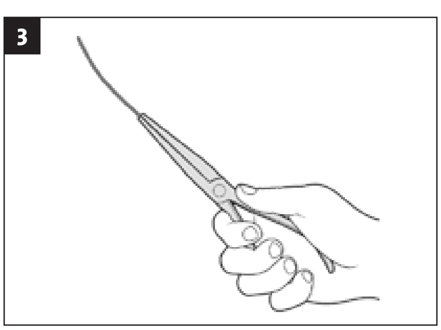
7. **Heat the ordinary wire.** Ask the first volunteer (with *ordinary* wire) to step forward. Say: "*Let's see how this wire responds to heat.*" Hold the wire with the pliers and heat it with the heat gun. Nothing will happen.

### SAFETY NOTES

- Be careful not to direct the heat gun toward audience members while in use.
- Allow materials to cool completely before being handled by visitors.
- After using heat gun, set aside out of reach of visitors, to cool.




### How to Demonstrate the Shape-Memory Wire

**1** Demonstrator hands straight wire to volunteer to bend

**2** Demonstrator holds bent wire with pliers and heats with heat gun

**3** Shape-memory wire will straighten while regular wire will not

8. **Heat the Nitinol wire.** Retrieve a bent Nitinol wire from a volunteer. Say: "*So let's see how this wire responds to heat.*" Hold the wire with the pliers and heat it with the heat gun. The wire will straighten itself out.

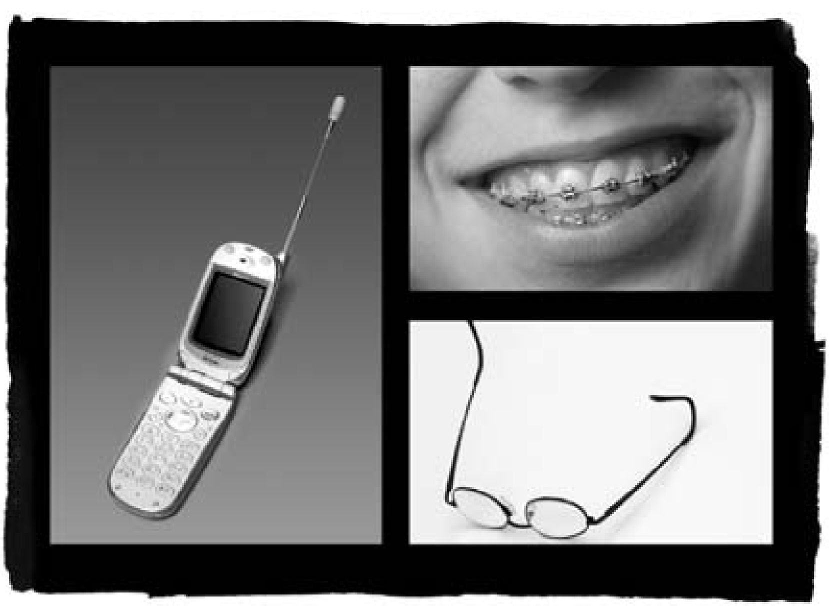
9. **Ask for predictions.** "*Do you think it could happen again?*" Make sure the wire is cool, and then ask the volunteer to reshape the wire and repeat the test.

10. **Explain** to visitors that they just witnessed an example of shape memory. And that:
    - "*Nitinol (a nickel-titanium alloy) is a shape-memory material—one of many classes of smart materials that can be programmed to do things that ordinary stuff cannot.*"
    - "*What happened was, at a certain temperature, the atoms in the wire shifted back to their 'remembered' shape—a straight form. This can be done over and over again.*"
    - "*By contrast, the ordinary wires are passive. They respond to low levels of heat by expanding and higher levels of heat by melting (not burning) but they do not have shape-memory properties.*"

11. **Relate the science to everyday life.** "*Perhaps you are wondering why you should care about shape-memory alloys.*" Then ask everyone to smile. Inquire: "*Who's wearing braces (or has worn braces)?*" Ask a brace wearer how it feels to have them tightened. Suggest that Nitinol wire braces can save people from this periodic agony. The main wire running across all the teeth is programmed to bend into an arch at body temperature to apply constant and gradual pressure on the teeth.

12. **Brainstorm other uses.** "*Can you think of some other uses of Nitinol wire?*" (It is currently used in thermostats, automatic shut-off valves, and some fasteners. Some other future uses might be car bumpers.)

# Applications



**Applications of Shape-Memory Alloys**

- thermostat control wires or other devices that could be used to prevent burns (e.g., anti-scald devices on showers) or on fire sprinkler valves
- staples (or couplings) that close themselves with heat
- flat, compact space antennae that save space during launch and then unfold themselves in orbit
- heart stents that expand after insertion to hold open clogged cardiac arteries
- cell phone antennaes or eye glasses frames that regain their shape if bent

## PART 2: SHAPE-MEMORY POLYMER

1. **Refine the concept** of smart materials: Ask: "*Is every material that changes shape a smart material?*" Accept all responses.

2. **Introduce plastic.** Show your audience the common plastic (polyethylene or polystyrene sample) and explain that the scientific term for plastic is polymer, which is a long chain of molecules.

3. **Ask for predictions.** Ask what a blast of heat is likely to do to the plastic. (Some might suggest it will change into some other shape. Agree that this is certainly a logical assumption, especially since the very definition of plasticity is the ability to be bent, molded, extruded, deformed, or otherwise reshaped.) Accept all responses, then heat the plastic with the heat gun until it stops shrinking. (Tip: Directing the heat gun down into the mouth of a plastic cup works well.)

4. **Invite interaction.** Pass around "before" and "after" samples of the shrunken plastic for comparison. Challenge your guests to make the shrunken plastic revert to its previous form—as the Nitinol wire did. Solicit suggestions. Try reheating it; no effect. Try stretching it; it won't budge. Emphasize that this shape change is a one-way street.

5. **Introduce smart plastic.** Say: "*Now we are going to see some smart plastic.*" Pass out the shape-memory polymer strips and invite guests to play with them to test their shape-memory properties. Ask visitors to bend the material into the desired shape (a coil works best, the tighter the better) and return it to you.

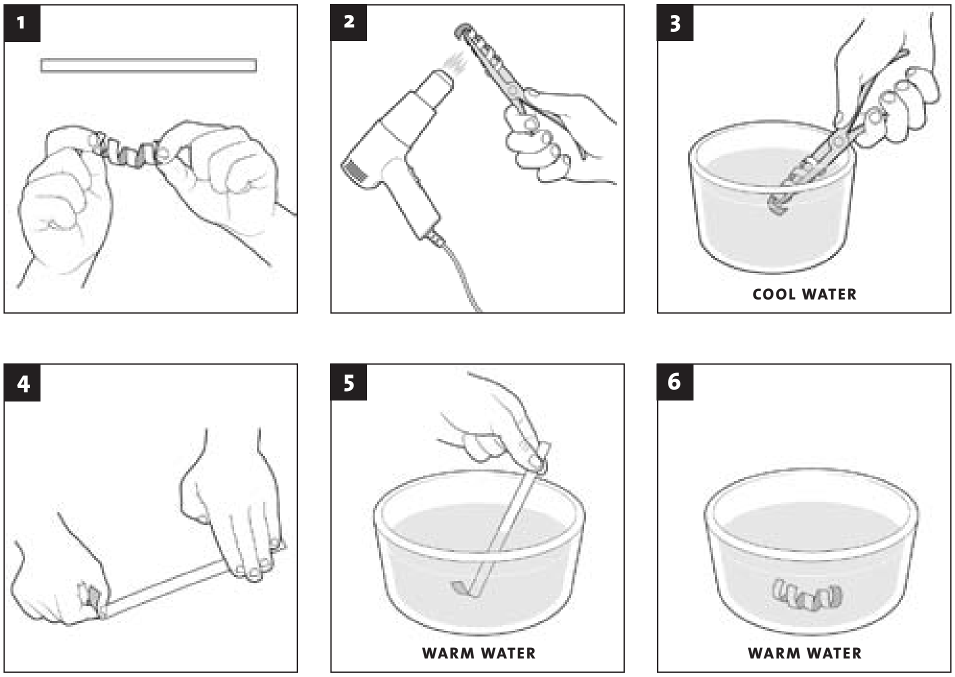
6. **Set the coil shapes.** Hold the coil shape in place with the pliers and heat with the heat gun on low for about 30 seconds. Submerge the plastic in the beaker of cold water to cool for 15 seconds.

7. **Straighten the coils back out.** Pass the plastic coils back to the visitors to straighten. When straightened, ask them to drop it into the beaker of warm water.

8. **Observe the shape memory.** When dropped into the water, the plastic strip should begin to recoil. (Note: This may occur slowly, but movement should be visible immediately.) Explain that shape-memory polymers are actually two polymers combined, each with different melting points. One polymer responds at a certain temperature to set the permanent memorized shape of the object and the second polymer responds at a different temperature to set the temporary shape. The water temperature is higher than the temperature at which the plastic reverts from its temporary shape (straight) to its memory shape (coil trained by the heat gun). Say: "*It remembers the shape that you gave it.*" Repeat with a few more visitors' samples.

### How Does Heat-Shrink Plastic Work?

- The large family of heat-shrink **thermoplastics** (such as polyethylene or polystyrene) works the same general way.
- During manufacturing, the heat-shrink plastic is stretched out, molded, and rapidly cooled to lock in a shape.
- Heat causes the molecules to relax back to their pre-stretched state—and the plastic to shrink.
- It's a one-way street: The plastic won't shrink past a certain point, and it won't revert to its stretched, molded shape unless melted and remanufactured.




**How to Demonstrate the Shape-Memory Plastic**

**1** Demonstrator hands straight plastic strip to volunteers to coil

**2** Demonstrator holds coiled strip with pliers and heats with heat gun

**3** Demonstrator plunges coil (still in pliers) into cool water

**4** Volunteer straightens coil

**5** Volunteer drops coil into warm water

**6** Plastic strip will regain its coiled shape

9. **Further define smart materials.** Ask: "*What makes this material smarter than the common plastic samples?*"

   Some answers are:

   - It can be programmed to remember a shape.
   - It's a two-way street; the plastic can remember its memorized shape again and again, no matter how many times you deform it.
   - You can also reprogram it. Thus, the plastic can both "remember" and "re-learn."
   - The action happens automatically in response to a stimulus—no human intervention or mechanical parts are needed.

10. **Relate the science to everyday life.** Discuss some of the applications (see page 72), which are not on the market yet, but are under development and being tested.

11. **Encourage your guests to think like inventors** and brainstorm other ways that shape-memory polymers could be used in the future.

# Applications


**Real and Potential Applications of Shape-Memory Polymers**

- clothes embedded with shape-memory plastic strips; body heat causes them to unwrinkle or crease themselves
- polymer or composite car parts that, if crumpled in an accident, could be repaired by heat
- autonomous kinetic sculptures made of shape-memory materials
- sutures (at right) that tie themselves and keep wounds closed at an optimal tension
- smart utensils such as forks that, when placed in hot soup, turn into a spoon
- stents that can be inserted into arteries and then expand to hold them open

# Glossary

- **alloy**–a blend or combination of two or more metals
- **phase change**–a change from one state of matter (solid, liquid, or gas) to another; for example, from solid to liquid or liquid to gas
- **piezoelectric**–a type of material that responds to an applied force by producing electricity; also, when an electric field is applied, it will produce a force (Buzzers are commonly made from quartz, which is a piezoelectric material.)
- **polymer**–a long chain of molecules; all plastics are polymers
- **shape memory**–a property of materials in which various shapes can be programmed to form in response to certain changes in the environment, such as heat or light
- **smart material**–a material that senses a change in its environment and responds in a specific way
- **thermoplastics**–plastics that are capable of melting and can change phase from solid to liquid and back again
- **thermoset plastics**–plastics that scorch or burn without melting first

# General Resources

These general materials science resources support NOVA's four-part *Making Stuff* series and include resources specific to each episode, and each of the four demonstrations and four activities.

## BOOKS

Amato, Ivan. *Stuff: The Materials the World Is Made Of*. New York, NY: Basic Books, 1997.

Ball, Philip. *Made to Measure: New Materials for the 21st Century*. Princeton, NJ: Princeton University Press, 1999.

Woodford, Chris. *Cool Stuff and How It Works* (three-book series). New York, NY: Dorling Kindersley, 2005, 2007, 2008.

## ORGANIZATIONS

*Association of Science-Technology Centers (ASTC)*
astc.org
The umbrella organization for science centers and museums has a useful resource center and publications for improving demonstrations and exhibits.

*ASTM International (ASTM)*
astm.org
Originally known as the American Society for Testing and Materials, ASTM International sets technical standards for materials, products, systems, and services.

*Materials Research Society (MRS)*
mrs.org
"The materials gateway" site for members of the materials science community includes pages and links for NOVA's *Making Stuff* series and other partnership outreach programs.

*Nanoscale Informal Science Education (NISE) Network*
nisenet.org
Here's where scientists and informal science educators join forces to provide, access, and exchange resources about the science of the very small. The site includes current nanoscale research, an online collection of educational resources (exhibits, programs, activities, demonstrations, and so on), scientific images, community forums, events, and links.

*National Nanotechnology Infrastructure Network (NNIN) Education Portal*
nnin.org/nnin_edu.html
K–12, university, and community educational materials on nanotechnology products, careers, natural and artificial structures, the nanoscale, and more. Nanooze is an online children's science magazine available in English, Spanish, and Portuguese.

*National Science Foundation's Materials Research Science & Engineering Centers (MRSECs)*
mrsec.org
The Education Outreach page lists programs, contacts, events, workshops, and links to more than 30 university members of MRSEC.

## WEB SITES

*AZoM: The A to Z of Materials*
azom.com
Search the database for technical and general articles and videos about any of the materials mentioned in the *Making Stuff* episodes or guides.

*DemoFiles: The Science Demonstration Cookbook*
demofiles.org
Online database of demonstrations contributed by teachers and museum educators (including one for walking on oobleck), tips and tricks, and a forum for sharing ideas.

*NOVA's* Making Stuff *Web site*
pbs.org/nova/makingstuff
Don't miss the Inside NOVA blog: Adventures in "Making Stuff." Go behind the scenes with host David Pogue and the crew as they film the series.

*Science Saturdays*
sciencesaturdays.org
Free streaming or downloadable videos of science talks aimed at a general audience of kids. "Strange Stuff: From Smart Materials to Nanotechnology," "Metals with Memories," "If the Walls Could Think: Smart Materials in Buildings," and "Batteries, Transportation, and Climate Change" relate to *Making Stuff* activities. Go to strangematterexhibit.com/demoworks_final.pdf to download *Demoworks*, a collection of 43 quick demonstrations prepared by materials scientist Ainissa Ramirez, the host of Science Saturdays.

*Strange Matter Exhibition*
strangematterexhibit.com
The Web site for a traveling exhibition about materials science features interactive online modules that invite visitors to "Zoom Inside Stuff, Transform Stuff, Crush Stuff, and Improve Stuff." This site also provides family and teacher resources.

*University of Wisconsin-Madison MRSEC*
mrsec.wisc.edu/Edetc
The focus is nanotechnology and advanced materials. The education program includes several guides with resources and links, topic-specific activities with online training videos for demonstrators, a board game and a quiz game, and a video lab with how-to clips for working with advanced materials.

# Making Stuff: Stronger


#### BOOKS

Eberhart, Mark. *Why Things Break: Understanding the World by the Way It Comes Apart*. New York, NY: Three Rivers Press, 2003.

Gordon, J.E. *The New Science of Strong Materials or Why You Don't Fall Through the Floor*. Princeton, NJ: Princeton Science Library, 2006.

#### ARTICLES

Hazlewood, Kelsey. "Roundup: Bulletproof Vests." *Wired* magazine, February 22, 2010. Available online at wired.com, along with a video of a product test.

Keim, Brandon. "Carbon Nanotube Muscles Strong as Diamond, Flexible as Rubber." *Wired* magazine, March 19, 2009. Online version includes scientist Ray Baughman's images and videos.

#### WEB SITES

*DuPont: Welcome to Kevlar®*
www2.dupont.com/Kevlar/en_US
The manufacturer explains the product, technical specs, and many uses and applications of Kevlar®.

*National Highway Traffic Safety Administration: Crashworthiness Research*
nhtsa.gov/Research/Crashworthiness
A compilation of reports from studies of crashworthiness of vehicles including school buses.

*Space Elevator video*
pbs.org/wgbh/nova/space/space-elevator.html
NOVA scienceNOW explores how carbon nanotubes could provide the lightweight strength needed to form a miles-long tether into orbit.


## Demonstration: Breaking Point: Testing Tensile Strength


#### WEB SITES

*Michigan Tech's Virtual Tensile Test*
mse.mtu.edu/outreach/virtualtensile/index.htm
Informational site with diagrams, charts, and a video of fiberglass, Kevlar®, and carbon fiber tensile tests.

*MicroWorlds: What Is Kevlar® Made Of?*
lbl.gov/MicroWorlds/Kevlar/KevlarClue1.html#Activ1Return
Tutorial about what makes Kevlar® strong on a molecular level is aimed at middle school and above.

*The Wonders of Spider Silk*
earthlife.net/chelicerata/silk.html
Facts about and images of spiders and their silk—one of nature's strongest threads.

# Making Stuff: Smaller

## WEB SITES

*"Cancer Nanotech" interactive*
pbs.org/wgbh/nova/body/cancer-nanotech.html
Based on one of several NOVA scienceNOW segments about nanotechnology.

*Microchip Clips videos*
thetechvirtual.org/projects/microchip-clips
The Tech Museum of San Jose, California, held a contest to create the best two-minute video about microchips.

*"Nanotechnology Takes Off" video*
kqed.org/quest/television/view/189
This Quest multimedia program includes a downloadable educator guide.

*"Talking Nano"*
talkingnano.net
Six DVDs address materials sciences issues. Chaptered and keyed to standards. Also available in 10-minute segments on youtube.com/nanonerds, which includes talks, demos, nano research and newscasts.

*"When Things Get Small" video*
ucsd.tv/getsmall/
Whimsical, half-hour romp through nanoscience concepts produced by University of California Television. Portuguese and Spanish subtitles available.

*"Zoom Into" video series*
dailymotion.com/user/Weird_Weird_Science
In one continuously increasing close-up, each narrated video zooms into a material (steel, plastic, carbon fiber, concrete, and so on) to the atomic scale—and beyond.

## Demonstration: Nanowires and the Ever-Shrinking Microchip

### BOOKS

Brady, Susan and Willard, Carolyn. *Microscopic Explorations: Grades 4–8*. GEMS (Great Explorations in Math and Science) series. Berkeley, CA: Lawrence Hall of Science, 1998.

Broll, Brandon. *Microcosmos: Discovering the World Through Microscopic Images*. London: Firefly Books, 2007.

### WEB SITES

*Institute for Research in Materials (IRM) at Dalhousie University*
irm.dal.ca/Image%20Gallery
Scanning electron microscope (SEM) image gallery.

*Materials Research Society's "Science as Art" Images*
mrs.org/s_mrs/doc.asp?CID=1803&DID=171434
Downloadable color images on micro to nano scale.

*Microscopy Society of America*
microscopy.org/education/projectmicro
This nonprofit group teamed up with the Lawrence Hall of Science to produce Project MICRO (Microscopy In Curriculum–Research Outreach), an effort to get microscopist-volunteers into classrooms nationwide.

*Molecular Expressions: Chip Shots Gallery*
micro.magnet.fsu.edu/chipshots/index.html
"Microprocessors under the Microscope" is one of a dozen online image galleries. There's also an extensive primer on microscopy and a virtual microscope Java applet. The "Secret Worlds: The Universe Within" page shows incremental images in powers of 10 from galactic scale down to quarks.

*Nanozone*
nanozone.org
Lawrence Hall of Science's exhibit-based Web site for kids features informative cartoon interactives about nanotechnology (what it is, how small it is, who works on it, and why it's important). A black-and-white scanning electron microscope (SEM) image gallery reveals everyday objects in super close-up.

*National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT)*
nclt.us
Host site of the NanoEd Resource Portal (nanoed.org), a collection of lessons, online learning tools, simulations, scientific papers, workshops, and events prepared for the nanoscale science and engineering education (NSEE) community.

# Making Stuff: Cleaner

### BOOKS

Emsley, John. *A Healthy, Wealthy, Sustainable World*. London: Royal Society of Chemistry, 2010. See Chapters 4 (biofuels), 5 (plastics), and 6 (cities).

Leonard, Annie. *The Story of Stuff: How Our Obsession with Stuff Is Trashing the Planet, Our Communities, and Our Health—and a Vision for Change*. New York, NY: Free Press, 2010. Project Web site: storyofstuff.com/staff.php. DVD available.

Schlesinger, Henry. *The Battery: How Portable Power Sparked a Technological Revolution*. Washington, D.C.: Smithsonian, 2010.

### WEB SITES

*MIT's Virus Battery*
web.mit.edu/newsoffice/2009/virus-battery-0402.html
Press release, images, and downloadable article about Angela Belcher's battery built from genetically engineered viruses. Belcher is also profiled in an April 2009 *Scientific American* article, "Building Tiny Living Batteries".

*Plastipedia*
bpf.co.uk/plastipedia/plastics_history/default.aspx
British Plastics Federation's extensive encyclopedia of all things plastic.

*Plastic Marine Debris*
marinedebris.noaa.gov/info/plastic.html
How big is the plastic problem? FAQs about how plastic degrades and the Great Pacific Garbage Patch, a vast island of plastic in the ocean.

### Demonstration: Instant Cheese Bioplastic

#### RECIPES

Acid and milk combine to produce two easy-to-make cheeses: paneer (or panir) and queso blanco. Search online for recipes and how-to videos.

#### ARTICLE

Dell, Kristina. "The Promise and Pitfalls of Bioplastic." *Time* magazine, May 3, 2010.
A balanced look at what "bioplastic" really means. Available online at time.com.

#### WEB SITES

*American Chemistry Council: Plastics Division*
americanchemistry.com/s_plastics/index.asp
Three hands-on plastics (HOP) science kits for grades K–4, 5–8, and 9–12 are available for sale; the free Web site offers a learning center with science information and reports about plastics and the environment.

*Macrogalleria: A Cyberwonderland of Polymer Fun*
pslc.ws/macrog/index.htm
Polymer games, home and school activities, experiments, demonstrations, and information aimed at children.

*Worldcentric: Compostable Plastics*
worldcentric.org/biocompostables/bioplastics
Science and environmental background on the biodegradability of plastics from a social enterprise whose mission is sustainability. Note: This organization funds itself by selling environmentally friendly and fair trade products.

## Making Stuff: Smarter

#### ARTICLES

L. McDonald Schetky. "Shape-Memory Alloys." *Scientific American*, November 1979, Vol. 241, No. 5, pp 74-82.

*Smart Materials*
azom.com/details.asp?ArticleID=123
Definition and overview of technology and applications.

*Smart Stuff*
philipball.co.uk/m02_01.php
Science writer Philip Ball clearly explains what smart materials are and what they can do.

#### BOOKS

Benyus, Janine. *Biomimicry: Innovation Inspired by Nature*. New York, NY: Harper Perennial, 2002.

Pakhchyan, Syuzi. *Fashioning Technology: A DIY Intro to Smart Crafting*. Sebastopol, CA: O'Reilly Media, 2008. A companion *Smart Materials Kit* (available at makershed.com) provides starter materials, including Nitinol.

#### WEB SITES

*Autoline Detroit*
autolinedetroit.tv
Search the podcasts for "smart materials" to see amazing applications in the automotive industry.

*Biomimicry Institute*
biomimicryinstitute.org/home-page-content/home-page-content/biomimicking-sharks.html
An article on shark skin–inspired technology and other innovations in biomimicry.

*Shape-Memory Alloys*
smaterial.com/SMA/sma.html
Information site about how shape-memory alloys work, applications, news, links, and more.

### Demonstration: Shape Shifters: Shape-Memory Alloys & Polymers

#### BOOK

Goodstein, Madeleine P. *Plastics and Polymers Science Fair Projects*. Berkeley Heights, NJ: Enslow, 2010.

#### WEB SITES

*Inventables*
inventables.com
Search for "shape memory" to investigate emerging and cutting-edge shape-memory materials by independent inventors, who provide specifications and suggested applications. Inventables founders Zach Kaplan and Keith Schacht also have a Ted talk (ted.com) on futuristic materials, including shape-memory plastics.

*Nitinol University*
nitinoluniversity.com/2010/05/nitinol-the-book-an-introduction
In addition to a reference library and fact sheets, this site features *Nitinol: The Book* by Tom Guerig and Alan Pelton.

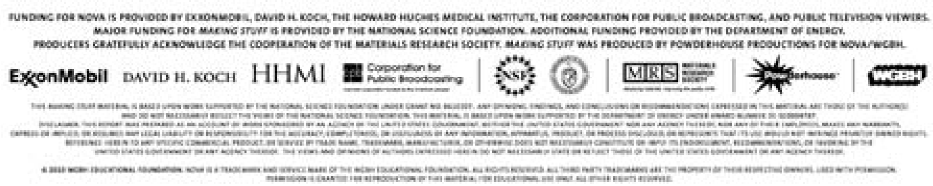
# Guidelines for Using the MAKING STUFF Logo and Related Language

All event, promotional, advertising, and printed materials related to *Making Stuff* must carry credit information. If the option below is too long or seems inappropriate for the piece you are producing, contact Jennifer Larese to discuss other options.

**Contact:**
Jennifer Larese
Outreach Coordinator
WGBH Educational Outreach
One Guest Street
Boston, MA 02135
617-300-4316
jennifer_larese@wgbh.org

## Crediting *MAKING STUFF* funders and producers

The following block of text and logos, which can be found at pbs.org/nova/education/makingstuff, must be placed on all materials that will be displayed or distributed in 2010.




The following block of text and logos, which can be found at pbs.org/nova/education/makingstuff, must be placed on all materials that will be displayed or distributed in 2011.


### Use this logo, available in color and black and white, on your *Making Stuff* materials

## Referring to *MAKING STUFF with David Pogue* in print

- The full show title is:
  *MAKING STUFF with David Pogue*
  (MAKING STUFF should appear in caps and the full title in italics)
- The abbreviated show title is:
  *MAKING STUFF*
- The show episodes are (use this order when referring to the episodes):
  Stronger, Smaller, Cleaner, Smarter
- The show and episodes together are:
  *MAKING STUFF: Stronger, Smaller, Cleaner, Smarter*

## Referring to the *MAKING STUFF* host (David Pogue)

- The host credit should be: Hosted by David Pogue.
- Only preapproved biographical information about David Pogue may be used. **Note**: Check NOVA's press site for approved biographical information at pressroom.pbs.org.

## Adding a tune-in message

If adding a message about when *MAKING STUFF* airs, use the following text, always with the PBS logo:

- **General tune-in**

  Watch *MAKING STUFF with David Pogue* on PBS (check local listings)
  A four-part series exploring the materials that will shape the future
  Premiering January 19, 2011

  Visit pbs.org/nova/makingstuff PBS

- **Tune-in for a specific public television station**

  Watch *Making Stuff with David Pogue* on [insert your local PBS station name here]
  A four-part series exploring the materials that will shape the future
  Premiering January 19, 2011 at [insert air time here]

  Visit pbs.org/nova/makingstuff PBS

## Referring to the *MAKING STUFF* Web site

- When possible, include the URL for the *MAKING STUFF* Web site:
  pbs.org/nova/makingstuff

# Check out these other PBS and WGBH resources.

PEEP and the Big Wide World

### AGES 3-6

Celebrate the curiosity and adventure of young children with simple science explorations.
**peepandthebigwideworld.org**

Curious George

### AGES 3-6

Discover science, engineering, and math along with Curious George.
**pbskids.org/curiousgeorge**

FETCH! with Ruff Ruffman

### AGES 6–10

Try the great FETCH activities based on challenges from the show.
**pbskidsgo.org/fetch**

THE GREENS

### AGES 9-12

Investigate environmental issues and take action to protect the planet.
**pbskidsgo.org/greens**

DESIGN SQUAD as built on TV

### AGES 9-13

Unleash your kids' ingenuity and get them thinking like engineers through hands-on activities.
**pbskidsgo.org/designsquad**

NOVA NOVA scienceNOW

### AGES 11 AND UP

Dig deep into science topics with classroom-ready resources from the most-watched science television series on PBS.
**pbs.org/nova/teachers**

dot diva

### AGES 14 AND UP

Check out this career site for teen girls who believe in the potential of computing to build a better world.
**dotdiva.org**

Engineer Your Life™ Dream big. Love what you do.

### AGES 14-18

Meet inspiring women engineers who make a real difference in the world. Find out if engineering might be your dream job.
**engineeryourlife.org**

teachers' domain

### EDUCATORS

Use this media-rich library of teaching resources to make concepts come alive in engaging and interactive ways.
**teachersdomain.org**

# Credits

The NOVA *Making Stuff* Toolkit was produced by the Educational Outreach Department of WGBH.

**Director, Educational Outreach**
Julie Benyo

**Associate Director, Educational Outreach**
Thea Sahr

**Director of Education, NOVA**
Rachel Connolly

**Educational Content Manager**
Sonja Latimore

**Senior Editor**
Sara Pratt

**Associate Editor**
Claudette Dawes

**Outreach Coordinator**
Jennifer Larese

**Writer**
Lorraine Hopping Egan/
Hopping Fun Creations

**Associate Creative Director**
Alison Kennedy

**Designer**
Danielle Pierce

**Illustrator**
Zeke Smith

**Print Production**
Lenore Lanier Gibson

**Advisors**
Carol Lynn Alpert
Director, Strategic Projects
Museum of Science, Boston

Amy Moll, Ph.D.
Professor, Materials Science and Engineering
Boise State University

Ainissa Ramirez, Ph.D.
Associate Professor of Mechanical Engineering & Materials Science
Yale University

Richard Souza
Manager, Education and Outreach
Materials Research Society

**Reviewers**
Costel Constantin, Ph.D.
Assistant Professor, Department of Physics and Astronomy
James Madison University

Jerry Floro, Ph.D.
Associate Professor, Materials Science and Engineering
University of Virginia

Megan Frary, Ph.D.
Assistant Professor, Materials Science and Engineering
Boise State University

Tommie Kelley, Ph.D.
Advanced Research Specialist
3M

Alex King, Ph.D.
Director, Ames Laboratory
Department of Energy

Marlann Patterson, Ph.D.
Assistant Professor, Physics
University of Wisconsin-Stout

Greta Zenner Petersen
Director of Education
University of Wisconsin MRSEC

Karine Thate
Education Associate, Strategic Projects
Museum of Science, Boston

Rick Vinci, Ph.D.
Associate Professor, Materials Science and Engineering
Lehigh University

Funding for NOVA is provided by ExxonMobil, David H. Koch, the Howard Hughes Medical Institute, the Corporation for Public Broadcasting, and public television viewers.

Major funding for *Making Stuff* is provided by the National Science Foundation.

THIS *MAKING STUFF* TOOLKIT IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION UNDER GRANT NO. 0610307. ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRESSED IN THIS MATERIAL ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.

Additional funding for *Making Stuff* is provided by the Department of Energy.

THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE DEPARTMENT OF ENERGY UNDER AWARD NUMBER DE-SC0004787.


*Making Stuff* was produced by Powderhouse Productions for NOVA/WGBH.

Producers gratefully acknowledge the cooperation of the Materials Research Society.



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