

It's a

# Materials World



Gaining insight into the materials science and engineering applications all around us. Vol. 2 No. 2 March 2002

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*Created by Students for Students*

## **A Quick Note From the Editor**

I hope you all enjoyed the last edition of *It's A Materials World*. It's been awhile since the first edition, but the second one is finally here. The intent of this magazine is to show you some examples of the exciting things that you can do with Materials Science and Engineering (MSE), and let you know more about our department. Please take the opportunity to look through this edition, especially since most of you will have to choose a major by the end of the semester. Also, feel free to contact the department or any of the authors to answer any questions you may have.

## **A Skateboarder's Dream**

*Dan Babish, Senior  
dbabish@vt.edu*

A skateboard may appear to be just a board with four wheels, but to a materials engineer, there's more than meets the eye. For instance, the board itself is constructed in a metal or concrete form by pressing together planks of wood using polyvinyl glue (a polymer). The boards are pressed together for about an hour at a pressure of 300 pounds per square inch.

The wheels are another important component. Urethane (another kind of polymer) wheels are most commonly found on modern day skateboards. Urethane wheels have excellent abrasion resistance, which means they hold up against the normal wear and tear of skating. For those who want to improve on their tricks, urethane wheels are a great choice. The wheels provide great traction, giving the skater more control no matter how hard he or she pushes off the ground. One other impressive property of

urethane wheels is the amount of rebound they exert even though they are a solid structure. As the wheel turns, the section that is in contact with the ground temporarily remains flat due to deformation. Urethane wheels return to their original round shape faster, pressing back out against the pavement before the wheel loses contact with the ground. Old wheels recovered from deformation more slowly. This caused a loss of energy, which ultimately means the wheel rolled slower. In general, urethane wheels fit the needs of all skaters. For those who like speed, the wheels spin quickly. For those who like to do tricks, the wheels give the skater excellent control.

Skateboarding can be a fun and exciting sport for those who want to ride and do tricks, or it can be an evolving design career for a materials engineer.

## **Medical Alternatives Made Possible by Materials**

*Robyn Herman, Senior  
rherman@vt.edu*

Imagine that you are having persistent stomach pains, so you go to the doctor and set up an appointment for an endoscopy session. Endoscopy is a general term used to describe the process of using a lighted, flexible instrument to observe the digestive tract, as well as other organs. The doctor places a camera and a light fixture down the throat into the stomach and intestines to diagnose ulcers, cancer, and irritable bowel syndrome. Sounds like fun, right?

A company called Given Imaging has now created an alternative to this procedure. They have invented a pill-like capsule that contains a camera and light source that photographs the digestive tract.

The pill glides completely through the digestive system within twenty-four hours, taking two still images per second and recording them on film that is worn like a Walkman around your waist. After the twenty-four hours is complete, the doctor can download the data and compile a home video of your intestines to troubleshoot symptoms.

Materials engineering comes into play in this situation because the capsule has to be biologically compatible with the human body. This pill must withstand the high acid content of the stomach and intestines while not reacting with a person's organs or fluids. The material chosen had to be transparent, so that the camera inside could take the pictures while at the same time operating at a constant internal body temperature. The components of the camera were also carefully considered by materials engineers. The tiny camera is composed of a metal oxide semiconductor that requires far less power than the traditional charge-coupled device chips. This new biological feat could not have been successful if materials engineers were not consulted for the proper materials selection.

## When Smart Materials Meet Ski Technology: Piezoelectric Skis

*Christophe Temple-Boyer, Former Student*  
*ctempleb@vt.edu*

When speeding down the side of a mountain, every skier has experienced the inconvenience of a bumpy slope. When skis vibrate, it becomes more difficult to maintain control; in addition, one's legs start to burn, often resulting in sore muscles and a face covered with snow. Wouldn't the world be a lot better if your skis could absorb vibrations?

If a vibrating ski was filmed, it would become apparent that vibrations cause the edges of the skis to lift off the surface of the snow. The loss of contact between the ski edges and the snow results in reduced control and responsiveness. The companies K2 and ACX have collaborated to develop a vibration control damping device that utilizes the properties of piezoelectric materials. The first pair of piezoelectric skis from K2 was commercialized for the 1995-1996 season. But what is so interesting about piezoelectric materials?

What materials engineers refer to as piezoelectrics are just ceramic materials exhibiting a particularly interesting structure, shown in the figure below. The atomic structure of typical piezoelectrics is a cube with an "unstable" titanium atom in the middle. When the material is deformed, the central atom

deviates from its original position, creating a polarized structure. That is, piezoelectrics change into an electrical dipole when they deform.



[www.ams.mit.edu/research/materials/character/piezoelectricity.htm](http://www.ams.mit.edu/research/materials/character/piezoelectricity.htm)

K2 and ACX used piezoelectrics to eliminate not only the vibrations, but the source of the vibrations—energy. The piezoelectric material is coupled to an integrated circuit to store and release energy. When the ski begins to vibrate, the piezoelectric device deforms and “sucks up” the vibrational energy, releasing it into the circuit as an electrical current. No more energy means no more vibrations! In a fraction of a second, the delivered current is emitted from the skis as heat or through an LED. Thus, the piezoelectric can return to its original structure and dampen more vibrational energy.

Since 1996, K2 and ACX have developed more piezoelectric devices and extended their production to snowboards.

## Employment Opportunities for the Materials Engineer

*Tiffany Tibbs, Senior*  
*ttibbs@vt.edu*

Materials Science and Engineering is a rapidly growing field, and the job market proves it! Employers have always realized the importance of knowing how to build a bridge, airplane, or microprocessor. But now more focus is also placed on how a material selection and design approach can maximize safety, the longevity of products, and minimize construction and repair costs. In addition to the sharply growing demand for materials engineers, MSE graduates are better prepared than many of their classmates in other engineering programs thanks to special departmental programs such as the writing and communications courses that are integrated into the MSE curriculum.

Although Materials Science and Engineering is a small department compared to others in the College of Engineering, there were over 40 companies specifically requesting resumes from MSE majors at

*Continued on page 4...*

## Polymers

### Examples:

Teflonb, Polyvinyl Chloride (PVC), Polypropylene (PP)

### Applications:

non-stick surfaces  
CD's  
Food Packaging  
Bulletproof Glass

## Metals

### Examples:

Steel, Gold , Iron, Titanium, Tungsten

### Applications:

Shape Memory Glasses  
Frames, Bridge Decks  
and Cables, Artificial Joints  
Baseball Bats

## Ceramics

### Examples:

Silicon Carbide,  
Aluminum Oxide,  
Zirconia

### Applications:

Catalytic Converters  
Fiber Optic Cable  
Dental Crowns  
Optical Lenses

## Composites

### Examples:

Fiberglass,  
Kevlarb,  
Reinforced Concrete

### Applications:

Car Bodies  
Airplane Components  
Bicycle Frames  
Bulletproof Vests

Material Science

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and Applicatons

## Electronic Materials

### Examples:

Silicon  
Magnesium Oxide  
Gallium Arsenide

### Applications:

CD Player Lasers  
Computer Microchips  
Transistors  
LED Displays

### *Employment Opportunities Continued...*

the 2000 Engineering Expo. That's 40 companies competing for 20 to 25 students, approximately one-third of which are not actively seeking a job, but plan to continue on to graduate school. Those are pretty good odds! Graduates from the classes of 1997-2000 who sought employment in materials-related fields all found gainful employment. If you are planning for an exciting future and for a career that is in high demand, consider Materials Science and Engineering.

## **Marshmallow Engineering**

*Kelly Hales, Senior*  
*kehales@vt.edu*

Whoever thought that materials science and engineering would play a role in making cereal? I bet you never imagined an engineer working with Lucky Charms. In fact, there is much more behind the scenes at the General Mills headquarters in Minneapolis, Minnesota than the average person thinks. Making those little yellow moons and green clovers is actually a tedious process.

After three decades in the cereal business, researchers say that Lucky Charms success lies in the marshmallows. Therefore, much thought goes into designing new shapes and colors. Although the recipe only consists of sugar, corn syrup, and gelatin, the manufacturing process determines which charms will make it in the box. Making the intricately shaped charms is difficult because the marshmallows can not be baked, they need to have a low moisture content (no one wants soggy marshmallows), the amount of gelatin has to be controlled so they will hold their shape, and the amount of starch is monitored to keep the pieces from sticking together. The ingredients are melted together and whipped, the color is added, and the foam is extruded (forced through a die of a specific shape, like the Play-Doh Fun Factory) into strips of marshmallows of a certain shape. The strips are then cut into individual pieces and dried slowly at low temperatures. The different colored foams are extruded in separate streams which all require the same flow rate. The flow rate is hard to control because the marshmallow foam is compressible, meaning that some areas may be really compact while others are full of air. Therefore, if the flow rate isn't controlled, the foam will not come out evenly.

If marshmallows are not your forte, extrusion is also important in processing polymers. You can heat a polymer until it flows, and then push it through a die to make a part. Although Virginia Tech does not yet offer "Marshmallow Engineering," Materials Science and Engineering is the next best thing.

## **The Patch Isn't Just for Smokers Anymore**

*Scott Trenor, Graduate Student*  
*strenor@vt.edu*

Everyone is familiar with the nicotine patches currently on the market to help people quit smoking. This is just one example of a transdermal drug delivery (TDD) system. The first transdermal (through the skin) system, developed by Transderm-Scop in 1980, used the drug scopolamine for the treatment of motion sickness. Although there are thousands of drugs that could benefit from such delivery systems, only eight drugs and 25 TDD systems have been developed. Current drugs utilized in TDD systems include not only nicotine but also nitroglycerin and various hormones such as estradiol and testosterone.

Why is the development of a TDD system a materials issue? The major reason for the small number of transdermal systems on the market today is the difficulty in finding an adhesive with the right properties. The adhesive system must be selected so that it allows the drug to pass through the adhesive layer at the proper rate. In addition, daily habits such as showering and exercising also pose challenges because the adhesive used in the patch systems must withstand water and sweat. Due to their ease of use, pressure sensitive adhesives (PSAs) are generally utilized for medical purposes such as bandages and hospital tapes. Pressure sensitive adhesives in medical uses must be biologically inert, non-toxic, and non-irritating to the skin. The PSAs must also be compatible with the included drug and any excipient (a substance used as a diluent or vehicle for drug movement) in order to remain chemically stable and offer the desired solubility. In the case of TDD systems, the excipients also include skin softeners (like those in soap and shampoo) that aid the drug in passing through the skin.

What are we doing here at Tech? Currently, there are a couple of different projects in the MSE Department that are directly related to TDD technology. The first is the delivery of nutritional supplements. How often do you forget to take your vitamins? By putting vitamins and minerals into a weekly patch, you may only have to remember to take your vitamins once a week. The second is a way to deliver drugs used to treat leukemia transdermally instead of by injection. Leukemia patients (usually children) sometimes need several injections of cancer drugs per day; TDD would prevent these patients from having to suffer multiple injections each day. Transdermal drug delivery is a very interesting example of how material science concepts can be applied to even the most cutting-edge medical technology.

## **Composite Materials: Bridges to the Future**

*Andrew Signor, Junior*  
*asignor@vt.edu*

When driving over a bridge, how often do you ask yourself: "Is this bridge safe to drive across?" What would life be like without the modern conveniences of highways and bridges? I would be willing to guess that the average citizen rarely, if ever, contemplates such issues.

According to the Federal Highway Administration (FHA), an estimated 40% or more of our nation's bridges are either structurally or functionally deficient. This statement alone should be enough to cause the average citizen to think about the importance of the maintenance of infrastructure systems. Infrastructure systems, such as bridges, roads, the air and water supply, electricity, communications, and waste disposal to name a few, are integral to a functional society. Unfortunately, they are often taken for granted and receive poor maintenance.

Because of the severity of our nation's infrastructure crisis, this problem can't be resolved with conventional materials such as steel and concrete. New materials need to be developed and applied. The application of advanced composite materials, such as glass, aramid (Kevlar), and carbon fibers in polymeric (plastic) matrices is becoming increasingly important to extend the service life of our nation's transportation infrastructure into the 21st Century. Because of the recent advancement of this new technology, a significant amount of research is being conducted in the areas of service life prediction and the design of composite materials for infrastructure applications.

Composite materials offer great advantages over conventional steel and concrete structures. Glass and plastic, if applied appropriately in place of steel and concrete, can greatly reduce the mass of a structure with no loss, or even an increase, in the strength of the structure. This significant drop in weight of building materials could greatly reduce the need of heavy construction equipment, which would result in lower construction time and costs. Another interesting result of building lighter structures is a significant decrease in damage due to natural disasters such as earthquakes. This is because the energy produced in a structure during an earthquake is directly proportional to its mass.

While composite materials offer many improvements over conventional building materials, they tend to be more susceptible to natural elements, such as water and ultraviolet light from the sun. Therefore, materials science and engineering research is aimed at creating composite materials

that will stand up to the harsh effects of these elements. The infrastructure system of our nation is presently in a state of crisis, and it is imperative that new materials and technologies be applied to solve this great problem.

## **MSE is Causing a Racket**

*Valerie Binetti, Senior*  
*vbinetti@vt.edu*

Tennis rackets have undergone many innovations since the 1970's when they were still being made of wood with leather grips. Back then, rackets were of a fairly uniform shape and size: 27 inches in length, a head size of 65 square inches, and 13 ounces in weight. In the last thirty years the materials used, the size of the head, and the weights of the rackets have drastically changed.

The most important change in tennis rackets came with the development of new materials. Rackets made of steel and aluminum were introduced to the tennis world and revolutionized the game of tennis in many ways; the fastest serve recorded is now 142 mph by Mark Philippoussis. Later, rackets with graphite and graphite blended with other material (such as Kevlar) were produced. The head size was also changed drastically. Rackets weighing 10 or 11 ounces, with a head size of 110 square inches became commonplace. The changes in the shape and weight of the racket made the game easier for players of all levels and increased the popularity of tennis in the late 1970's and early 1980's.

The changes in racket size and weight started the almost endless combinations of materials and designs in an attempt to further improve racket performance. "Hammerhead," "widebody," extremely large racket heads, and rackets with different shape heads such as triangles and hexagons were introduced to the market. Ultra light rackets weighing as little as 8.5 ounces were also designed, thanks to material developments. New materials, such as boron and titanium, have been introduced and combined in different amounts with aluminum, fiberglass and graphite.

Tennis rackets and other sports equipment are one of the many areas of our everyday lives that involve material science and engineering. Engineers are revolutionizing sports with advances in all types of equipment. So, the next time you play your favorite sport, thank a materials engineer!

*If you are interested in learning about many types of materials and practical applications, consider Materials Science and Engineering when you declare your major.*