

## The Home Forum.

## It's a small, small, small world



REMEMBER HOW PROUD you felt when you showed everyone you could ride a two-wheeler? That's how proud Krystyn Van Vliet acts as she opens the door to a large stainless-steel instrument at the NanoMechanical Technology Laboratory at the Massachusetts Institute of Technology.

"This is a nano-indenter," says Ms. Van Vliet, a material science graduate student at MIT in Cambridge, Mass. Then she points to a tiny, diamond-tipped needle inside. "We take a sample of the new material we are testing and push that diamond into the sample."

If the material is strong, the diamond will hardly break the surface. If it's soft, the tip might poke a hole in it.

Researchers need to know how strong a new material is before they can use it for soldiers' uniforms, computer chips, cars, or airplanes.

But it isn't easy to test a portion of material that is one hundred-thousandth smaller than a strand of your hair.

How small is that? It's a billionth of a meter – a nanometer. Samples are so tiny because scientists need to find out how materials behave at that size. Remember, they are building very small structures.

So Van Vliet, fellow graduate student Yoonjoon Choi, and others study new "nanomaterials" in the new NanoLab.

With its floor-to-ceiling glass walls and two projection screens that display nano-structures to passersby on a busy campus hallway, the lab itself is a teaching aid for students. This new science needs to be better known.

"Many people have never heard of 'material science and engineering,'" Van Vliet says. "When I tell people that I am a material scientist, they sometimes assume that I design fabrics." So what *does* she do? "I study how materials behave," she says.

#### How do you test something you can't see?

"When you are building a bridge, you need to know how strong the material is that you are going to use," Van Vliet says. So scientists put the material, often metal, through a series of tests: They pull it, bend it, and stretch it until it breaks. From the tests, scientists learn the strength of a material and how much they will need to build a safe bridge or other structure.

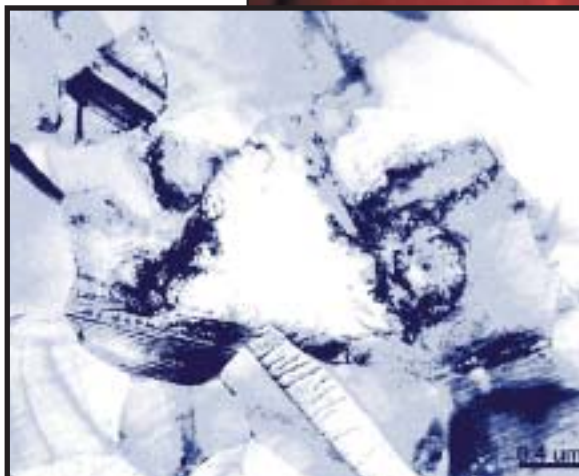
But when testing materials at the teeny-weeny level for use in computers, music CDs, and other items, the samples are too small to pull and stretch. Instead, you poke.

Using the nano-indenter, Van Vliet measures two things: the "load" (force) being pushed into the sample and how deeply the diamond point goes into it.



DINA MAYER

**DENTING WITH DIAMONDS:** Krystyn Van Vliet (center, above) points to one of two 'nano-indenters' used to test materials at MIT's NanoLab. The machine's tiny pyramid-shaped tip is pushed into materials like 'polycrystalline copper' (inset).



COURTESY OF A. GOULDSTONE, J. KOH, K.Y. ZHANG, AND S. SURESH, DMSE

"Measuring those two things while we are pushing in and pulling out the diamond indenter," Van Vliet says, "gives us enough infor-

moves along the sample's surface and makes a picture of the microscopic mountains and valleys on a sample's surface. It maps the topography of the sample.

The AFM is so sensitive that Choi can measure features that are only nanometers (billionths of a meter).

#### Big machines for looking at minuscule things

The NanoLab currently has three nano-scale machines: the atomic-force microscope and two diamond-tipped nano-indenters. The machines are quite large, but most of their bulk is insulation, to keep the needle from vibrating when people walk nearby. "We are trying to measure such tiny distances," Van Vliet says, "that a bang on the machine, someone jumping up and down on the floor, or even a loud noise can throw us off."

Even the walls of the NanoLab are designed to eliminate vibrations. The floor-to-ceiling windows have two layers of glass to help insulate the lab from the noise that people make just walking by.

The measurements are tiny, but the results may be big. Nanomaterials will likely have a major impact in the design of computers, cellphones, and many tiny machines that can be used to improve our daily life.

Laurie Toupin

ation to calculate how stiff the material is, how strong it is, when it will fracture, and how much load it will take before it permanently deforms [breaks]." If the material is strong, the diamond tip won't go in very far. If it's soft, the tip might make a deep dent.

Meanwhile, Mr. Choi stares at rows of orange hills and valleys on a computer monitor. A large yellow spike occasionally interrupts the scene.

"These spikes are defects in the sample," Mr. Choi says. "I'm looking for a piece of copper with no defects."

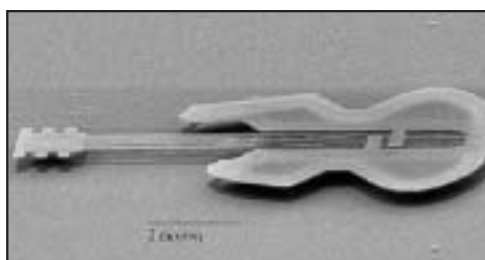
To find his perfect copper sample, Choi uses an atomic-force microscope (AFM).

A traditional optical microscope makes an image using reflected light. The atomic-force microscope touches the sample with very small forces. It contains a special "piezo crystal" that gets bigger or smaller as electrical current runs through it. As the crystal changes size, it moves "a cantilever [or beam] that looks like your finger, with a sharp point at the end," Van Vliet says. The cantilever

← If a human hair (100 microns) were the width of this page... →



...this is how long 'the world's smallest guitar' (10 microns) would be. An object one nanometer long would be 10,000 times smaller than the space above.



CORNELL UNIVERSITY/AP

**NANOGUITAR:** Cornell University researchers 'carved' it onto a silicon chip in 1997. (No, you can't play it.) It's 10 microns (millionths of a meter) long. But the actual size of the 'harp' on the facing page is only about 10,000 nanometers (billionths of a meter) – 1,000 times smaller than the nanoguitar.

## A glossary of 'nanoterms'

**micron (MY-cron):** 1/10,000th of a millimeter, or one-millionth of a meter. The width of a human hair be anywhere from about 20 to almost 200 microns wide.

**nanometer (NA-no-mee-ter):** One-billionth of a meter.

**molecule (MOLL-uh-cyool):** A molecule is the smallest particle of an element or compound that can still retain the characteristics of that element of compound. Example: A molecule of water is two hydrogen atoms bonded to one atom of oxygen.

# Tiny science, tough soldiers

**A**BLE to leap a 20-foot wall in a single bound! Stronger than a speeding bullet! Able to sense danger in the air! No, it isn't Superman, but it could be the soldier of tomorrow.

Researchers at the Massachusetts Institute of Technology in Cambridge, Mass., using nanotechnology, are working to create a "super uniform" for soldiers.

The new duds will enable a soldier to do everything listed above, yet weigh no more than paper, yard for yard (not counting boots, of course). They will be soft and flexible but able to harden into an intimidating forearm karate glove.

To develop the "cloth" that will be sewn into uniforms, MIT recently opened the Institute for Soldier Nanotechnologies. Here, physicists, chemists, and material scientists delve into a tiny world.

The lab has three main jobs, says Paula Hammond, a professor of chemical engineering. First, the fabric has to be comfortable to wear, she says. But it has to become stiffer under certain conditions to protect its wearer.

Second, it has to be lightweight. The typical United States soldier carries from 125 to 145 pounds of equipment. Researchers hope to trim nearly 100 pounds from that, to 45 pounds.

Third, the uniform should also be able to detect a change in the environment, such as light, temperature, or air quality. If some change poses a danger, a soldier's uniform would let him or her know. "We want clothing that will protect them against potential biological or chemical agents," Professor Hammond says.

To create such a "smart" jacket, scientists might insert tiny sensors into the fabric. When the sensors detect cold temperatures, the uniform might respond by becoming more insulating. When it gets warm, the uniform might become more "breathable," to cool off the soldier. Smart materials can also be designed to respond to hazardous materials, such as nerve gas or biological agents.

Creating the sensors is just the first step. Connect the sensors to a microprocessor, and you'll get a pair of very intelligent pants.

What about leaping that 20-foot wall?

"There is a hope that we can increase the soldiers' capabilities by storing energy while they are walking," Hammond says. "This involves a lot of physics."

Every time you take a step, you release energy when your foot strikes the ground. The energy is released as sound (footsteps) or goes into making impressions in the ground (footprints). Hammond's group hopes to capture some of that wasted energy in a spe-

cial sock or shoe made from a material that stores energy somehow.

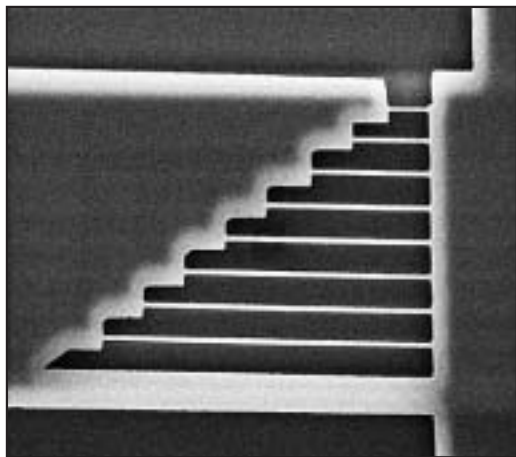
"We aren't sure where this is going yet," Hammond says. The "jump" may be only one good thrust. A soldier might have to walk another 20 miles before he or she has stored enough energy for another leap. But one good jump might save him.

Physicists, electrical engineers, and material scientists are working together to develop the uniforms. Hammond expects wearable results within five years.

Eventually, this research will affect the clothes other people wear as well - fire fighters, police officers, and other emergency workers, for example.

"This is a very exciting world," Hammond says. "On the nano level, you can change a material so that it will do just about anything."

L.T.



CORNELL UNIVERSITY

**NANOHARP:** Tiny 'strings' aren't stretched, so it's really more like a xylophone, makers say.

## You need a laser to play this harp

**T**HIS may be the world's smallest harp, but it doesn't play music. It's an example of a nano-electrical-mechanical device.

Like a real harp, it has "strings." The strings are 50 nanometers (nm) in diameter. That's 50 billionths of a meter, or about 150 atoms thick! They range in length from 1,000 to 8,000 nm. The whole "harp" is the size of a red-blood cell.

Each "string," made from silicon, can vibrate. If one could hear them, each would make a different sound, says Harold Craighead. He's a professor of applied and engineering physics at Cornell University in Ithaca, N.Y.

"We carved the harp from the same sort of material that computer chips are made from - silicon wafers," Professor Craighead says. The carving tool was a beam of electrons.

The strings are "plucked" with a laser beam. By studying how each string behaves and how long it vibrates, scientists find out how materials behave at such a tiny scale.

The research may lead to motion sensors that can detect the movement of a single molecule or bacteria. It could also lead to 3-D displays on hand-held computer games. "Children today should expect to see such devices before they grow up," Craighead says.

L.T.

TODAY'S ARTICLE ON CHRISTIAN SCIENCE

Bringing a spiritual perspective to daily life

## Our family

**TAKE A TOUR WITH ME** of Uwe Ommer's photographs of families from around the world, currently on exhibit at the Frist Center for the Visual Arts in Nashville. There are close to 100 pictures, some hanging outside and some within the Center. Each photograph is large, about four feet by four feet, so you are face to face with the families.

Sylvie is from Guinea. She's standing with her two children, adopted after her husband left her. Both children are in their best clothes, both holding equally well-dressed dolls.

Each of the four children from the Welsh family also holds a pet or a doll, no doubt important companions for them in their remote area of Wales.

A Scottish grandfather and his son, shrimp fishermen, are shown without their wives, who refused to be in the family picture without first visiting the hairdresser.

The man and woman from Eastern Europe are laughing heartily. His arms enfold her. You can feel their love, strong after 40 years of marriage. They are with their donkey.

An Irish bride and groom are shown on their wedding day. They say they want lots of children. A young boy is suited as handsomely as the groom is. A beautifully dressed preteen girl is leaning into the groom's arm, fast asleep. Perhaps it took too long to prepare for the photograph.

The Turkmenistan family is seated on their hand-woven carpets. An Ivory Coast woman, a teacher with her three children, is in front of her school blackboard. The California couple and child are wearing sporty clothes fitting their outdoor life style. The Roma (Gypsy) parents say they plan to stop roaming soon so their girls, shown in layers of ruffles, can go to school. There are Iranians, Albanians, Russians, Chinese, Masai, Egyptians, and many more.

Some of the family members wear sneakers, some sandals or boots, and some wear no shoes at all. You see their bikes and donkeys, camels and elephants, and even monkeys that are trained to drop nuts for Thai coconut planters.

In portrait after portrait, the faces look at us. There is pride in who they are. A sense of dignity. They acknowledge and welcome us. As we walk and look, we're no longer looking at inter-

esting strangers. We see ourselves in their faces and stories. There is a feeling of unity, and love for these people. These are our children, brothers, mothers. We are all one family.

Images in the news are in sharp contrast to these family portraits. News scenes show people in angry mobs, tell of suicide bombers, of corrupt officials and dishonest businessmen. In the family portraits there is only love. Intuitively we know this is the truth. We feel reassured. There is hope.

The Bible states, "Have we not all one father? hath not one God created us?" (Mal. 2:10) Our hope is on a solid foundation. God is our Father, the head of the entire family of man. Our infinitely loving Father naturally provides, nurtures, and protects His children. We're under His constant care.

As members of God's family, we each have family responsibilities - tasks we do to provide, nurture, and protect those in our immediate family, but also those in our larger family. Helping one another affirms our place in God's family. He

gives us the wisdom, strength, and joy we need to be good family members.

Most important are our prayers. Rejoicing in the mighty fact of God's universal fathering love lights our way to see and feel God's parenting love. We can all know we're part of God's family. This same light dissolves any darkness of hatred, fear, or dishonesty that would disrupt and destroy our family relationships. Such prayer is a family thing to do.

As we leave the art center, we look again at our family of families. Yes, God is our Father. He loves us all.

*With one Father, even God,  
the whole family of man  
would be brethren; and  
with one Mind and that God,  
or good, the brotherhood of  
man would consist of Love  
and Truth, and have  
unity of Principle and  
spiritual power which  
constitute divine Science.*

Mary Baker Eddy  
(founder of the Monitor)

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