Q&A with a Flexible Hybrid Electronics Engineer

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NANOOZE

Ultra-thin displays that are super flexible are built with OLED technology

ALL ABOUT ORGANIC LIGHT-EMITTING DIODES

And why they are so cool!

WHAT EXACTLY IS AN OLED?

HOW OLEDS ARE MADE

WHERE YOU MIGHT FIND AN OLED

NANOOZE

ALL ABOUT THE THINGS TOO SMALL TO SEE

Welcome to Nanooze!

What is a Nanooze? (Sounds like *nah-news*.) Nanooze is not a thing, Nanooze is a place to hear about the latest exciting stuff in science and technology. What kind of stuff? Mostly discoveries about the part of our world that is too small to see and making tiny things using nanotechnology. Things like computer chips, the latest trends in fashion, and even important stuff like bicycles and tennis rackets. Nanooze was created for kids, so inside you'll find interesting articles about what nanotechnology is and what it might mean to your future. Nanooze is online at **nanooze.org**, or just Google "Nanooze"—you'll find interviews with real scientists, the latest in science news, games and more!

How can I get Nanooze in my classroom?

Copies of Nanooze are **FREE** for classroom teachers. Please visit **nanooze.org** for more information or email a request for copies to: info@nanooze.org.

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What's in a name?

Organic? Hmm... Are we talking about foods that are, well, a bit more expensive but also better for you? Not exactly. Here, organic describes the types of molecules used to create **Organic Light-Emitting Diodes** (OLEDs). OLEDs are not good to eat, but they are one of today's hottest nanometer-scale materials that are revolutionizing a number of devices.

In this case, **organic** means made of carbon-based materials. **Light emitting** means they generate their own light. **Diodes** are electronic devices that allow electrons to move in just one direction. Diodes used to be made only from inorganic materials such as silicon, copper, and other metals. Because a diode allows electrons to flow in only one direction, it has a positive end and a negative end. Electrons move from the negative end to the positive end. When the electrons move through a layer of organic molecules, some of the energy these organic molecules absorb is given off as light.

Why are OLEDs cool?

OLEDs are super energy efficient. They produce light on their own because they have molecules that give off light when they are excited by electrons. It doesn't take a lot of electrons to produce light, which means these molecules don't produce a lot of heat. This is especially good for devices like cell phones, laptops, and televisions—all things that need to light up, but also be energy efficient.

Grab an incandescent light bulb when it has been on for a bit of time and—ouch!—it is hot! Fluorescent and LED bulbs don't heat up as much, which is why they are more energy efficient—they produce light, but not a lot of heat. Any energy that goes into heat instead of light is lost energy.

This issue of Nanooze is all about OLEDs—how they are made, what they can do, why they are exciting, and where you might find them next.

NANO KNOW-HOW

Learning about nano stuff is fun, but it can be complex, so it helps to keep these four important facts in mind:

1. All things are made of atoms.

It's true! Most stuff, like you, your dog, your toothbrush, your computer, is made entirely of atoms. Things like light, sound and electricity are not made of atoms, but the sun, the earth and the moon are all made of atoms. That's a lot of atoms! And they're incredibly small. In fact, you could lay one million atoms across the head of a pin.

2. At the nanometer scale, atoms are in constant motion.

Even when water is frozen into ice, the water molecules are still moving. So how come we can't see them move? It's hard to imagine that each atom vibrates, but they are so tiny that it's impossible to see them move with our eyes.

3. Molecules have size and shape.

Atoms bond together to form molecules that have different sizes and shapes. For instance, water is a small molecule made up of two hydrogen atoms and one oxygen atom, so it is called H_2O. All water molecules have the same shape because the bonds between the hydrogen atoms and the oxygen atom are more or less the same angle.

Single molecules can be made up of thousands and thousands of atoms. Insulin is a molecule in our bodies that helps to control the amount of sugar in our blood. It is made up of more than one thousand atoms! Scientists can map out the shapes of different molecules and can even build most types of molecules in the lab.

4. Molecules in their nanometer-scale environment have unexpected properties.

The rules at the nanometer scale are different than what we usually encounter in our human-sized environment. For instance, gravity doesn't count because other forces are more powerful at the molecular level. Static and surface tension become really important. What is cool about nanotechnology is that we can make things that don't behave like we expect. ***Things are really different down there!!***

Q&A

with
Nancy Stoffel

Flexible Hybrid Electronics Engineer

What is your current job and what do you like about it? I work for GE Research in Upstate New York. This job is great! I get to work on teams with very smart people, on things that are changing the world around us. My focus the last few years has been on flexible hybrid electronics, which is a way of saying that I find ways to make everyday objects "smart" by putting sensors or actuators and communication devices in them. Last year we made a blanket that could be used in a neonatal intensive care unit [a hospital unit for babies that need a lot of extra care]. This blanket allows nurses to monitor the babies without wires, and allowed the parents to walk around and hold the babies while still keeping an eye on the babies' heart rate and breathing.

I am also working on putting sensors into engines and machines and structures to improve the way that they run. For example, we are developing sensors into giant (75 meters long) wind blades so that we can manufacture them faster and make them run more efficiently. This makes the electricity generated by wind less expensive, and drives down the need for fossil fuels.

What is a typical day like for you? I spend half my time working with people in the lab, doing experiments. I spend the other half of my time communicating about the work that we are doing, and finding out about problems that we can solve. It is great fun to hear about a challenge and then pull together a team of people to solve it. Often, we need scientists and engineers and businesspeople with very different backgrounds to solve a problem.

When you were a kid, what did you want to be? And if it wasn't a scientist, what was it and why did you change your mind? First choice: dolphin trainer. And second: medical doctor. I decided not to be a doctor because I need my sleep and I was afraid. I love to read and I also wanted to write novels, but not until I was at least 50, because by then I would have done something interesting... Still working on living that interesting life.

What did you do to get your current job? What kind of education did you need? I went to college to be an engineer. Then I worked for IBM for five years making the hardware for supercomputers. I really liked it but wanted to be the expert that people turned to. So I went back for more school and attended Cornell University. I studied materials science and got a doctorate degree.

Tell us something fun about yourself. And it doesn't have to be about science. I have two large poodles named Portia and Amber. They are very happy that I have to stay home from work during the pandemic. They keep me company in my new office in the basement. They lie at my feet and look adoringly at me. I reward them for this by periodically giving them treats.

Nancy's dogs, Amber and Portia.

***Giant sensors** lining turbine blades help monitor efficiency.*

***Tiny sensors** embedded in baby blankets monitor vital signs easily and unobtrusively.*

Nancy works with her team to design flexible electronic sensors for a wide range of uses.

What are OLEDs?

Let's get into the layers

NANOTECHNOLOGY, CAKE, AND OLEDS

Nanotechnology can be used to build very complicated materials that are made of different layers. OLEDs are made using nanotechnology and have different layers that are produced using nanofabrication. Think about a delicious layer cake where the layers of cake are separated by chocolate cream filling. Can you picture it? Getting hungry? If it were an OLED, the cake layers would conduct electricity and the filling layer would light up. As the electrons move from one layer of cake to the other, through the chocolate cream filling, the electrons excite the filling and it starts to give off light. Yum!

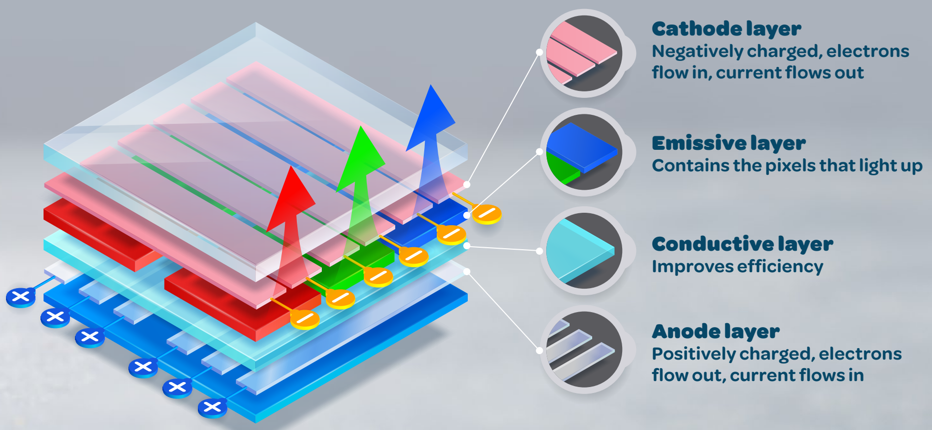
THE THINNEST OF LAYERS

OLEDs are made of at least four layers, from top to bottom: cathode, emissive layer, conductive layer, and anode. The cathode and anode function just like in a battery, and the electrons move from the anode to the cathode through the other layers.

Each of these layers can be made really thin, about 100 nanometers in thickness (or about 1/1,000th the width of a hair). And because they are that thin, they can be made transparent, and also flexible.

TRANSPARENT AND FLEXIBLE

OK. So a cake isn't see-through, but what is really cool about OLEDs is that they can be made transparent in addition to being flexible. OLEDs don't require backlighting or any external light because the "chocolate cream filling" gives off light itself. That means that the OLEDs can be made from just those layers, each one super thin, transparent, and flexible. The only thing they require is some kind of power source like a battery, and that battery can be small because OLEDs are super efficient.



Lots and lots of layers

Making an OLED

A BRIEF HISTORY

OLEDs were first invented about 50 years ago. Three scientists—Alan Heeger, Alan MacDiarmid, and Hideki Shirakawa—won the Nobel Prize in Chemistry in 2000 for their work in developing conductive materials that are used to make OLEDs. Nanotechnology is a process that dates back hundreds of years, and most processes are based upon lithography, where a material is chemically etched using a patterned mask. OLEDs are manufactured using a similar process—the individual layers are created using masks to make a pattern.

BUILDING PIXELS

Each layer of an OLED involves a different mask to make a pattern of unique OLEDs with different colors. An individual OLED pixel is created in each color, and each color pixel is turned on when needed. These OLED pixels can be around 5,000 nanometers across or about five times the size of a single bacterium. And since OLEDs don't use a backlight, when the OLED pixel is not lit up, that pixel is true black.

PRINTING OLEDS

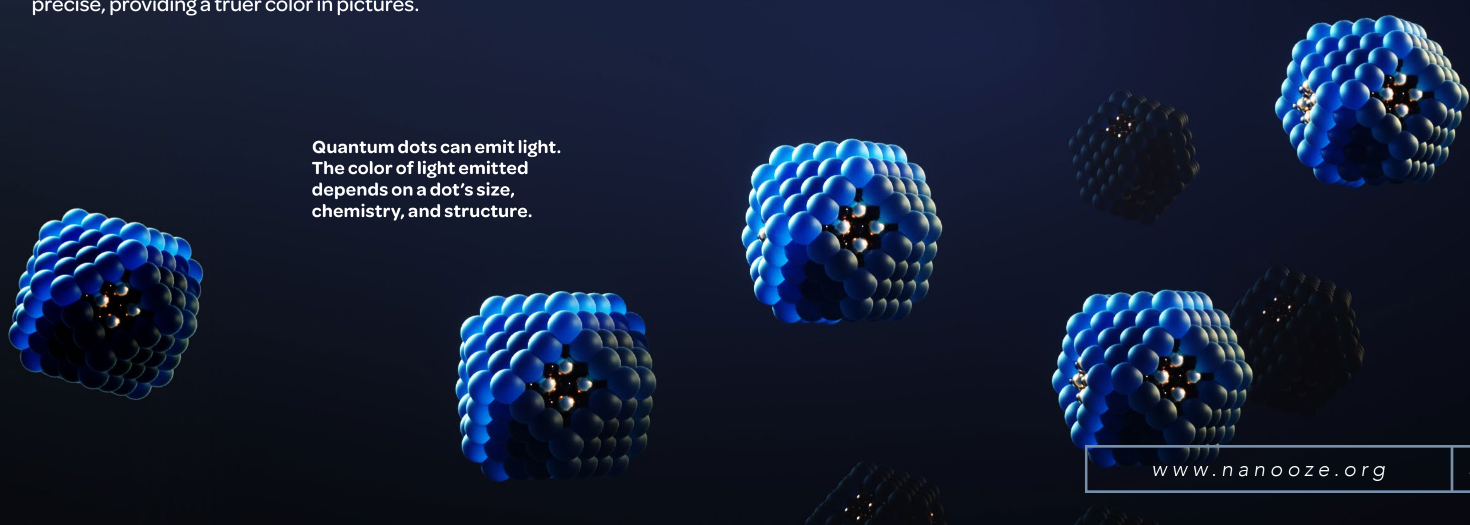
In the future, instead of using masks, OLEDs will be printed using ink jet printers that are similar to one you might use at home. The materials used to make OLEDs include plastics that can be made super thin. This means that OLEDs can be bent and curved, but won't break. Different chemicals are used to produce each color. When they are charged, some of the energy they give off is light in a specific wavelength or color.

Building with quantum dots

The most advanced OLEDs are built using quantum dots, which give off light when excited. Quantum dots are only a few nanometers in size, so small that they contain only a thousand or so atoms. When used for OLEDs, quantum dots can make pixel sizes much smaller and therefore provide higher-resolution displays. Plus, the colors produced by quantum dots are more precise, providing a truer color in pictures.

Quantum dots are man-made semiconductiong nanoparticles that are only a few nanometers across.

Quantum dots can emit light. The color of light emitted depends on a dot's size, chemistry, and structure.



Ella Maru Studio

OLEDs in your life

Where might you find them currently and what's in store for the future?

FLEXIBILITY IS KEY

One of the neatest tricks OLEDs can perform is the feat of flexibility. Because OLED layers are so thin and emit light themselves instead of requiring a backlight, they can be extremely flexible instead of rigid. It's like a video screen embedded in a piece of plastic wrap! Imagine just unrolling a screen and putting it anywhere you want.

TAKING PICTURE QUALITY TO A NEW LEVEL

OLEDs are also high resolution, which refers to the number of pixels you can pack into a space. Most displays now are at least 1,040 pixels per inch across their width. A lot of TVs are 4K, meaning they have 4,000 pixels, and there are even 8K versions. How many more pixels do we need? That depends on how good your eyesight is and how far you sit from the display. But because of the way OLEDs are built, more pixels can be squeezed into less space, which means a more detailed, richer picture can be produced than was ever possible before.

INTO THE FUTURE WITH OLEDS

Chances are there are OLEDs around you in both small and large (sometimes very large) formats. A new form of OLED called AMOLED, or Active Matrix OLED, will include touch sensitivity (which as of this writing requires a separate layer). Super AMOLED will display more colors and even higher levels of contrast. Typical liquid crystal displays have 1,000:1 contrast, meaning that the "white" is 1,000X brighter than the black. Super AMOLED will have 100,000:1 contrast, so the blacks will be much blacker, making the viewing experience much more real. The human eye still tops the list, though—our eyes have the ability to see contrast up to 1,000,000:1 in a moving image.

Where can I get one?

Products are available today that have OLEDs:

Televisions
Bigger, brighter, and higher resolution

Lighting

Heads-up displays in cars
Having important data (*not* the latest TikTok videos) right in front of you

Foldable phones
Bigger screens that can be folded up into smaller packages

Displays integrated into eyeglasses
Facial recognition (Hey, is that LeBron?)

Most of them are *still* pretty expensive though!

But there are so many other products that engineers are dreaming up because OLEDs can be bent into different kinds of shapes.

New advances in OLEDs will not just involve what they are used for today, but also for how they can be used with other things:

Clothing with displays to advertise stuff

Windows that have transparent OLEDs embedded into them

Books with pages that are OLEDs but feel like paper

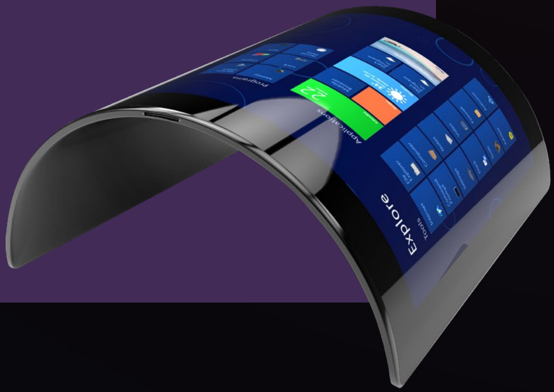
3D displays that don't require those weird glasses

Touch-sensitive displays that include a feel, like you poked a piece of Jell-O

What kinds of fun things would you invent?

Can you imagine different kinds of applications?

What problems might OLEDs solve?



Carbon has a molecular weight of 12 and sits between boron and nitrogen on the periodic table. The atomic radius is about 0.1 nanometers across.

Carbon

A most useful atom

CARBON IS EVERYWHERE

We find carbon in all living things—it makes up molecules like sugars, fats, and DNA. Carbon is the second most abundant element in the human body (oxygen is first), and the fourth most abundant element in the universe (after hydrogen, helium, and oxygen). Life as we know it on Earth is dependent on carbon.

VARIED FORMS

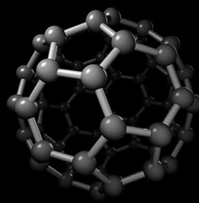
Because carbon atoms have four electrons available to form bonds with other atoms, it can form different molecular structures utilizing single, double, and even triple bonds. It can form bonds with other carbon atoms to create things like diamonds or graphite. It can bond with other elements like oxygen, sulfur, and hydrogen to take make different forms, some of which can hold a lot of energy. Fats, for example are full of energy because of the carbon-carbon bonds. These are the same basic molecular bonds as those found in gasoline, which, when burned, releases enough energy to make our cars go. Where did the petroleum to make the gasoline come from? A few million years ago it was organic matter—plants and animals that decomposed beneath the Earth's surface.

DIFFERENT PROPERTIES

Carbon-based molecules are versatile and very different from other molecules. They can be superhard, like diamonds, and supersoft, like mucus (yeah, the stuff in your nose). All contain carbon, but the bonds are what make them all different. Diamonds (pictured) are almost solid carbon, with each carbon atom joined to another four carbon atoms, forming a crystal matrix that is very rigid. Mucus (pictured) is soft and almost like liquid, because instead of a rigid matrix, the carbon atoms are joined in long, very flexible strings.

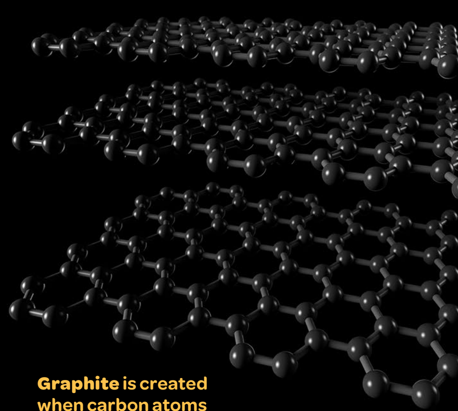
VERSATILE MOLECULES

Life and all living things contain carbon. Of course, not just carbon, but other atoms and molecules as well. But because of the very versatile carbon, we have versatile molecules. Fats that give us energy, enzymes that break down sugars, and DNA, the blueprint for life. Perhaps, then, it isn't very surprising that OLEDs made from carbon would be very useful as well.

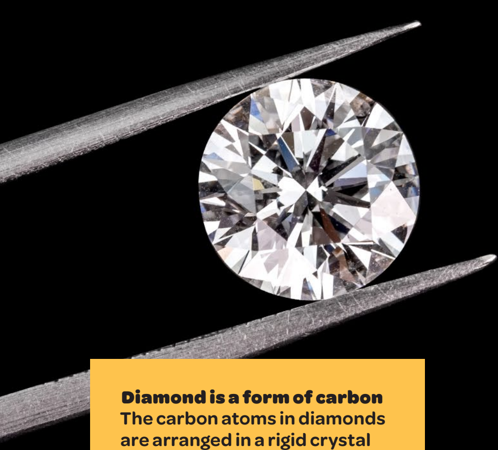


Fullerene is created when carbon atoms form a sphere.

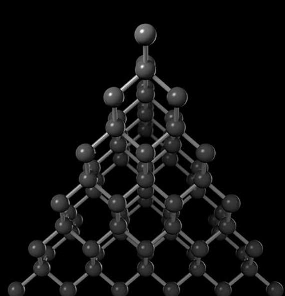
Even mucus contains carbon atoms! Our bodies, as well as all life we know of, contain carbon.



Graphite is created when carbon atoms form layers.



Diamond is a form of carbon
The carbon atoms in diamonds are arranged in a rigid crystal structure. This structure makes diamonds superhard.



Diamond structure, graphite, and fullerene: Martin McCarthy / NISE Network