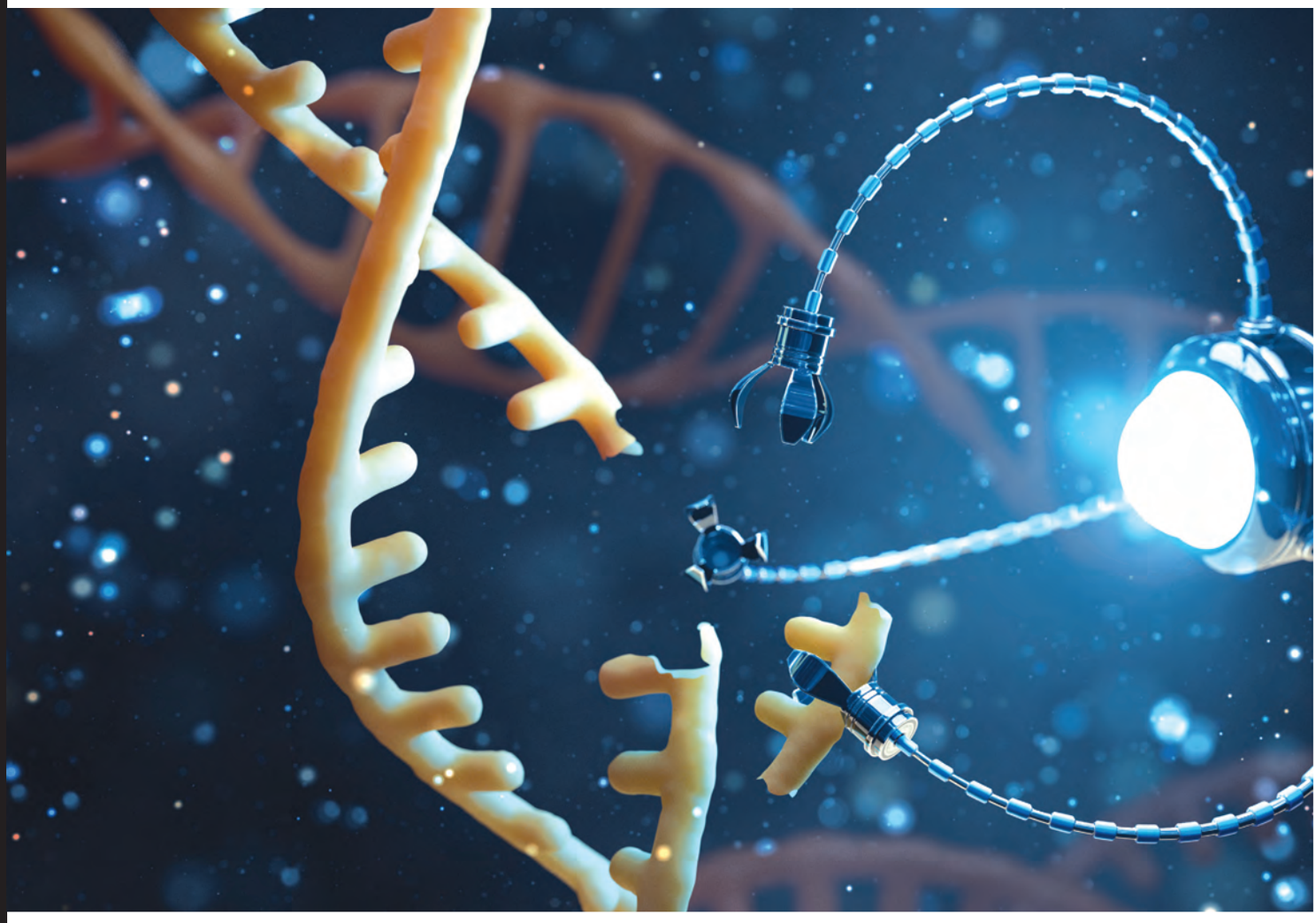
Nanotechnology:

Good Things Come in Small Packages



When scientists split the atom, there was sure to be a reaction. Some began wondering "What do we do with the pieces?" Curiosity is the soul of discovery. Playing with those pieces has resulted in life-enhancing breakthroughs, from clothing to medicine. And no one knows what might come next.

by **Judy Siegel-Itzkovich**

WHEN someone wants to make something, he can chisel it out of a larger material (top down) like a woodcutter or sculptor or assemble small parts (bottom up) like Lego into a composite object. But the properties of the original material do not change.

However, when creating something using nanotechnology, the resulting product develops many completely new properties — including different melting points, color, its ability to conduct electricity and heat, optical capabilities and more.

The term nanotechnology was coined during a scientific conference in 1974, by Prof. Norio Taniguichi of Tokyo Science University, to describe semiconductor processes such as thin-film deposition that deal with control on the order of nanometers — or one billionth of a meter. His definition is still accepted today: "Nano-technology mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule."

Albert Einstein never dreamed about the world of nanotechnology; neither did science fiction authors, because they look only at what exists, and their imagination takes it just another step forward. The idea of building "small" things is usually attributed to the brilliant physicist Prof. Richard Feynman, based on the talk he gave at an American Physical Society meeting at the California Institute of Technology on December 29, 1959. He predicted that machines would build smaller machines and other products with atom-by-atom control, a process that was later called molecular manufacturing.

Feynman hypothesized in his speech that it would be possible to print the entire *Encyclopedia Britannica* on the head of a pin, which is 1/16 of an inch across. "If you magnify it by 25,000 diameters, the area of the head of the pin is then equal to the area of all the pages of the *Encyclopedia Britannica*. Therefore, all it is necessary to do is to reduce in size all the writing in the *Encyclopedia* by 25,000 times."

But Hashem already designed a technique of stuffing enormous amounts of information in an exceedingly small space — all genetic data is stored in every living cell in the form of DNA molecules.

Nanotechnology received useful tools in 1981 when Gerd Binnig and Heinrich Rohrer at IBM's Zurich Research Laboratory invented the scanning tunneling microscope (for which they were awarded the Nobel Prize in Physics five years later), followed by the introduction of the atomic force microscope in 1989. The original microscopes cost millions of dollars, but today, they are sold for about $20,000.

Besides giving physicists and chemists something to study, what good is nanotechnology to the average person? Every day,

serious nano research is published around the world about its use to diagnose and treat diseases faster and better.

There is already a great number of practical applications, including the manufacture of reproducible "writing" of electronic circuits, better drug delivery inside the body, better encryption of data to reduce the risk of being stolen by hostile forces, nano-silver antibacterial socks, clear sunscreens, wrinkle- and stain-resistant clothing, deep-penetrating therapeutic cosmetics, faster recharging batteries for cordless electric tools, improved touch screens for cellphones and digital cameras, automobile bumpers that resist denting and scratching, golf balls that fly straighter, tennis rackets that are stiffer and rebound faster and baseball bats with better flex, to name a few. And beneficial applications will be developed in the future that are not even dreamed of today.

Developed countries around the world launched nano research at institutions of higher learning during the last two decades, and six of Israel's seven public universities — the Technion-Israel Institute of Technology, the Weizmann Institute, Hebrew University (HU), Tel Aviv University (TAU), Bar-Ilan University (BIU) and Ben-Gurion University (BGU) — are prominent among them. They try not to duplicate studies and applications so as not to waste resources.

Prof. Chaim Sukenik

"Nano is important because the smaller the objects or particles are, the easier it is to get into places," said Prof. Chaim Sukenik, the founding director of Bar-Ilan's Institute for Nanotechnology and Advanced Materials (BINA) and former director of BIU's Minerva Center for Nanoscale Particles and Films and currently president of the Jerusalem College of Technology (known as Machon Lev, for its founder, Professor Zeev Lev, *z"l*) in an interview with *Hamodia*.

"For example, the blood vessels of an unborn child are very thin, so when you inject a contrast agent for scanning them due to a medical problem, most of the agents won't fit. BIU researchers injected magnetic nanoparticles, and it worked. The surface-to-volume ratios of nanoparticles are much superior; with more surface area, new characteristics develop."

If you take a block of solid gold and chop it into cubes of one centimeter, a micron of gold is still the same gold. But when you get down to nanoparticles, you have a "quantum confinement effect" that changes fundamental properties and offers many more possibilities. It changes color to blue, purple and yellow, depending on the size of the nanoparticles, Sukenik said.

"There are nano films that are two dimensional and one-atom thick such as graphene. Films that are one-molecule thick can be self-assembled onto surfaces and can have dimensions of kilometers in length," Sukenik continued. Nanomedicine and nano delivery systems can serve as diagnostic tools or to deliver therapeutic agents to specific targeted sites in a controlled manner. Prof. Yechezkel Barenholz of the Hebrew University used nanoscale assemblies to encapsulate an existing anti-cancer drug and significantly improve its delivery. Called Doxil, it was the first FDA-approved nano-drug.

A single layer of carbon can be rolled into conductive nanotubes that act as antennas for radios and other electromagnetic devices and in brushes for commercial electric motors, continued the JCT president. "Household detergent is today composed of little nanoscale balls that separate dirt from clothing when mixed with water. Sunscreen lotions have been made more effective by adding inorganic nanomaterials to them to create more surface area and absorb more sunlight to cut the risk of skin cancer. It was cosmetic companies who invested in many nano projects because of this," he recalled.

The natural balance of forces of atoms is to self-assemble, noted Sukenik, "so this works from the bottom up. Membranes in our bodies develop spontaneously with the help of water. Today, most biological systems are bottom up. We have learned to take nanoparticles and use them to create complex devices. But silicon chips for computers and other electronic equipment are made from the top down, by slicing and patterning them using light or etching solutions."

"Plastic does not conduct electricity, but if you introduce conductive nanoparticles, it can get this property," added Sukenik, who completed his undergraduate studies at Yeshiva University and his doctorate in chemistry at the California Institute of Technology and came on *aliyah* to Israel with his family in 1995. He has been involved in nano for the last two decades.

BIU's current president, Prof. Arie Zaban, came to his post from the chemistry department, where his main interests included sustainable (including solar) energy, nanoporous, wide-band-gap semiconductor electrodes and nanosize layers for the development of low-cost plastic solar cells and polymers.

Prof. Dror Fixler

BINA has six centers of excellence: a nano-materials center, nano-medicine center, a nano-energy center, a nano-magnetism center, a nano-cleantech center and nano-photonics center. Each of these is making strides to make our lives better, Zaban told *Hamodia* in an interview.

"Nano is a huge world. It is very Jewish to be part of it, as we virtually participate in creation. Nanotechnology opened a world of new materials that we didn't know before that have a great variety of properties. There is a two-dimensional chemical table of elements, but now there is a third dimension of size." He is grateful to the Israeli government for, at an early stage of nano, investing significant funds in the universities' centers and research.

Bar-Ilan's BINA center, whose founding director was Zaban and which is now headed by Prof. Dror Fixler, boasts 600 staffers including 66 researchers plus students at various levels. A returning scientist from South China Normal University, he studied electro-optics and photonics at BIU, with his interests including the development of nanotechnologies to improve medical testing and communications networks.

"We do research, but we also want to help people, to integrate solutions for public health, drug delivery and more," said Fixler. A nano advance in diagnostics includes positron emission tomography (PET) scan, which helps reveal how body tissues and organs are functioning, using a radioactive tracer to show this activity. Such scanning can sometimes detect disease before it shows up on other imaging tests.

Among the applications developed at BINA, said Zaban and Fixler, is a "medical-jewelry" ring that is worn on the finger. It can tell the level of oxygen saturation in one's body. The individual can't feel anything is wrong, but if the level is too low, terrible damage can be done. Many COVID-19 patients decline and even die because their oxygen saturation level has plummeted, they explained.

BINA Prof. Rachela Popovtzer, head of the nano-bioengineering lab, has found a way to overcome the blood-brain barrier that prevents important medications from reaching the brain. Another field is the development of clean energy from hydrogen, which could fight climate change that worries the whole world, they said.

BINA has an important niche in applications for quantum computers. These are important for fighting hackers — computers in Russia and China — that were installed to cause havoc and steal data. "Today, everything is so open. The hackers can empty bank accounts and cause havoc for medical equipment in other countries."

Asked about some initial predictions that nanoparticles might cause harm to the environment and about fake news spread during the current pandemic, Fixler quotes *Devarim* (18:10-12): "There shall not be found among you one who causes his son or daughter to pass through the fire, one who practices divinations, an astrologer, one who reads omens, a sorcerer; or an animal charmer, one who inquires of *Ov* or *Yidoni*, or one who consults the dead. For anyone who does these is an abomination of Hashem, and because of these abominations Hashem, your G-d, banishes [the nations] from before you."

The Torah, says the BINA director, warned us against such people who sit and predict and wait for things to happen. "We must base decisions on scientific facts. We in the field will not cause harm. We must do, especially at a time like this during COVID-19. Nanotechnology could help deal with the coronavirus. When doing, one makes mistakes, but you have to decide out of deep thought and faith."

While the Israeli nano experts didn't try to predict what nanotechnology would bring in the next 10 or 20 years, they agreed that it would certainly improve day-to-day life around the world and be for a blessing. ■