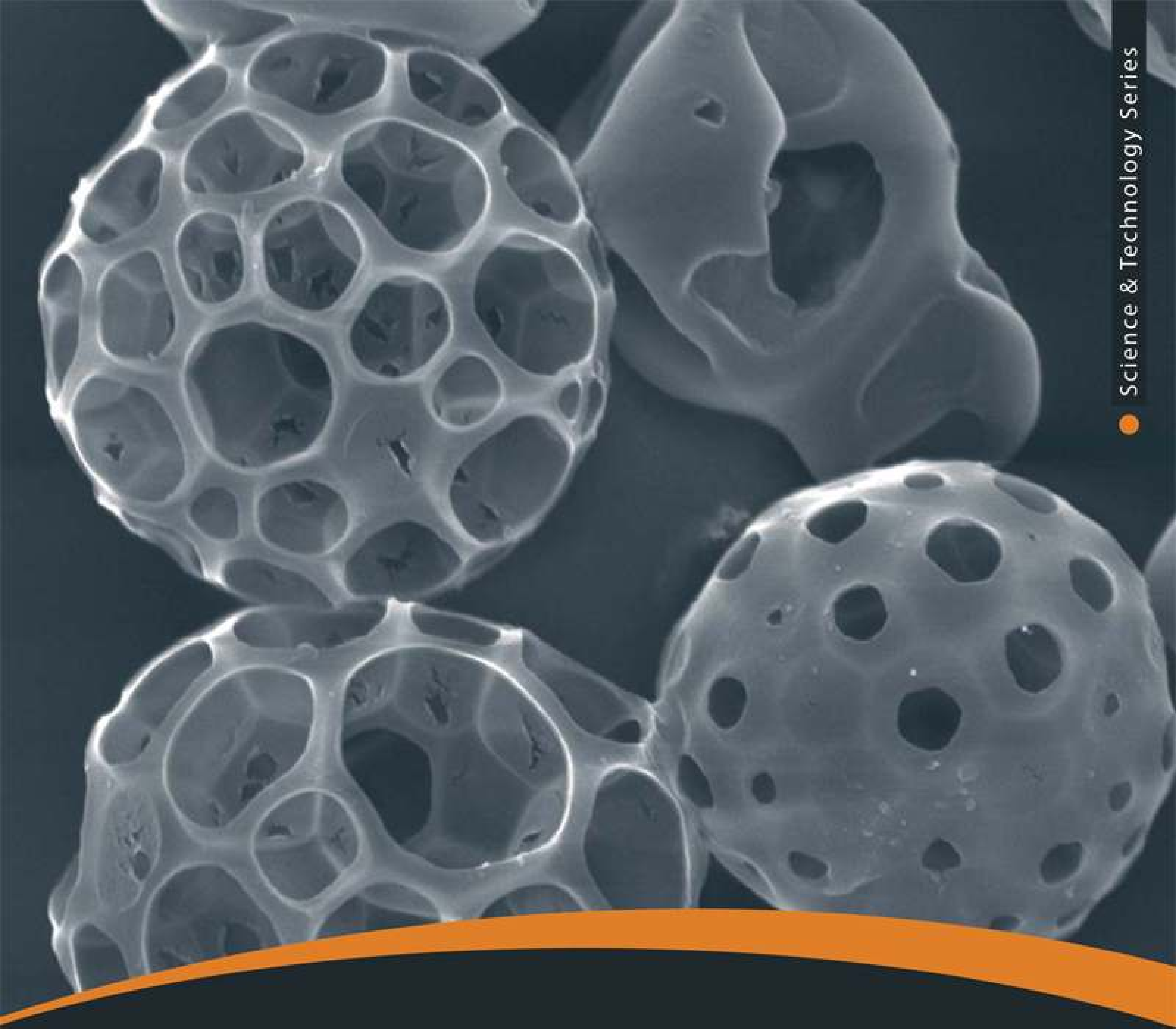
Science & Technology Series



Materials Science Research

The Stuff of Scientific Dreams

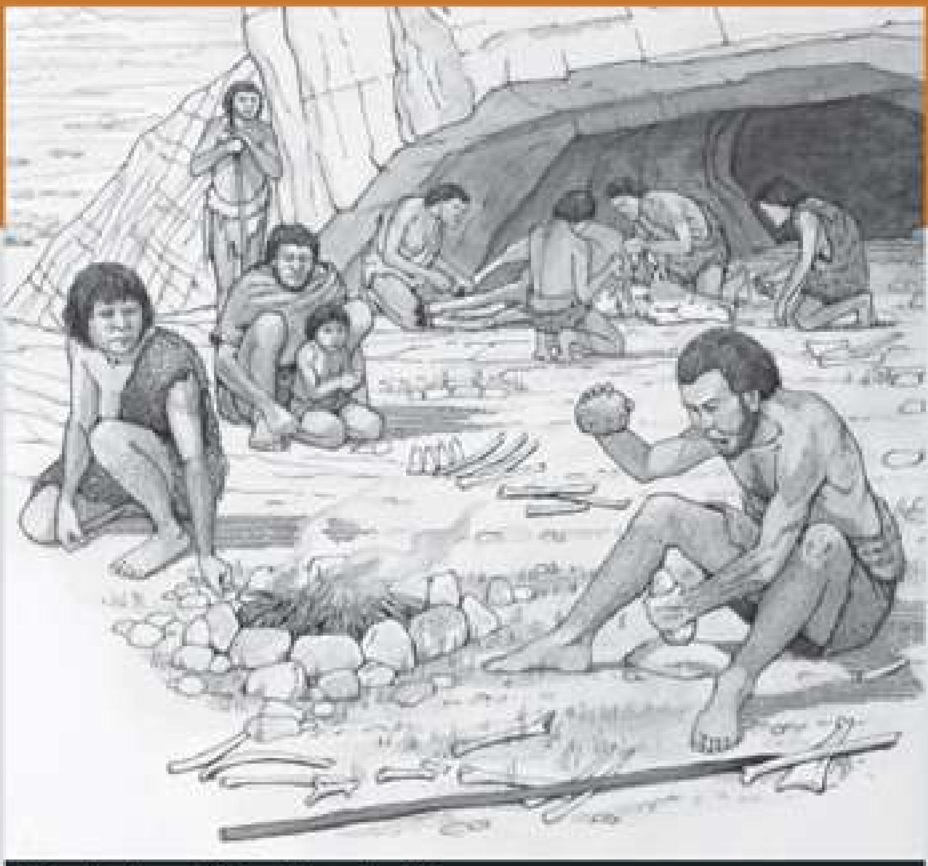
Tradition of Excellence
Bar-Ilan University

BIU Materials Science research is creating exciting change in communications, computers, medicine and energy production.

Pictured from left to right:
Dr. David Zitoun
Prof. Chaim Sukenik
Prof. Chaya Brodie

Stuff of Scientific

Dreams



Depiction of Pre-Historic Man

Imagine the excitement when some pre-historic man discovered that fire could transform mud into a durable ceramic vessel. Now fast-forward, and imagine a material that soaks up to fifty times its weight in crude oil. Or a lightweight battery strong enough to power long trips in the family car. These advances – and many others – may be just around the corner, thanks to Materials Science, a field that is creating exciting change in communications, computers, medicine and energy production.

A leader in Materials Science research, Bar-Ilan University has been ranked number three in the world for citations per published paper in this field, beating out prestigious institutions such as Harvard, MIT, Oxford and Cambridge. The University's outstanding impact has been noted by the European Union, which designated BIU as the EU's "Marie Curie Training Site for Novel Fabrication Methods for Nanoscale Materials." Materials-related research brings millions of dollars in grants into the University every year, and is the driving force behind a host of patents and industrial collaborations.

For years, Bar-Ilan has built its competitive edge from the bottom up, investing carefully in infrastructure, while successfully recruiting top young researchers. Together with BIU's veteran scientists – many of whom are leaders in their fields – these young recruits benefit from dynamic, cross-discipline cooperation between researchers trained in physics, chemistry, nanotechnology and the life sciences. The BIU team is helping us understand materials, improve them, and match them to the critical needs of the future.

Practical Productivity

Materials research is a fast-moving field, and nowhere is this more evident than in the laboratory of Prof. Aharon Gedanken. A multiple patent holder with over 500 scientific publications to his credit, Gedanken is a Bar-Ilan graduate who has been a faculty member since 1975. Now "emeritus," Gedanken still publishes an average of 25-30 papers on nanomaterials every year, a level of productivity matched by only a handful of scientists worldwide.

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Prof. Gedanken is a pioneer of sonochemistry – a discipline in which reactions are accelerated through the application of ultrasonic sound waves. His many discoveries include a process that removes useful metals from polluted water; a cheap method for producing an important material for the tool-cutting industry; and advanced methods for fabricating nano-scale structures with special catalytic properties. Together with BIU Prof. Shulamit Michaeli, Gedanken recently fabricated RNA-based nanoparticles that can "silence" specific genes. Also recently, he expanded on his past discoveries related to bio-diesel production, by establishing a one-step method for converting harvested micro-algae into useable bio-fuel.

Materials and Medicine

Based on the materials research of Profs. Shlomo Margel and Chaya Brodie, BIU has launched a new company called "Nano Thera" that may give hope to victims of glioma – an aggressive and incurable cancer of the brain. Together with doctoral student Sigalit Gura, Prof. Margel created a patented method

for producing remarkably uniform magnetic nanoparticles. Later, in collaboration with Prof. Brodie and PhD student Benny Perlstein, Margel devised a coating that enabled the "loading" of these nanoparticles with a cancer-killing peptide, resulting in a compound that targets glioma cells in a process that – because of the particle's magnetic nature – can be followed by MRI. Unlike chemotherapy – which involves delivering poisonous compounds to cancerous tissues – Margel's and Brodie's nanoparticles trigger a genetic program within the cancer cells that leads to cell death.

Another BIU materials scientist working on cancer treatment is Dr. Rachela Popovtzer. Popovtzer synthesizes gold nanoparticles that target and attach to malignant cells. This creates a "golden" signal on a CT scan that reveals the location of cancer within the body, even at a very early stage of the disease. In a separate project, Popovtzer created gold nanorods that heat up when exposed to near-infrared light. These nanorods – which attach themselves to cancer cells – can be activated non-invasively by light from the skin surface, destroying the cancer while leaving healthy tissue unharmed.

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Materials science also fights infection. Prof. Jean-Paul Lellouche has engineered a silica-based nanoparticle that can carry a "payload" of bacteria-killing medication. The nanoparticle's inorganic shell prevents the medication from leaking into the inter-cellular environment and damaging healthy cells. Once a bacterium engulfs the nanoparticle, however, the shell is destroyed, releasing the bacteria-killing medication at full strength, right on target. In collaboration with Prof. Shulamit Michaeli, Lellouche has also designed nanoparticles for delivering "silencing RNA" – genetic material that prevents the expression of specific genes.

Also related to preventing infection, Prof. Chaim Sukenik has created a chemical technique for depositing thin films – coatings between 10 and 200 nm in thickness. Shown to repel bacteria when applied to the silicon rubber used in medical devices such as catheters, this same technique has also found use in the space industry. A recent study demonstrates that Sukenik's thin films protect a lightweight material used in satellites from erosion that occurs in low earth orbit.

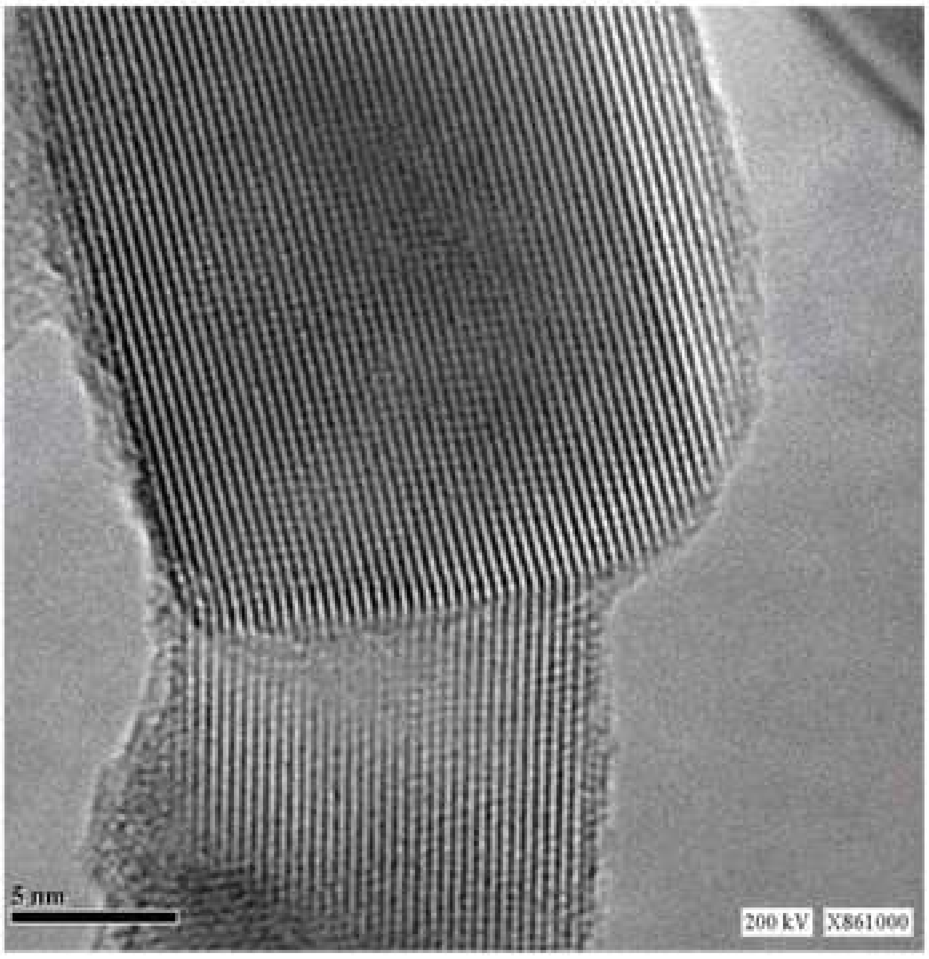
In a development that will help scientists design medically-useful materials, Dr. Yitzhak Mastai has created a technique to distinguish between chiral pairs – molecules that may look alike, but are actually mirror images of one another. Mastai's work is significant both for basic research, and for the pharmaceutical industry.

Materials for Energy

Prof. Arie Zaban has demonstrated how metallic wires mounted on conductive glass can form the basis of photovoltaic solar cells that produce electricity with efficiency similar to that of conventional, silicon-based cells, but are much cheaper to produce. Zaban reduced costs by finding a new way to produce quantum dots – a highly photoactive material vital to his solar cell operation. In previous research, Zaban created a low-cost solar cell technology in which dye-activated semiconductor nanoparticles are arranged in a sponge-like array on flexible plastic sheets.

Bar-Ilan alumnus Prof. Doron Aurbach is best known for the important role he played in the development of both lithium and lithium ion batteries – now standard issue in cellphones and computers. Today, his research focuses on magnesium-based batteries that can be cycled thousands of times. Aurbach's group – which collaborates with a number of leading industrial concerns - is also working on new technologies for storing the non-polluting energy harvested from wind turbines and solar power stations.

The transfer of charge between a liquid electrolyte and a solid electrode is central to the function of solar cells, batteries and fuel cells. Despite this, little is known about the structure of such interfaces on the molecular level. Prof. Moshe Deutsch uses synchrotron radiation as part of a cutting edge technique that characterizes these interfaces. Recently, Deutsch's lab was the first in the world to reach atomic-scale resolution in examining the interface between mercury electrodes and aqueous electrolytes – an achievement that has revealed important new insights relevant to many renewable energy and battery applications.



Dr. David Zitoun has created a patented method for producing amorphous silicon nanoparticles. He plans to apply these nanoparticles to developing a new, "ink-jet" based method for printing solar cells. In another area of his research, Zitoun creates contaminant-free surfaces for thin films, powders and other manufactured nanomaterials. Employing a "one-step" strategy in which metallic nanoparticles are synthesized directly from precursor materials bound to silicon, Zitoun's method results in a perfectly clean interface between layers, and may form the basis of new hybrid materials for energy conversion and storage.

Materials Theory

Once, new materials were discovered through trial and error. Today, scientists manipulate materials based on quantitative data about the forces that give materials their distinctive characteristics – data emerging from the labs of BIU experts in materials science theory.

As a center of materials science excellence, Bar-Ilan University is making a fundamental contribution to the basic science that will lead to reshaping the world – for the better.

Prof. Yitzhak Rabin examines the forces at work when DNA and proteins penetrate membranes, with the aim of developing a new approach to sequencing individual strands of DNA based on tracking their passage through nanopores – natural or man-made holes in electrically insulating membranes. In research that may lead to strategies for the treatment or prevention of gene-based disease, Rabin is currently conducting mathematical studies aimed at predicting DNA's ever-changing shape and the effects of such changes on protein-DNA binding. In another project, Rabin is examining how the structure of gels affects their physical properties. His work may contribute to the eventual development of novel "soft matter" devices such as artificial muscles.

Dr. Eli Sloutskin, a Bar-Ilan alumnus, is an expert on crystallization. Examining crystal "precursors", Sloutskin and his collaborators at Harvard discovered that these precursors - classically assumed to be spherical in shape - actually appear in a range of complex shapes. Based on this discovery, Sloutskin was able to correct the classical theory of crystallization, which typically mis-predicts crystallization rates by many orders of magnitude. In another project, Sloutskin created a completely new type of "colloidal" material - material composed of micron-sized particles suspended in a solvent. Sloutskin's colloidal particles, which appear in a variety of shapes but are identical in mass and volume, can never form a crystal; instead, they form glass. This novel material may help scientists understand the physics of glass formation, a fundamental process that is still poorly understood.

Plastic is all around us in the modern world, but soon plastics may find new uses, replacing expensive materials in the world of electronics. Dr. Joseph Frey designs and synthesizes functional polymers that may someday form the basis of disposable components in applications ranging from solar cells, to energy-saving lighting equipment, to sensors for detecting chemical warfare agents. Frey's many projects share a common goal: to clarify the self-organization that occurs during polymer synthesis and control it, in order to achieve materials with specific, predetermined functions.

Another scientist who examines how materials get their specific properties is Prof. Shmaryahu Hoz. Hoz studies "auxetic" compounds – materials that, contrary to expectations, become thicker when stretched, and thinner when compressed. In auxetic materials, matter flows inward upon impact to strengthen the affected zone – a quality that could be useful for specialized applications, such as bulletproof vests. Together with colleagues from the Technion, Hoz used quantum theory to predict that a certain class of rod-shaped molecules would behave auxetically. This discovery may help scientists manufacture more compounds of this type. In another exciting achievement, Hoz broke the world hardness record by engineering a man-made material 40 times harder than diamond.

Shaping the Future

Materials drive discovery. As a center of materials science excellence, Bar-Ilan University is making a fundamental contribution to the basic science that will lead to future technologies, and re-shaping the world – for the better.

For more about the research of BIU faculty listed in this brochure go to: www.biu.ac.il and click Research.

Students on their way to class in BIU's Engineering Complex

Bar-Ilan University
Science and Technology

Bar-Ilan University stands at the forefront of cutting-edge research. Bar-Ilan researchers are making breakthroughs that improve life around the globe in areas such as drug-development, nanotechnology, medical research, bio-engineering, microscopy, optics, communications, energy, security, and more. As part of a national program to combat Israel's brain drain, BIU has taken the lead by committing to absorb dozens of returning experimental scientists within its world-class research infrastructure, and has added state-of-the-art physical facilities in engineering, brain sciences and nanotechnology to house these innovative initiatives. The Science and Technology Series highlights some of the University's most exciting research endeavors.

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