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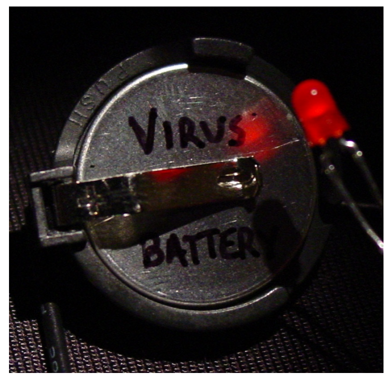
2013 Winner of the $500,000 Lemelson-MIT Prize
Dr. Angela Belcher

Applying Lessons in Nature to Build New and Improved Materials

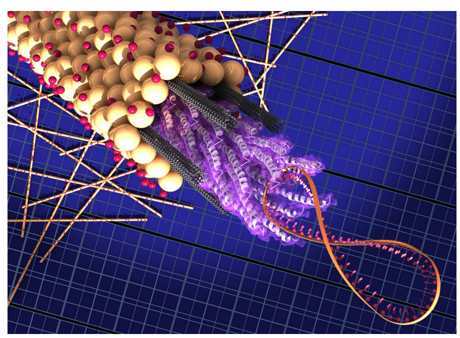
Angela Belcher was inspired by the way soft-bodied organisms in the sea use inorganic minerals in their environment to grow finely-tuned hard materials in the form of shells and bone. She was fascinated by how these organisms constructed nanoscale materials under environmentally-friendly conditions. This biological process has served as a launchpad for her inventive approach using bacteriophages, or simple viruses with single-stranded DNA that have the ability to infect bacteria, to build a toolkit of organic proteins that can specifically bind to most elements in the periodic table. Belcher uses collections or libraries of genetic information to rapidly find benign viruses that can identify inorganic building blocks that are used as the basis for technologically-important materials. By using and constructing Phage Display Libraries, which contain billions of viruses with unique genetic sequences, Belcher and her team can side step millions of years of evolution and develop new biological templates to grow and self-assemble electronic devices and other useful materials. Once the best genetic sequence is discovered, it can be used to manufacture components in electronic devices such as batteries, display screens, solar cells as well as materials to manufacture fuels. The inventions are all environmentally sustainable.

Biological-Based Battery



Belcher has engineered organic viruses that can simultaneously bind and grow two different types of materials and assemble them into more efficient battery materials. Examples include viruses that can latch onto tiny carbon nanotubes to act as good conducting material, and that are programmed to then coat themselves with nanoscale inorganic materials including iron phosphate, cobalt oxide and gold, turning each virus into self-assembled nanowires. These nanocomposited all-in-one nanowires form electrode materials, the major component of a working battery. Belcher used the material to create state of the art, high-powered batteries at room temperature that have the ability to power small electronic devices, such as laser pointers and LED lights. Using the unique properties and programmability of biology within the technology, her team has developed batteries that are soft and flexible. She is now working on batteries with new architectures that could be used in larger applications including electric vehicles.

Biological Solar Cells



Belcher has shown that viruses can be engineered to improve the efficiency of electron collection in inexpensive solar cells. Belcher and her team have been able to engineer viruses to pick up single-walled carbon nanotubes and keep them together in a pattern that enables an efficient flow of electrons. The virus, with the carbon nanotubes, also contains the genetic sequence to grow and assemble nanoscale titanium dioxide around the carbon nanotubes, forming a complex. By adding a very small amount (one percent by weight) of this complex to traditional recipes for these types of dye sensitized solar cells, the efficiency can be boosted by 33 percent. This occurs by using biology to carefully control the interfaces of materials and their placement in a device and nicely demonstrates how a small amount of carefully-engineered biological additive can make a great impact on the device performance of solar cells.

Engineering Viruses to Produce Fuel

Belcher's interest in nature has also led her to investigate photocatalysis, a process in which energy from light, such as sunlight, can be utilized in creating clean renewable fuels. Belcher has modified viruses that act as a template for self-assembly of molecules and inorganic nanoparticles that can harness sunlight and split water to its basic components: oxygen and hydrogen, similar to the natural process of photosynthesis in plants. Hydrogen can be used as a green fuel in which its only by-product after use is water and hence water is the source of renewable clean energy. Belcher and her team are also using photocatalysis to convert waste carbon dioxide into fuel as well as clean up chemical pollutants.

Belcher's company, Siluria Technologies founded in 2007, is also using the basic components of this virus to develop efficient and economic catalysts to convert methane, the main component of natural gas, into ethylene, the world's largest commodity chemical used for both fuels and as a building block for a wide array of chemicals and plastics found in thousands of everyday products. Ethylene can be converted into fuels such as gasoline, diesel and aviation fuels. Siluria has achieved success across all the key economic and technical parameters – Conversion, Selectivity, Catalyst Activity, Operating Temperatures and Pressures, and Catalyst Strength and Life. Siluria is now implementing a scalable "gas to chemicals and fuels" process in its pilot plants using biologically templated catalyst and conventional process industry equipment and are building a demo unit on the U.S. Gulf Coast.

Transparent Conductors for Electronic Devices

Belcher co-founded Cambrios Technologies in 2002, an electronic materials company, to develop biologically-inspired synthetic roots to technologically-important electronic materials. Inspired by more environmentally-friendly, solution-based processes used by organisms, and biology's ability to exquisitely control nanostructured material, Cambrios Technologies has developed low-cost, large-area transparent conductors for the electronics industry. To do this, Cambrios developed an ink (ClearOhm) that contains tiny threads of criss-crossing silver nanowires that are coated onto the screen of a phone or other device to make it touch-sensitive. The wires are so small that the coating appears transparent and demonstrate that this silver nanowire technology is the best alternative to currently existing indium tin oxide (ITO) based materials. Cambrios' ClearOhm coating material enables high-conductivity transparent film ranging from 10 to 300 Ohms/square with superior optical performance. Touch sensors based on ClearOhm Ink are more cost effective than existing technologies, thus allowing faster mass-market adoption of touch-enabled tablets, laptops, Ultrabooks and All-in-One computers. The technology has other applications including OLED displays and thin film photovoltaics. Today Cambrios is a leader in nanotechnology-based solutions.

Belcher's technology has many other applications that she is currently developing. These include non-invasive detection and diagnostics of very small tumors for ovarian cancer treatment; development of catalyst for conversion of wasted carbon dioxide; and green building supplies as a method of carbon dioxide sequestration and storage; and environmentally-friendly manufacturing of materials and development of new catalysts for low temperature and water based synthesis of chemicals.