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A New Attraction

A few chemical companies are combining chemistry and magnetics

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TurboBeads

MAGNETIC CHEMICALS TurboBeads links chemistry to nanomagnets for a new kind of separation.

It's old hat for physicists, and even biologists use it, but magnetism is uncharted territory for most chemists. That's a reality that a handful of companies are trying to change.

Firms ranging from the start-up TurboBeads to the giant BASF are pushing magnetics as a way of manipulating metal-containing compounds. Magnets have long been used industrially to lift, move, and separate objects, but these chemical companies are adding chemistry to broaden magnetics' utility.

Robert Grass, chief executive officer of Switzerland-based TurboBeads, admits that the biologists got there first.

In the mid-1970s, the Norwegian polymer chemist John Ugelstad invented a way of making polymer beads that are both porous and uniformly sized. He reacted the beads with an iron salt solution, causing them to be infused throughout with fine iron oxide.

Seeing industrial potential, Ugelstad licensed the beads to the Norwegian firm Dyno Industrier. Today, the technology is owned by the laboratory products company Invitrogen, which markets Dynabeads-brand polystyrene beads for the separation of biological materials. Merck KGaA's Estapor beads and Miltenyi Biotec's MACS MicroBeads are competing products.

Customers use the beads by coupling them with an antibody or other targeting ligand. When the beads are added to a mixture containing a desired biological material—a peptide, for instance—the ligand binds to it. Applying a magnet to the solution draws the bead-peptide complex into a corner of the test tube or beaker. Unwanted components are removed by aspiration, leaving just the bead-peptide complex, which is easily broken apart to recover the peptide.

According to Grass, magnetics are now widely used in biological labs for separations. "But go to a chemist and say you can use a magnet to recover something, and he or she will usually say, 'What are you talking about?' " he laments.

It's not only ignorance. One reason magnetics haven't caught on in the chemistry lab is that organic solvents can play havoc with the polymer beads. Moreover, iron oxides are a poor magnetic material, Grass notes, and they aren't stable in an acidic environment.

TurboBeads' technology has its roots in Grass's Ph.D. thesis at the Swiss Federal Institute of Technology, Zurich (ETH). Grass formed the company in 2007 as a spin-off of the institute.

As he explains it, TurboBeads is exploiting two technological advances. One is a technique for coating iron, cobalt, or other strongly magnetic metals with a graphenelike carbon layer. The result is a core-shell combination with "astonishing stability," Grass says, and thus no chance of metal oxidation. The other advance is a means of attaching useful ligands—catalysts or chelating agents, for example—via strong carbon-carbon bonds.

Grass sees big potential for TurboBeads in separations involving low concentrations of a material that is either highly desirable or highly undesirable. For example, the company is working with a customer that wants to recover more precious metal from a refining stream. "The standard process can get a lot out, but there's still some metal wasted," Grass says.

The high-purity chemical maker Strem Chemicals is also pursuing magnetic chemistry. Last year, the company set up a nanochemistry laboratory at the Institut de Science et d'Ingenierie Supramoleculaires at France's University of Strasbourg. The lab is headed by Nina Matoussevitch, a nanochemist and former member of Helmut Bönnemann's research group at Max Planck Institute for Coal Research, in Mülheim, Germany.

Back in 2004, Strem licensed technology developed by Bönnemann for making metal-based nanoparticles, including magnetic fluids. Now that Matoussevitch is aboard, the company is actively developing magnetic materials and looking for projects to undertake with customers. "It's a rather new venture, but we're making an investment in it," Strem President Michael E. Strem says.

At the other end of the corporate size spectrum, BASF is making its own foray into magnetic chemistry with two initiatives. In August, the company announced the launch of a line of magnetorheological fluids (MRFs) it has dubbed Basonetic. The fluids are based on carbonyl iron powder, a product that BASF pioneered some 80 years ago and for which it claims world market leadership.

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BASF produces carbonyl iron powder in Ludwigshafen, Germany, by reacting iron with carbon monoxide. The resulting iron pentacarbonyl [$Fe(CO)_5$] is purified and then decomposed. The result, BASF says, is spherical particles of highly pure iron that have good magnetization behavior.

In pursuing the magnetic fluid market, BASF will be going up against Lord Corp., a U.S. company that claims to own the world's most extensive portfolio of MRF formulation, device, and system patents.

Lord describes its fluids as a mixture containing 20–40% iron particles plus a carrier liquid and proprietary additives that discourage gravitational settling of the iron. At rest, MRFs are free-flowing. When a magnetic field is applied, the iron particles line up and rapidly turn the liquid semisolid, the degree of solidification varying with the strength of the field.

One notable application of Lord's technology is the MagneRide shock absorber system from Delphi, the former General Motors auto parts subsidiary. According to Lord, the system—available in cars from GM, Audi, Acura, and Ferrari—provides smooth, continuously variable dampening without the clunky electromechanical valves used in traditional controllable shock absorbers. Other MRF applications include vehicle clutches, prosthetic joints, and bridge suspensions.

BASF has supplied carbonyl iron powder to the MRF industry for many years, according to Christoffer Kieburg, a project manager in BASF's metal systems business. By moving downstream into the fluids market, he says, the firm will be offering the industry a choice in sourcing.

As a chemical company, BASF has the ability to tailor the iron particles with unique morphology and surface modifications, Kieburg notes. One problem with MRFs is the tendency of the iron particles to settle. Kieburg says BASF offers thixotropic agents and other additives to help customers find the right balance between low sedimentation and low viscosity.

On another magnetic chemistry front, in August, BASF struck an agreement with the Taiwanese electronic components maker Delta Electronics to develop magnetocaloric technology for cooling systems. Their goal is to replace conventional gas compressors in refrigerators and air-conditioners.

As BASF explains, the German physicist Emil G. Warburg observed in 1880 that ferromagnetic materials heat up when introduced into a magnetic field and cool down again when removed. Magnetic-field-generated temperature differences have been used for cooling in laboratories since the 1930s, the company says, but the effect was never strong enough for commercial use.

Now, though, new materials are yielding much bigger temperature differences in even weak magnetic fields. Among materials with a large magnetocaloric effect, BASF is working on chemically stable manganese-iron compounds. It's also exploring the pnictides. These compounds of the nitrogen group elements—phosphorus, arsenic, antimony, and bismuth—have been attracting attention for their superconducting properties (C&EN, Oct. 20, 2008, page 15).

Initial estimates by materials researchers, BASF says, are that magnetic refrigeration could use as little as half the energy of conventional refrigerators that are based on the compression and expansion of gases. "We're all ready to go," says Thomas Weber, managing director of BASF Future Business. "What we need now are prototypes for cooling systems to demonstrate the energy-saving potential in everyday use."

TurboBead's Grass, himself a chemical engineer, sees the chemical enterprise's heightened interest in magnetics as an outcome of the interdisciplinary research that has proliferated in science in recent years. The new technologies would not be possible, he says, without cooperation between physicists, chemists, and biologists.

Still, more can be done. "There's so much information on magnetic materials that can be obtained physically," Grass says. "The question is, 'How can I combine the physics and the chemistry?' "

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