Studies would lead to lighter, cheaper magnets

December 23 2013, by Anne M Stark

A Lawrence Livermore researcher prepares a sample at Oak Ridge National Laboratory's Spallation Neutrons and Pressure Diffractometer Credit: SNAP

(Phys.org) —Sometimes you have to apply a little pressure to get magnetic materials to reveal their secrets. By placing a permanent magnet under high pressures, Lawrence Livermore researchers are exploring how atomic structure enhances magnetic strength and resistance to demagnetization. This fundamental research into magnetic behavior has important implications for engineering stronger, cheaper magnets.

Permanent magnets based on rare earth elements are in high demand for energy technologies such as windmills and electric motors that generate rotational energy through opposing magnetic forces.

In September 2013, a team from Lawrence Livermore National Laboratory (LLNL) and the National Institute of Standards and Technology conducted neutron scattering research at Oak Ridge National Laboratory's Spallation Neutron Source Spallation Neutrons and Pressure (SNAP) Diffractometer to examine the magnetic properties of a rare-earth-based permanent magnet containing the elements lanthanum and cobalt, known as LaCo5.

"We're using high pressure to tune the structural and magnetic properties of permanent magnets like LaCo5," said Jason Jeffries of the LLNL research team. "We can see how the atomic structure of the material changes as the magnetic moment, or the magnetic strength, of the system changes under pressure."

Researchers applied 20 GPa—about 200,000 times atmospheric pressure—to a 100 mg sample of LaCo5 with a SNAP pressure cell. The suite of pressure cells available at SNAP includes some that can achieve pressures near 100 GPa and that can be used to study a range of materials under high-pressure conditions applicable to research in solid-state physics, hydrogen storage, planetary ices and geochemistry, among other fields. Jeffries said the LLNL team hopes to expand their research to pressures as high as 25 to 50 GPa.

One of the team's most important research goals is to see if expensive, rare earth elements that are increasing in scarcity and driving up the cost of permanent magnets can be substituted with cheaper elements or entirely new, engineered materials.

"For instance, if we could replace or reduce the amount of neodymium in a commercial neodymium iron boron magnet, which is used in many electric motors, then we could make a significantly cheaper magnet," Jeffries said. "This costly element makes up a small fraction of the crystal stoichiometry, yet it is what is determining the price."

Neutron scattering allows researchers to determine the length of chemical bonds and reorganization of molecular units within a structure under high pressure.

"Neutrons are sensitive to the ordered magnetic moments of the system, allowing us to see magnetic effects, which are hard to capture with x-ray scattering," Jeffries said. "If we can understand why a magnetic property is enhanced then perhaps we can engineer magnetic materials with optimized properties."

Apart from reducing the cost of magnets by reducing the need for rare earth compounds, understanding how to develop a stronger magnet could also help scientists and engineers reduce the size and weight of magnets for energy-conscious designs.

"Motors that need a lot of magnetic material are heavy," Jeffries said. "And reducing weight in vehicles, for example, can improve fuel efficiency or range."

Although researchers (with this team and others) are studying a range of permanent magnets, experimental work like that being conducted on SNAP could help reduce trial-and-error in magnetics research by improving predictive models.

"The experiments are there to help us understand and improve our theoretical models," Jeffries said. "Ultimately, computer models that are refined based on experimental results could perform theoretical calculations to predict the properties of new or less-observed magnetic materials." Theoretical models will help researchers determine whether the magnetic strength of a compound might be improved by replacing an element or manipulating a bonding mechanism.

"This is the fundamental science that could lead to applications for building better magnets," Jeffries said. "And the capabilities of high-pressure diffractometers like SNAP are under-represented for studying magnetism. There's much more to be learned."

Provided by Lawrence Livermore National Laboratory