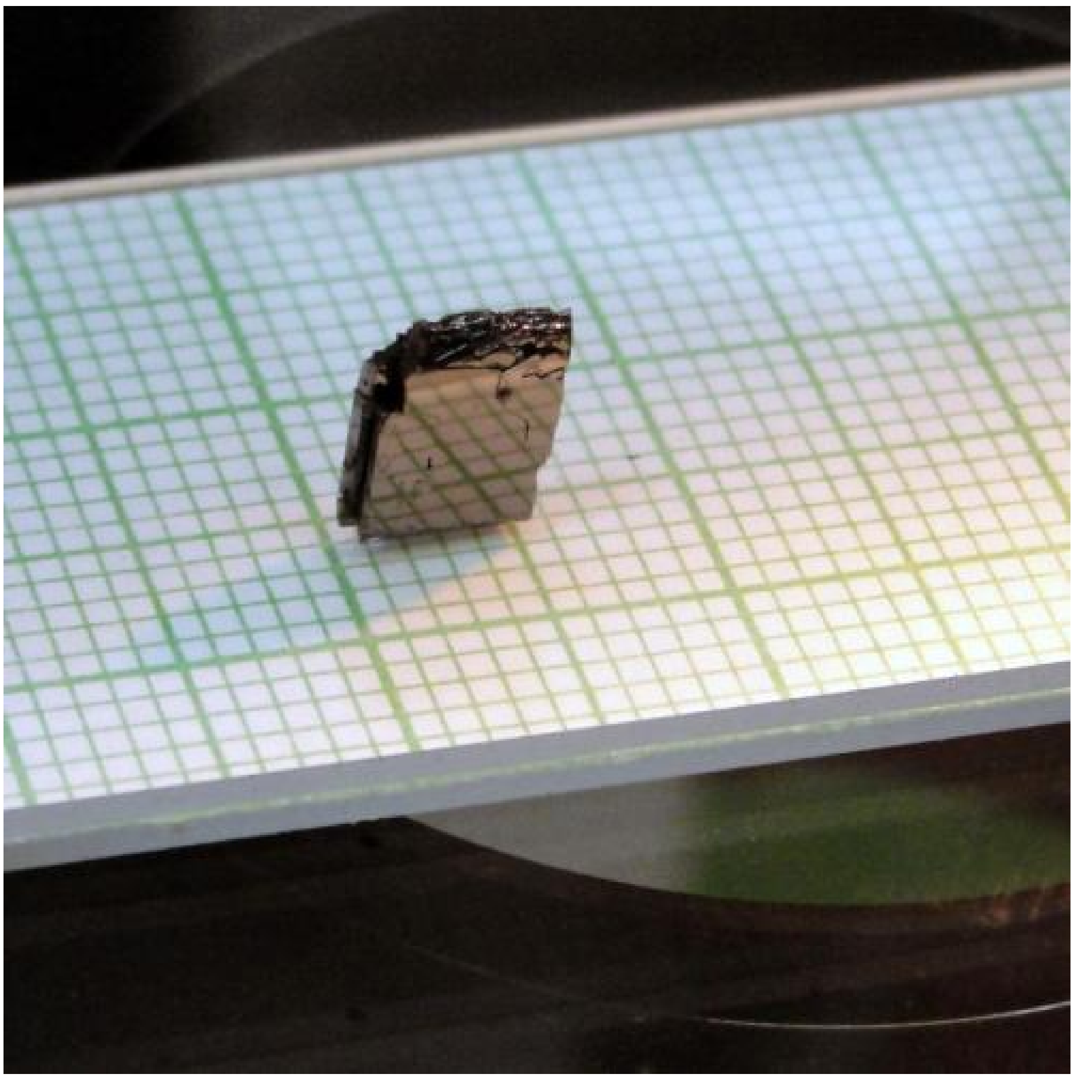
Researchers see rare-earth-like magnetic properties in iron

April 28 2014, by Paul Canfield



A single crystal of lithium-iron nitride is shown. Scientists at the US Department of Energy's Ames Laboratory observed magnetic properties in iron-ions in these lithium-iron nitrides that are typically associated with rare-earth elements. Credit: Ames Laboratory

(Phys.org) —Scientists at the Department of Energy's Ames Laboratory have observed magnetic properties typically associated with those observed in rare-earth elements in iron. These properties are observed in a new iron based compound that does not contain rare earth elements, when the iron atom is positioned between two nitrogen atoms. The discovery opens the possibility of using iron to provide both the magnetism and permanence in high-strength permanent magnets, like those used in direct-drive wind turbines or electric motors in hybrid cars. The results appeared in *Nature Communications*.

In modern magnets, iron gives most magnets their strength, and comes with the benefits of being abundant and cheap. But the magnet recipe must also include rare earth elements, which lend magnets "permanence," or the ability to keep the direction of the magnetic field fixed (also called anisotropy). The challenge is rare-earths materials are expensive and at risk of domestic supply shortages. So, ideal next-generation permanent magnets will rely more heavily on iron or other abundant materials and less on rare earths.

"The breakthrough here is that we see magnetic anisotropy normally associated with rare earths ions in iron," said Paul Canfield, Ames Laboratory physicist. "This isn't an industrial breakthrough at this point because these magnetic properties only reveal themselves at cryogenic temperatures. But, it's a basic science breakthrough that hopefully will point the way to future technical breakthroughs."

Canfield's research group is internationally known for expertise in design, discovery, growth and characterization of new and promising materials. In this effort, Canfield and his colleagues, including postdoctoral research associate Anton Jesche, designed a new technique to grow lithium-iron-nitride single crystals from a lithium-nitrogen solution.

"Using nitrogen in solution growth had not yet been well explored because, since we typically think of nitrogen as a gas, it's challenging to get into a solution" said Jesche, "But we found that lithium – lightest solid element—looked like it could hold nitrogen in solution. So, we mixed together lithium and lithium-nitride powder, and it worked. It created a solution."

Then the group added in iron and, to their surprise, the iron dissolved.

"Usually iron and lithium don't mix," said Canfield, who is also a Distinguished Professor of physics and astronomy at Iowa State University. "It seems adding nitrogen to the lithium in the solution allows iron to go in."

The resulting single crystals of iron-substituted lithium nitride yielded even more surprises: the opposing external field required to reverse magnetization was more than 11 tesla, as much as an order of magnitude larger than that of commercially available permanent magnets and two or more orders of magnitude larger than is typically found in single crystals. Further evidence of iron's exotic state in this compound is the field-induced quantum tunneling found for very diluted iron concentrations at the relatively high temperature of 10 Kelvin, a temperature orders of magnitude higher than what had been seen before.

"With detailed measurements, we saw that these single iron ions are indeed behaving like a single rare-earth ion would," Canfield continued. "And we believe this has to do with the special, fairly simple, geometry that the iron finds itself in: one iron atom positioned between two nitrogen atoms. We hope this crystal growing technique and this specific material can be a model system for further theoretical study of these rare-earth-like iron ions. As it stands, these materials have clear implications on finding rare-earth-free replacements for permanent magnets—and perhaps also may impact data storage and manipulation in quantum computer applications."

More information: Paper: [www.nature.com/ncomms/2014/140 … full/ncomms4333.html]

Provided by Ames Laboratory