

## Physicists Harness Effects of Disorder in Magnetic Sensors

University of Chicago scientists have discovered how to make magnetic sensors capable of operating at the high temperatures that ceramic engines in cars and aircraft of the future will require for higher operating efficiency than today's internal combustion technology.

The key to fabricating the sensors involves slightly diluting samples of a well-known semiconductor material, called indium antimonide, which is valued for its purity.

Most magnetic sensors operate by detecting how a magnetic field alters the path of an electron. Conventional sensors lose this capability when subjected to temperatures reaching hundreds of degrees. Not so in the indium antimonide magnetosensors that Rosenbaum and Hu developed with support from the US Department of Energy.

"This sensor would be able to function in those sorts of temperatures without any degradation," said Rosenbaum, the John T. Wilson Distinguished Service Professor in Physics.

Rosenbaum's research typically focuses on the properties of materials observed at the atomic level when subjected to temperatures near absolute zero (-460°F). More than a decade ago, he led a team of scientists in experiments involving silver selenide and silver telluride, two mate-

rials that exhibited no magnetic response at low temperatures. But when the team introduced a tiny amount of silver (one part in 10,000) to the materials, their magnetic response skyrocketed.

In silver selenide and silver telluride, the magnetic response disappears at room temperature, which limits their technological applications. But Rosenbaum and Hu now have used two methods to recreate the effect at much higher temperatures in indium antimonide. Disordering the material, simply grinding it up and fusing it with heat produces the effect. So does introducing impurities of just a few parts per million.

"What's nice about it is that, first, it's an unexpected phenomenon and second, it's a very useful one," said University of Cambridge physicist Peter Littlewood. "Normally, in order to make large effects, you have to have pure samples."

Before Rosenbaum and Hu's latest experiments, two theories duelled to explain the effect. In 2003, Littlewood and Meera Parish explained the effect using classical physics, the laws of nature that govern physics above the atomic scale. Nobel laureate Alexei Abrikosov of Argonne National Laboratory devised an explanation based on quantum physics - the dominant physics at ultrasmall scales.

"We've shown that both theories work, just in



different regimes," Rosenbaum said.

Littlewood lauded the sequence of events as an example of how science ought to work. "There's a discovery of a result. There's a theory about it. Further experiments are done to test the theory. They work and that provokes another idea, and you bounce to and fro," Littlewood said. "That's how we like to describe science progressing. One is rarely lucky enough to do that over a long period."

# MicroMag™ Magnetometers

## Vibrating Sample and Alternating Gradient Magnetometers

State-of-the art design...with comprehensive operating software, speed and sensitivity.

- First order reversal curves (FORC)
- IRM and DCD remanence
- Moment vs. temperature
- Dia/paramagnetic susceptibility
- Moment vs. time
- Hysteresis loops vs. temperature
- Multiple segments vs. field
- Biological samples
- Carbon nanotubes
- Ferrofluids
- Weak thin films
- Minor loops
- Delta-M curves
- Initial permeability

AGM sensitivity  
**10 nemu**  
at 1 s per point  
VSM sensitivity  
**500 nemu**  
at 1 s per point



Cryostat and Furnace Options 10 K to 1070 K  
Offering cost-effective AGM and VSM combination systems

31 Airpark Road  
Princeton, NJ 08540

sales@princetonmeasurements.com  
www.princetonmeasurements.com

Tel: (609) 924-7885  
Fax: (609) 924-0807