Three's company: New alloy sets magnetism benchmark

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The burgeoning field of spintronics leverages electron spins—as opposed to their charge—to enhance solid-state devices like hard drives and cell phone components by prolonging battery life. Spintronic developments, however, are increasingly running up against a barrier known as the Slater-Pauling limit, the maximum for how tightly a material can pack its magnetization. Now, a new thin film is poised to break through this decades-old benchmark.

A team of researchers from Montana State University and Lawrence Berkeley National Laboratory announces this week in *Applied Physics Letters*, that they constructed a stable thin film made from iron, cobalt and manganese that boasts an average atomic moment potentially 50 percent greater than the Slater-Pauling limit. Made with a technique known as molecular beam epitaxy (MBE), the ternary body-centered cubic (bcc) alloy features a magnetization density of 3.25 Bohr magnetons per atom, besting the previously considered maximum of 2.45.

"What we have is a potential breakthrough in one of the most important parameters of magnetic materials," said Yves Idzerda, an author on the paper from Montana State University. "Large magnetic moments are like the strength of steel—the bigger the better."

The Slater-Pauling curve describes magnetization density for alloys. For decades, iron-cobalt (FeCo) binary alloys have reigned supreme, posting a maximum average atomic moment of 2.45 Bohr magnetons per atom and defining the current limit for stable alloy magnetization density. Previously, researchers mixed FeCo alloys with high-magnetic-moment transition metals, like manganese. When these ternary alloys are made, however, they lose much of their bcc structure, a key component to their high magnetism.

Instead, this team turned to MBE, a meticulous technique akin to draping a substrate with beads of individual metal atoms, one layer at a time, to create a 10-20 nanometer film of $Fe_9Co_{62}Mn_{29}$. Roughly 60 percent of the available compositions kept the bcc structure as a thin film, compared to only 25 percent in bulk.

To better understand the alloy's composition and structure, the group used X-ray absorption spectroscopy and reflection high-energy-electron diffraction. The X-ray magnetic circular dichroism results showed that the new material yielded an average atomic moment of 3.25 Bohr magnetons per atom. When tested with a more standard vibrating sample magnetometry, even though this magnetization density dropped, it was still significantly above the Slater-Pauling limit—2.72.

Idzerda said this discrepancy will provide areas of future research, adding that the interface between manganese and the substrate within the crystal might account for the gap.

"I have guarded optimism for this because the technique we used is a little bit nonstandard and we have to convince the community of this material's performance," Idzerda said.

Idzerda and his team will now investigate the robustness of iron-cobalt-manganese alloys, and more efficient fabrication techniques. They also plan to explore how molecular beam epitaxy might lead to other highly magnetic thin films, potentially mixing together four or more transition metals.

More information: "Large moments in bcc FexCoyMnz ternary alloy thin films," *Applied Physics Letters* (2018). DOI: 10.1063/1.5006347

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