Permanent Magnet Materials without Neodymium and Dysprosium

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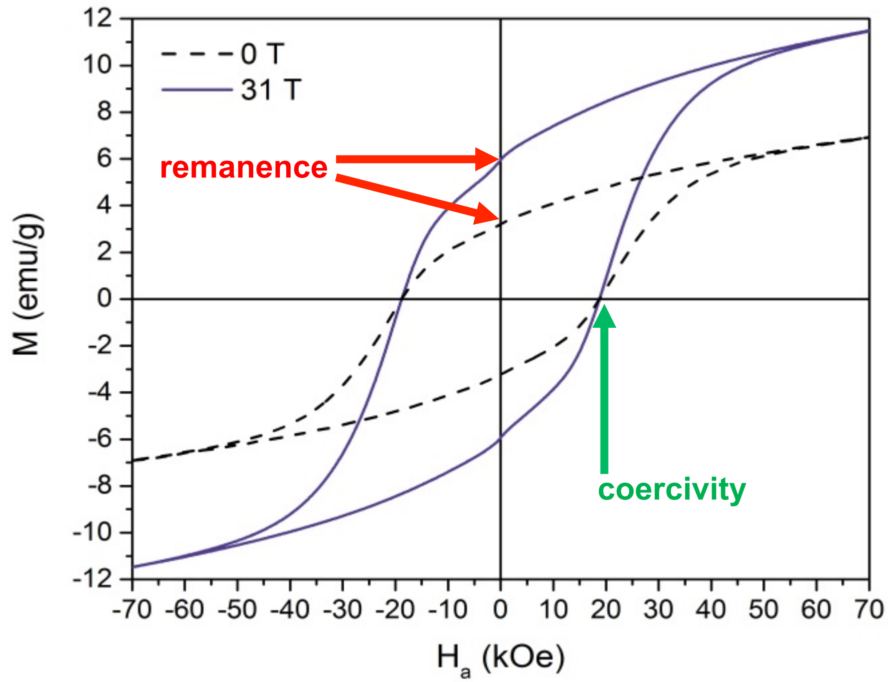
The super-strong $(Nd,Dy)_2Fe_{14}B$ permanent magnets (in which Nd = Neodymium and Dy = Dysprosium) find widespread applications due to their outstanding hard magnetic properties. Since 2010, however, supplies of Nd and Dy have been restricted in order to clean environmental contamination related to past mining and manufacturing. Also, the vast majority of known Nd and Dy reserves are limited to a few countries around the world. This has led to a search for new, powerful permanent magnetic materials that do not contain Nd or Dy.

This MagLab/user collaboration has developed new methods for fabricating permanent magnets from Manganese-Gallium (Mn-Ga) and from Iron-Cerium-Boron (Fe-Ce-B) to achieve the desired materials properties. Samples of Mn-Ga made by ball-milling and pressing were annealed under 31T magnetic fields at various temperatures. Samples of Fe-Ce-B were made by rapid solidification.

After high magnetic field annealing, Mn-Ga samples showed an improvement in remanence (red arrows) while maintaining the high coercivity (green arrow). Samples heat treated at 315°C with an applied field of 31T increased remanence by 50% (see figure). This indicates that high magnetic field annealing can be used to tune magnetic properties. We enhanced the magnetic properties of Fe-Ce-B ribbons by engineering both microstructure and volume fraction of the $Ce_2Fe_{14}B$ phase through optimization of the chamber pressure and the wheel speed necessary for rapid solidification.



Two room-temperature hysteresis loops for samples with the same nominal chemistry of $Mn_{0.8}Ga_{0.2}$ that have been processed in two contrasting ways: The dashed line are data from the sample annealed at 335°C in absence of a magnetic field. The solid blue line are data from the sample annealed in a 31T applied field. The 31T magnetic field stimulates formation of the favored ε-Mn_3Ga phase, resulting in higher remanence once the sample is cooled. The vertical axis is the magnetic moment of the sample in response to the applied magnetic field (horizontal axis).

Facility: DC Field Facility

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