CRC/TRR 270

HoMMage

Hysteresis Design of Magnetic Materials for Efficient Energy Conversion

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Magnetic Materials for EV Traction Motors

Abstract:

Higher power density, higher efficiency, and cheaper cost are the three drivers for EV motor development. The motor's power density is linearly proportional to the excitation frequency before its torque flats out. Higher frequency leads to higher core loss, with the top contributor coming from the soft magnetic materials in the stator and rotor. To implement the high-speed high frequency high power density strategy, the current 3.2% Si steel must be replaced with a new material that is more efficient at high frequency. The performance of electrical steel depends on its silicon content. Fe-6.5%Si has higher resistivity and lower iron losses than the widely used Fe-3.2%Si. However, Fe-6.5%Si is difficult to fabricate using the traditional cold-roll process since the ordered phases formed during the process embrittle the alloy. Rapid solidification is a viable route to make Fe-6.5%Si thin sheet since it suppresses the embrittling ordered phases. In this seminar, I will discuss the relationship among cooling rate, chemical ordering, mechanical, and magnetic properties of Fe-6.5%Si during the melt spinning process, which lays the foundation for preparing Fe-6.5%Si ribbon with tunable ductility. I will also show two novel concepts of using the rapidly solidified 6.5%Si steel: the ribbon bundle stator concept that uses Fe-6.5%Si narrow ribbon and ductile Fe-6.5%Si flakes that can be consolidated into near net shape motor stators or inductors.

Although soft magnetic material alone can power a motor, a motor with permanent magnets (PM) is more efficient. The stronger the PM, the more powerful and efficient the motor. Nd-Fe-B-based magnet is the dominant PM material. Meeting the EV's demand on Nd-based PM will require more than a 2x increase in Nd production by 2030 and at least 3x by 2040. Moreover, Nd-based magnets without heavy rare earth elements (HREE) have poor coercivity above 150 °C. The coercivity is sensitive to grain boundary structure, grain boundary chemistry, and grain size. In the second part of this seminar, I will discuss the grain boundary engineering approach to produce the HREE-free Nd-based magnet for higher temperature application.

About the speaker:

Dr. Cui is a professor at the materials science and engineering department at Iowa State University and a senior scientist at Ames National Laboratory. His research focuses on ferroic materials, including ferromagnetic, ferroelectric and ferroelastic for energy efficient and renewable energy applications. Specific examples include cryogenic magnetocaloric materials, non-rare earth permanent magnets, high silicon steel, shape memory metals, etc. He also works in the field of combinatorial materials science and developed several high throughput bulk materials synthesis and characterization methods. Dr. Cui has 9 granted patents and 81 papers published in peer reviewed journals.

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