Soft Magnetic Materials: Synthesis, Characterization, and Applications Introduction

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This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.

Introduction

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Soft magnetic materials have been continuously evolving ever since the nineteenth century, a time that brought major breakthroughs in electromagnetism. In 1820 Hans Christian Ørsted demonstrated that a wire carrying an electrical current behaved like a magnet. Just four years later, William Sturgeon discovered that by wrapping the wire around a piece of iron, the magnetic field became more powerful. This was the invention of the first electromagnet. Then, in 1831 Michael Faraday wound two coils around a ring of iron and discovered electromagnetic induction. During the early 1900s, soft magnets moved rapidly from iron to new materials with the development of novel alloys and manufacturing approaches. These advances led to prominent and practical applications, such as electric motors, generators, and transformers. Today, research on soft magnetic materials continues to be active and vibrant as they remain key pieces in the conversion, storage, and distribution of both energy and information.

A push for greater efficiency and decreased size in power electronics and electrical machines (motors and generators) demands higher performing soft magnetic materials. In order to be competitive, advanced soft magnetic materials must be affordable and their production volume needs to meet the anticipated demand. This drive for higher efficiency and diminished size, weight, and power (SWaP) is fueled in part by the development and adoption of wide bandgap (WBG) semiconductors. WBG devices enable very fast switching (1 kHz to as high as 10 MHz), high voltage operation, and high temperature operation in both power electronics and electrical machine drives. Researchers in the field of soft magnetics must rise to this challenge and create soft magnetic materials with high saturation magnetizations and low electrical losses. The magnetics community also needs to improve the theoretical assessment of magnetic behavior and energy losses at elevated switching frequencies. Convergence of fundamental and applied investigations has been a key to exciting developments in many fields and can also be fruitful for soft magnetic materials, particularly as the pace of research is increased.

This Focus Issue brings together the latest research on soft magnetic materials for next-generation electromagnetic devices, from power electronics, to transformers, to magneto-mechanical sensors and magnetic refrigeration. Additionally, the entire materials science paradigm (processing, structure, properties, and performance) are covered within this issue. Advanced synthesis and characterization techniques are vital to understanding both the nanostructure and dynamical properties in soft magnetic materials. The behavior of soft magnets on small length and short time scales will ultimately govern their performance in electromagnetic devices, while analytical and numerical modeling will serve as tools for analyzing and optimizing device design. This issue aims to be an inspiration to both the current and next generation of soft magnetic material scientists.

ON THE COVER:

The cover of this Focus Issue shows key technologies where advanced soft magnetic materials can impact our society: a wind turbine (electric generator), an electric motor, and power electronics. Additionally, the importance of modeling to soft magnet research is highlighted by the distribution of magnetic flux density in a wound toroidal inductor calculated using finite element analysis (FEA).