IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Laser Assisted Periodic Crystallization of Metallic Glass for Enhanced Magnetic Performance

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Seminar host: Pranav Shrotriya

Abstract

The talk gives a brief introduction on application of lasers in surface engineering. Lasers can be used to modify the surfaces in many different routes including synthesis of functional coatings, surface melting, surface texturing, surface hardening and laser induced phase transformations. An overview of laser machining, surface alloying, laser surface melting and cladding will be given and an emphasis will be made on laser assisted controlled crystallization of Fe-based amorphous materials for soft magnetic applications.

Magnetic materials play a vital role in applications ranging from electronics, transformers, and electric assisted vehicles. With the global energy crisis, there is a great demand for novel magnetic materials for efficient energy transportation with improved efficiency of motors. The properties of magnetic materials are critically dependent on microstructure, and a drastic change is observed when the grain size becomes comparable to the ferromagnetic exchange length (nanometers). Crystallization of amorphous precursors is one of the potential routes to obtain a nano-crystalline microstructure. Crystallization kinetics of amorphous materials at low temperatures suffers from slow diffusion due to the competing mechanisms of diffusion and annihilation of free volume, while at higher temperatures the lower thermodynamic driving force and greater kinetics can lead to rapid and uncontrolled growth of precipitates. Thus, it has always been a challenge to obtain nano-crystalline microstructure due to extremely high growth rates during crystallization of these materials from their amorphous precursors. However, the ability to achieve a nanocrystalline two-phase microstructure without alloying, offered by laser-assisted crystallization, has a tremendous potential for many applications. This presentation will focus on an understanding of laser materials interaction associated with crystallization of ferromagnetic metallic glasses. The underlying physics behind laser-assisted crystallization for development and maturation of novel hard and soft magnetic materials for energy related applications will be discussed. Laser-assisted crystallization involves localized controlled heating of the sample with very high heating and cooling rates thereby offering the ability of accurate spatial-temporal tailoring of the microstructure. In the present talk, the effects of laser irradiation on crystallization behavior of amorphous Fe-Si-B ternary system will be presented and the role of thermal stresses and temperature evolution on crystallization kinetics will be discussed. The underlying physics behind laser material interaction will be explained on the basis of extensive microstructure and compositional analysis done on the crystallized samples after laser processing. A comparison between the magnetic properties of laser and furnace annealing will be shown and the rationale for superior properties of laser processed samples will be explained. Furthermore, the effects of external magnetic field on crystallization behavior and microstructure evolution will also be discussed.

Biosketch

Currently, Dr. Dahotre is a University Distinguished Research Professor and former Chairman (2010-2013) of the Department of Materials Science and Engineering, University of North Texas (UNT), USA. Prior to joining UNT I held a joint faculty appointment with Oak Ridge National Laboratory and Department of Materials Science and Engineering of the University of Tennessee-Knoxville (2002-2010). Moreover, he was a senior faculty member of the Center for Laser Applications at the University of Tennessee, Space Institute-Tullahoma (1995-2010). He has been recognized for the pioneering contributions to fundamental understanding and engineering of laser-materials interactions along with implementation of high power lasers in materials processing and advanced manufacturing with primary emphasis on surface engineering, additive manufacturing and machining.

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.