Nanocrystallinity and enhancing magnetism in soft Fe-Si-Nb-Cu alloy

Michael Titus and Dr. R. Sooryakumar
Department of Physics, The Ohio State University

Introduction

- Fe-Cu-Si-Nb-B alloy discovered in 1988
- Applications in perpendicular recording media, transformers, etc.
- Nanocrystalline phases can be produced by annealing, improving soft magnetic properties
  - High saturation magnetization
  - Low energy loss
- This study aimed at developing enhanced magnetic properties through annealing and controlling atmosphere

Fabrication by rapid solidification (melt-spun quenching)

Experiment

- Ribbons annealed for temperatures T > 500°C
- Vibrating Sample Magnetometry (VSM) measures magnetic properties
- X-Ray Diffraction (XRD) determines crystalline properties
- Scanning Electron Microscopy (SEM) observes structural transitions and determines morphology

Results

X-Ray Diffraction
- XDS-2000 XRD used with Cu anode λ = 1.54 Å

Vibrating Sample Magnetometry
- External magnetic fields (H) allow for measurable magnetization B (= H + 4πM)
- Hysteresis loops obtained from VSM: Loops contain many critical points (Figure 6)

- Area within hysteresis loop corresponds to energy to switch magnetic moment of material (Figure 7)
  - For Fe alloy, very thin hysteresis loops, very little energy to change magnetic moment
  - Permanent magnets give broad loops, much energy to change magnetic moment

- Coercivity dependence on temperature shown (Figure 8)

- Special annealing condition (proprietary) further enhances magnetic properties (Figure 9)

Future Work

- Further development of special anneal study
- Understand cause for dramatic enhancement
- Examine new possibilities for annealing conditions

Conclusions

- Primary crystalization occurs at T1 = 480°C
  - Fe3Si DO3 crystals form
- Soft magnetic properties enhanced
- Secondary crystalization occurs at T2 = 600°C
  - FeB and/or Fe3B phase appears, inhibits soft magnetic properties
- Special annealing gives greatly enhanced magnetic properties
- Coercivity greatly decreases
- Saturation magnetization increases
- Supraparamagnetic effect may help explain enhanced magnetic properties
- Small grain size (< 10 nm) necessary
- Thermal fluctuations suppress magnetization, lowers coercivity and energy to realign moment.

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References


Contact

Michael Titus – titus.58@osu.edu
Dr. R. Sooryakumar – soorya@mps.ohio-state.edu