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Influence of the Al content on structural and magnetic properties of $Fe_{100-x}Al_x$ nanocrystalline alloys

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Introduction

- Today's interest in nano-particle magnetism is stimulated by a variety of potential applications, ranging from soft to hard magnetic materials and from ultra-high density information storage to biomedical applications.
- The formation of metastable phases and disordering of the lattice through mechanical alloying (MA) gives rise to interesting mechanical and magnetic properties.

Experiment

- $Fe_{50}Al_{50}$ metastable alloy is prepared from the mechanical alloy using a SPEX 8000 with time variation of 1 to 24 hrs.
- The ball to powder weight ratio is 5:1.
- The variations of structure are examined by XRD and EXAFS.
- EXAFS data are analyzed with FEFF.
- Particle size is calculated by Scherrer method.
- Saturation magnetization and coercivity are measured by using SQUID with the maximum field of 5 kOe.
- The size and shape of nano-particles are examined by using SEM.

Results and discussions

- Both XRD and EXAFS patterns showed that the alloy nature occurred after 12 hrs of milling time.
- In XRD, the $Fe_{50}Al_{50}$ peaks became weaker and broader, which is correspond to the deformation of structure and variation in the particle size.
- In EXAFS, the reduction of the amplitude is related to the disorder of local structure, and the variation in the phase is related to the change in chemical order.
- Saturation magnetization (Ms) is decreased with milling time, which seems to be due to the substitution of Fe atoms by Al atoms resulting in magnetic dilution and/or decreasing of particle size.
- The coercivity (Hc) is decreased with milling time indicating the increase in single-domain size owing to the particle size reduction.
- The SEM images indicate that the samples for all milling times are polycrystalline and grains size was decreased with milling time increased.

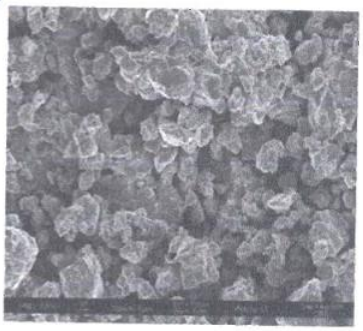

Fig. 1: Typical SEM images of $Fe_{50}Al_{50}$ nanocrystalline alloys at the milling times of 24 hrs

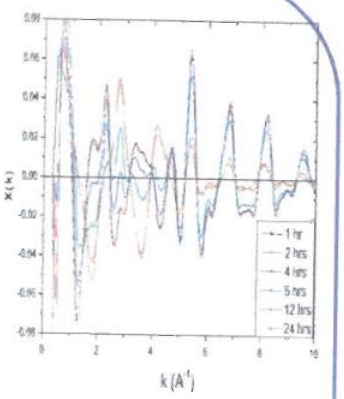

Fig. 4: The Fourier transformation of EXAFS spectra for $Fe_{50}Al_{50}$ alloys milled at different times, measured at the Fe K-edge.

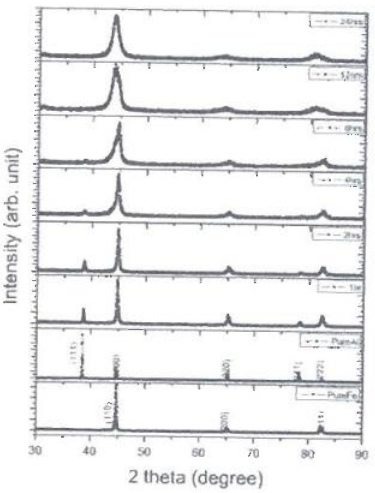

Fig. 2: XRD patterns of $Fe_{50}Al_{50}$ with different milling times.

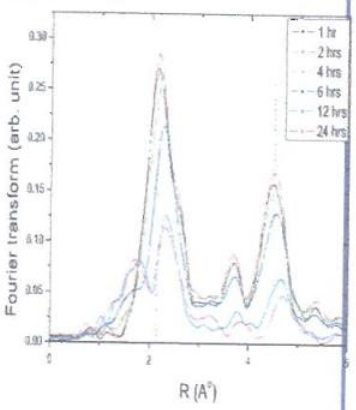

Fig. 5 EXAFS spectra of mechanically alloyed $Fe_{50}Al_{50}$ for different milling times

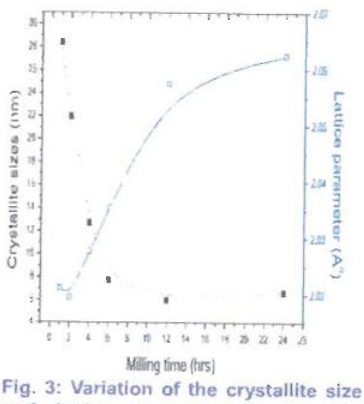

Fig. 3: Variation of the crystallite size and lattice parameter for $Fe_{50}Al_{50}$ nano-crystalline alloys as a function of milling time; error bars are 5 %.

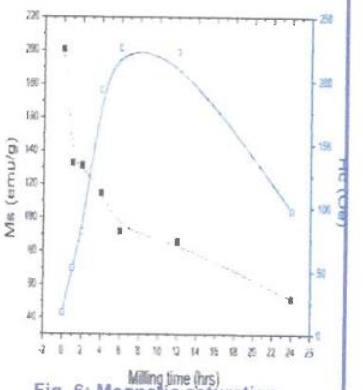

Fig. 6: Magnetic saturation (dash dot line) and coercivity (solid line) for $Fe_{50}Al_{50}$ alloys as functions of the milling time.

Conclusions

- $Fe_{50}Al_{50}$ metastable alloys were explicitly shown in the XRD pattern by shifted and broadened peaks, respectively.
- The significant change in the phase confirmed that new atoms around the central Fe atom and Al atoms increased during the MA process. The Al atoms are diffused into Fe structure, which is the structure to become CsCl structure.
- Magnetic saturation is decreased due to resulting magnetic dilution and decrease in particles size, and also the coercivity is decreased due to growing single-domain size as the particle size is reduced.

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