Institut für Materialphysik
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Long-range order in nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ studied by Mößbauer spectroscopy and x-ray diffraction

E. Kerimov[1], D. Scherjau[2], U. Brossmann[2], B. Sepiol[1], and R. Würschum[2]

[1]Institut für Materialphysik, Universität Wien, Strudlhofgasse 4, 1090 Wien Institut für Materialphysik, [2]Technische Universität Graz, Petersgasse 16, A-8010 Graz

Introduction

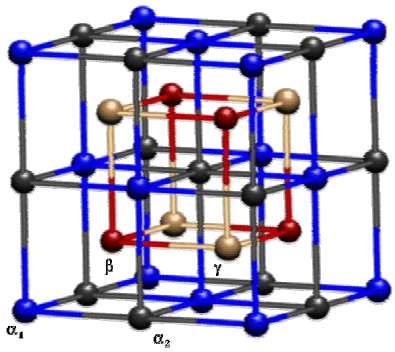
• Ferromagnetic nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ is of technical relevance for applications as softmagnet

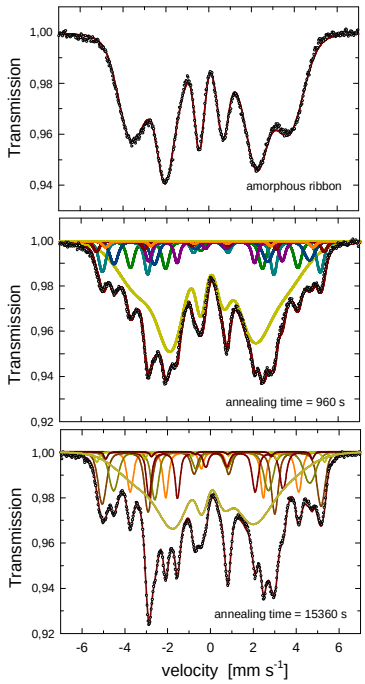
• Preparation is performed by means of crystallization of commercial melt-spun amorphous ribbons (Vacuumschmelze, Hanau, Germany)

• The present combined study of Mößbauer spectroscopy and x-ray diffraction (XRD) aims at an understanding of the atomistic processes underlying the formation of the B2- and D03-order of the Fe3Si-type nanocrystallites during nanocrystallization

• The ordering kinetics is compared with recent studies of Ge tracer diffusion [1]

[1] S. Herth, M. Eggersmann, G. Herzer, and R. Würschum: *Diffusion and induced magnetic anisotropy in nanocrystalline $Fe_{73.5}Si_{13.5}B_9Nb_3B_1$,* Phil. Mag. Letters, in press





Spectra consist of superposition of amorphous and nanocrystalline parts. Nanocrystalline part of spectra is presented by sextets corresponding to various iron sites in the $D0_3$ and B2 structures of Fe-Si alloys. $D0_3$ and B2 ordering parameter is deduced from the fraction of a-iron sites with n=0 … 8 NN Si atoms on the g- and b-sublattices

Experimental procedure

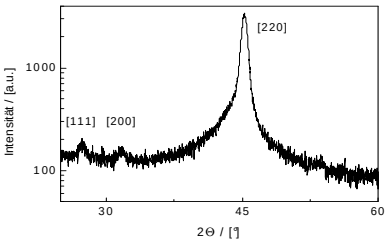
•Measurements of Mößbauer spectroscopy and XRD were performed at ambient temperature in dependence of isothermal annealing (nanocrystallization) at 550 ℃

•<u>Mössbauer spectroscopy:</u>

-Measurements in transition geometry using 57Co(Rh) Mößbauer source

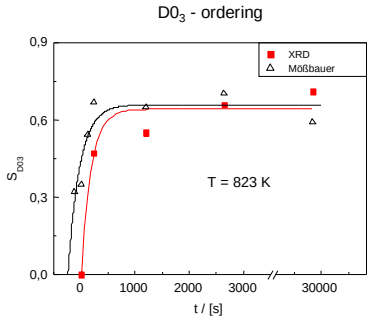
-Spectra analysis taking into account hyperfine parameters distributions and correlation of hyperfine parameters.

•X-ray diffraction was performed in Bragg-Bretano geometry



Calculation of ordering parameter from intensities of superstructure reflexes:

$$S_{D03}^2 = \frac{I_{[111]}}{I_{ref}} \qquad (S_{D03} + S_{B2})^2 = \frac{I_{[200]}}{I_{ref}}$$



Ordering kinetics:

$S = A\,(1-e^{-t/\tau})$ ⟶ $\tau \approx 200$ s

Comparison with self-diffusion data

Ge –diffusion (characterizing Si self-diffusion) in Fe_3Si nanocrystallites [1]:

D_{Ge} (823 K) = 2.4×10^{-20} $m^2 s^{-1}$

Time constant τ = 200 s of $D0_3$-ordering (according to Mößbauer spectroscopy and XRD) corresponds to diffusion length

$$L = \sqrt{D_{Ge}\tau} \cong 2.2nm$$

Conclusions

Kinetics of the ordering process is controlled by the slow Si self-diffusion in the Fe_3Si-type nanocrystallites of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$