FeNi-Alloys within the Range of the Invar Effect

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FeNi-alloys have been studied intensively in the past. One particular composition Fe$_{0.65}$Ni$_{0.35}$, the so called invar alloy, is most famous for its very low magnetic moment combined with an almost vanishing thermal expansion coefficient [1]. The physical origin for these anomalies is still a subject of debate. In the present study we concentrate on the invar region and compare structural data with XMCD results for unannealed FeNi-films and films after prolonged annealing [2]. Here report the structural data on annealed samples.

1 Sample preparation

We have prepared thin films of Fe$_x$Ni$_{1-x}$-alloys that feature a concentration gradient. The preparation was done via ultra-high vacuum (UHV: $p_0 < 5 \times 10^{-9}$ mbar) magnetron sputtering on Al$_2$O$_3$(110)-substrates using Ar as the process gas at room temperature. The alloys were co-deposited from two sources, and a composition gradient resulted from the aligning of the substrate between the two targets. This process also caused a thickness gradient between 800 Å and 600 Å.

After the deposition of the film one sample was annealed at 400 °C for 45 min at a pressure of $p_{an} = 10^{-8}$ mbar, the other one was left as is.

2 Structural characterization

The annealed sample was measured at the beamline W1 at HASYLAB, using the energy 10.5 keV. The intensity distribution from a two dimensional detector is shown in Fig. 1. Along the x-axis the detector covers a certain 2θ range of interest and in the y-axis a section of the Debye-Scherrer ring is seen, where $\Delta \theta = 0^\circ$ corresponds to the scattering plane. The color indicates the logarithmic intensity. A vertical intensity line implies a polycrystalline state of the sample, a sharp spot on the contrary an alignment of the lattice planes with textured or single crystalline features.

Between the substrate peaks at $2\theta = 28.7^\circ$ and $2\theta = 59.4^\circ$, a splitting of the fcc (110) peak can be seen for higher concentrations. This indicates the existence of two different fcc grains in the alloy. The splitting can also be seen at the (200) peak at a concentration of 73.8 at% Fe. Also there is an additional peak at $Q = 3.9$ Å$^{-1}$, which is growing in intensity with increasing iron content. It can also be seen, that the grains are polycrystalline for lower iron concentrations. In the region were the Invar effect occurs the structure becomes stronger textured. For high iron concentrations the structure is returning to a polycrystalline state again. The one additional peak at $2\theta = 43^\circ$ ($Q = 3.9$ Å$^{-1}$) remains sharp but fades away in intensity with decreasing Fe concentration. Its origin has so far not been identified. For further analysis, the samples were investigated via soft x-ray resonant magnetic x-ray absorption at BESSY II of the HZB.

References


HASYLAB’s beamline W1. The substrate peaks are at 28.7° and 59.4°. A highly textured fcc(200)-peak is seen around 70 at%. The other structural peaks of the invar alloy are fcc(111) at 33.1°, bcc(110) at 33.6°, fcc(200) at 38.6°, and bcc(200) at 48.7°.

Figure 1: Scans with a two-dimensional detector for samples in the range from 79.7 at% to 57.5 at% iron at HASYLAB’s beamline W1. The substrate peaks are at 28.7° and 59.4°. A highly textured fcc(200)-peak is seen around 70 at%. The other structural peaks of the invar alloy are fcc(111) at 33.1°, bcc(110) at 33.6°, fcc(200) at 38.6°, and bcc(200) at 48.7°.