It was demonstrated that nanocrystalline FeXN films (X is an alloying element), obtained by sputtering or electrodeposition, have excellent ultra-soft magnetic properties with a saturation magnetization up to \( M \approx 2.0 \, \text{T} \), a high magnetic susceptibility and a frequency range above 1 GHz. Here we report on a correlation between the microstructure, the micromagnetic ripples, and high frequency magnetism in the sputter-deposited FeXN films. The range of operating frequencies for the films is limited by the frequency of the ferromagnetic resonance (FMR) and by the width of FMR. Besides contributions to the FMR width due to dissipation sources, which are characteristic for crystalline and polycrystalline ferromagnetics, in nanocrystalline films there exists an additional contribution due to the local variation of the magnetic uniaxial anisotropy. Notwithstanding its importance, so far only a very few studies have been reported in literature.

The variation of the local anisotropy causes a magnetic ripple structure that can be observed with the Lorentz electron microscopy (LTEM) [1]. The coupling volume and the angular spread \( \Delta \phi \times \Delta \theta \) of the magnetic ripples are obtained from an analysis of the wavelength and angular distributions of the LTEM image ripples, as based on a Fourier analysis of the image. This was done for films with different thickness, grain size and microstructure, as illustrated by Fig. 1. The effect of the ripples on the FMR width is analyzed using an approach based on the Landau-Lifshitz equation without the dissipative term. The local dispersions of the magnetization give rise to a resonance frequency of increasing surface to volume ratio as the grains get smaller. Note that the measured magnetizations and grain sizes are all consistent with a 1 nm thick shell. Importantly, we would expect a non-magnetic oxide shell of this thickness to be sufficient to break exchange coupling between the grains that yield very poor soft properties. This was observed in these samples, as their predicted coercivity due to magnetization ripple is much lower than what was observed.

References: