Nanostructure of multifunctional and ultra-thin FeCo/TiN (bilayer period Λ≈ 2.3 nm) multilayer thin films

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The multifunctionality of nanostructured multilayer coatings of FeCo/TiN[1] also facilitates potential applications as the magnetostrictive phase in magnetoelectric (ME) sensors for biomagnetic field imaging[2] due to their magnetic properties e.g. magnetostriction coefficient of FeCo (λ_S≈70 ppm)[3] and temperature stability. In order to reach detection limits down to pT/Hz during sensing of low frequency magnetic field signals[4], tailoring of the magnetic susceptibility and saturation magnetostriction are crucial parameters from the ferromagnetic material's point of view to achieve a large ME response. In fact, the magnetic susceptibility and anisotropy field can be adjusted by tuning the individual layer thickness[1,5] while the magnetostriction is determined by the interface quality between adjacent layers[6] putting an emphasis on the detailed characterization of structural properties, film stresses and layer roughness on the nanoscale.

Here, we focus on image (spherical aberration, C_S)-corrected high-resolution transmission electron microscopy (HRTEM) methods to study the individual structures. Multilayer thin films of about 1 m total thickness were deposited by non-reactive dual magnetron sputtering according to the explanations given by Klever[1], growing in a columnar growth mode. When decreasing the bilayer thickness Λ down from 5.2 nm to 2.3 nm, superstructure reflections appear in ED pattern indicating a well-defined ordering of the bilayers (Figure 1a), whereas for the thicker bilayer the loss in superstructure information is accompanied by more distorted columns giving rise to smearing of reflections (Figure 1b). The epitaxial relationship is identified by means of a structural model containing the CsCl-type crystal structure for FeCo[100] and NaCl-type crystal structure of TiN[110], respectively. Interestingly, our HRTEM analysis confirms the epitaxial model (see Figure 2) also for the Λ≈ 2.3 nm bilayer and disagrees with the picture of pseudo-epitaxial solid solution layers in a pseudo-fcc crystal structure mentioned before elsewhere[7]. However, the interface quality with respect to defects, strain and chemical homogeneity is of high interest and will be investigated with high resolution scanning TEM imaging in combination with energy dispersive X-Ray spectroscopy (EDX) and X-ray diffraction methods.

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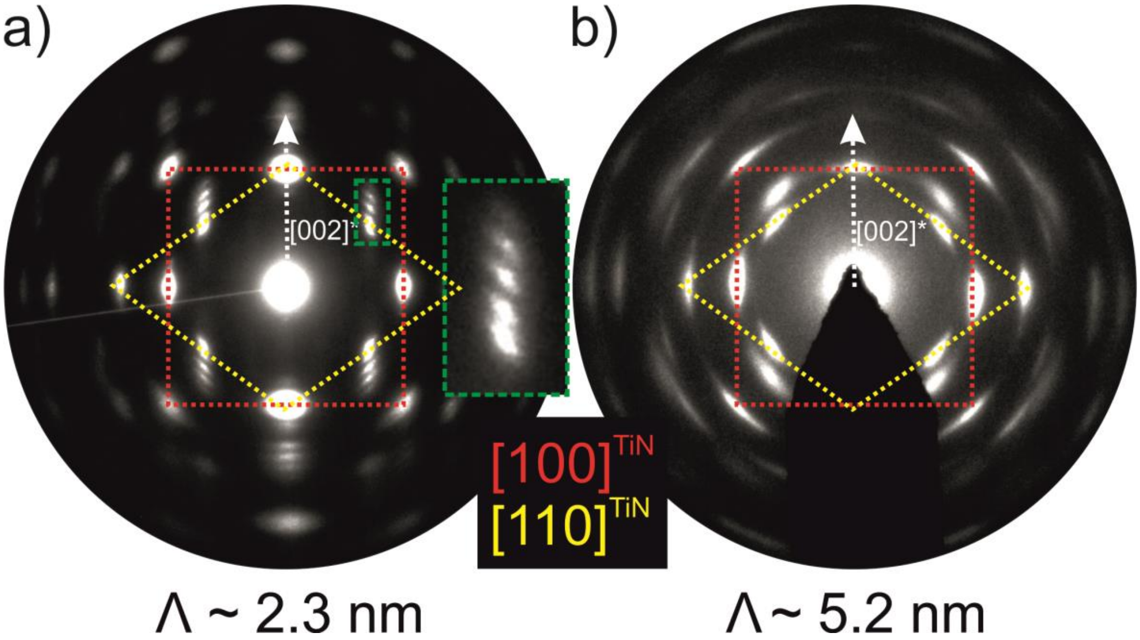

Figure 1: Selected area electron diffraction pattern of thin films with a bilayer period of a) Λ≈2.3 nm and b) Λ≈5.2 nm.

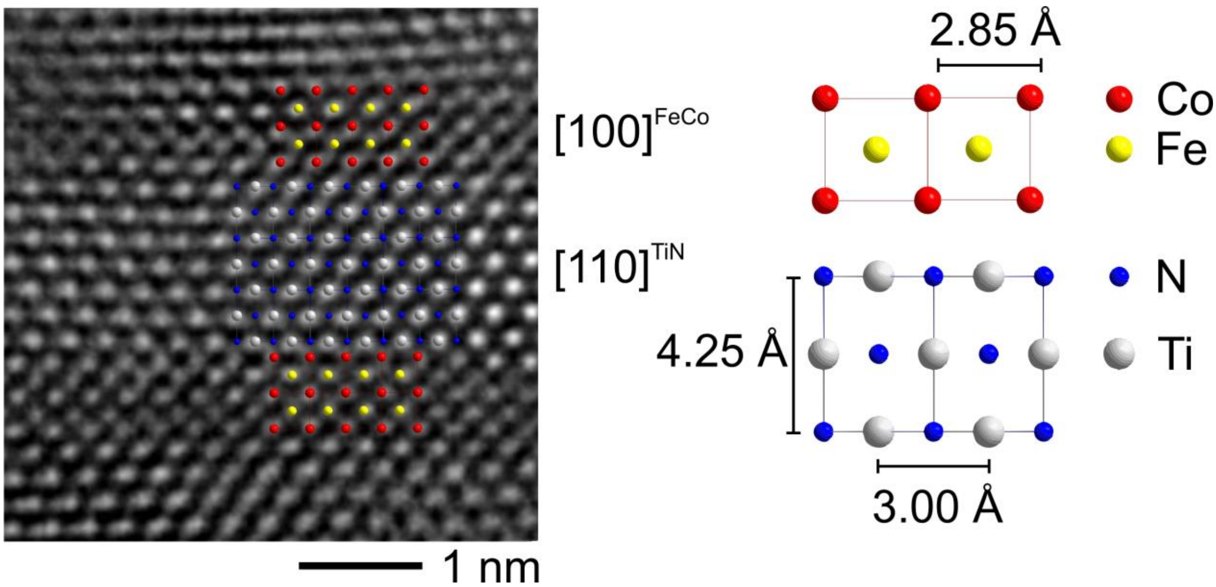

Figure 2: C_S-corrected HRTEM micrograph of a bilayer period of Λ≈2.3 nm and epitaxial model with a lattice mismatch of 5%.