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TEM-based analysis of the crystal structure of a Ge-rich layer sandwiched between spintronic Fe_3Si

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Introduction

The magnetic properties of Fe_3Si make it an excellent candidate for spintronic applications [1]. For a switchable device, two layers of Fe_3Si have to be separated by a thin semiconducting interlayer. Ge was chosen for this interlayer having a nominal thickness of 3 nm only. Sharp interfaces were ensured by solid phase epitaxy [2] which is a two-step approach comprising of layer deposition at 150 °C and re-crystallization at 300 °C. From bulk crystals Fm3m space group is expected for Fe_3Si and Fd3m for Ge [3].

Objectives

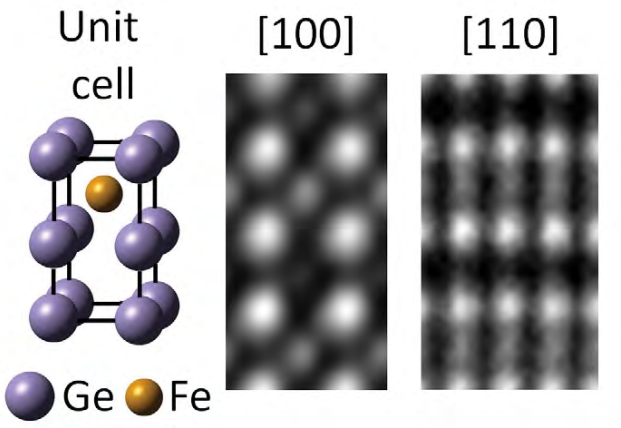
This work aims at both, crystal structure and composition analysis of the layer stack by transmission electron microscopy (TEM)-based techniques. In particular, nano-beam diffraction (NBD), high-angle annular dark-field atomic-resolution scanning TEM (HAADF ARSTEM) imaging and energy dispersive X-ray spectroscopy (EDXS) were applied for full crystallographic phase analysis.

Results

The generated crystallographic phase of Fe_3Si perfectly corresponds to both, the expected crystal structure and the chemical composition. In contrast to that, superstructure reflections along [001] are observed for the nominal Ge layer. This hints to an ordering along [001]. Moreover, EDXS revealed a composition ratio of about 6:3:1 for Ge:Fe:Si. Both results point to an unexpected crystallographic phase of the interlayer. For gaining real space information, HAADF ARSTEM imaging was performed along [100] and [110] direction (see Fig. 1, center and right image, correspondingly). Bright spots correspond to atomic columns. The brightness depends on the mean atomic number of the individual column. Both projections consistently reveal ordering along [001]. Brighter spots are dedicated to Ge and weaker spots to Fe columns. Filled interlayers exhibit a larger distance along [001] of z = 0.52 compared to z = 0.48 for the empty layers.

Conclusion

The semiconductor interlayer is composed of P4mm Ge_2Fe (see Fig. 1 left). The deviation of the position of the atomic columns from the ideal positions at 0.50 and 0.75 is most likely due to the relaxation of strain introduced by the ordering.



References:

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