Crystallization of CoFeB Electrodes in Magnetic Tunnel Junctions

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Motivation

The highest Tunnel Magneto Resistance (TMR) ratio so far reported for pseudo spin valves (P-SV) junctions reaches over 600% at room temperature.
For exchange bias spin valves (EB-SV) highest TMR is significantly lower and reaches about 360%.

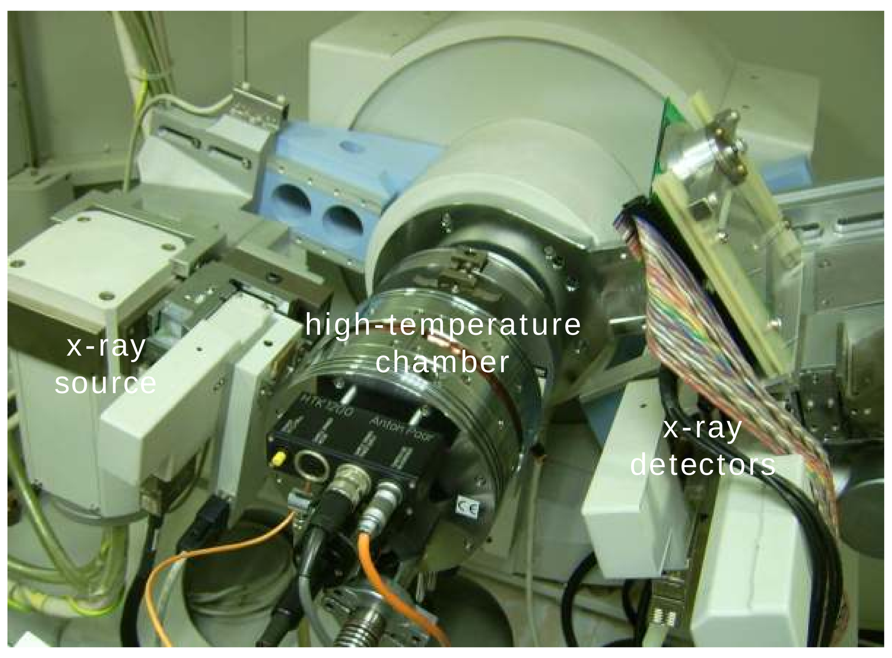
In this work we report on the crystallization asymmetry of top and bottom amorphous CoFeB electrodes in P-SV and EB-SV junctions.

Experiment

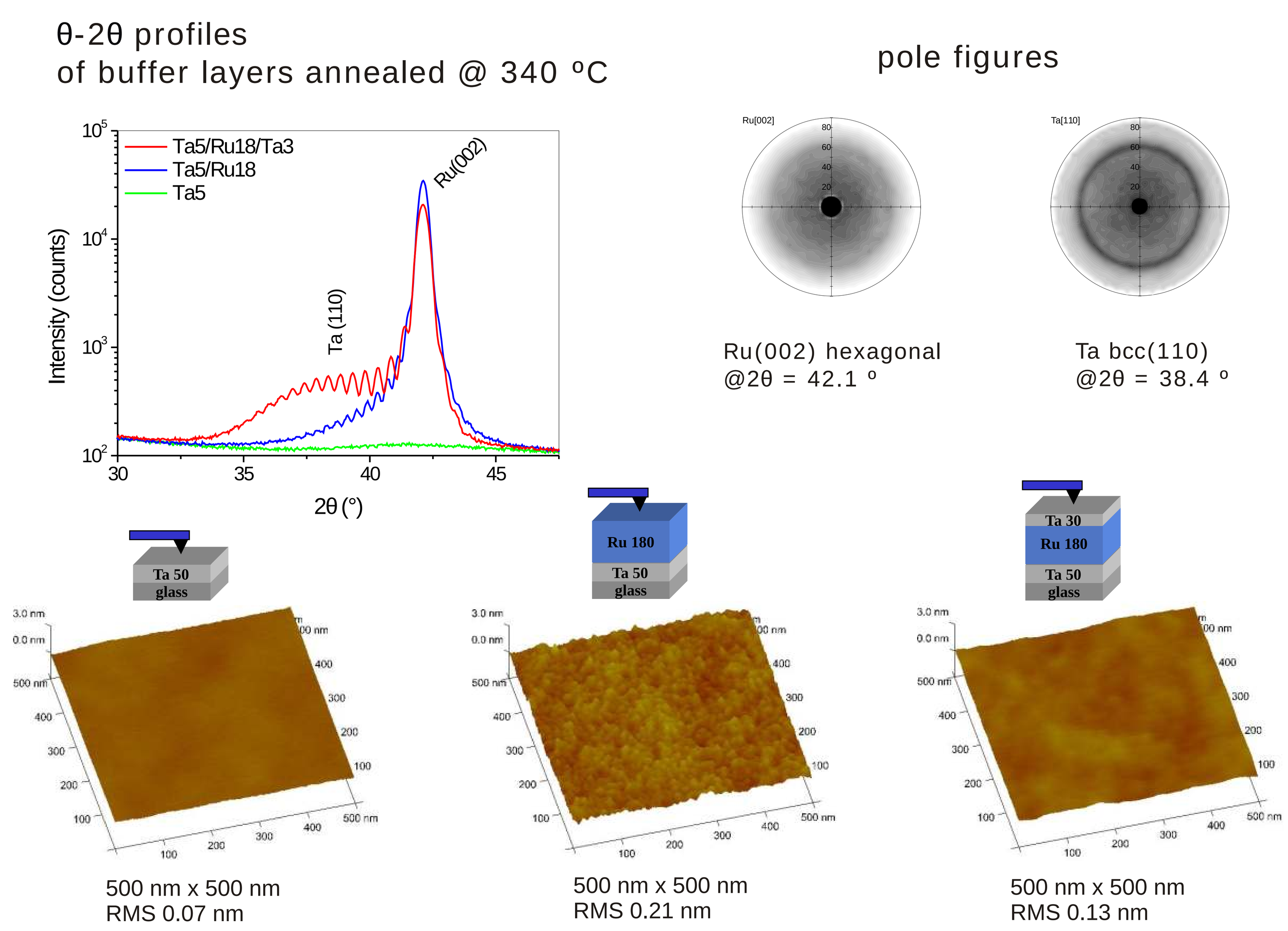
Samples were deposited by magnetron sputtering (Nordiko 2000 system).
The films were characterized by X-ray diffraction using X'PertMPD diffractometer with Cu-anode. Surface roughnesses were measured by AFM.
XRD θ-2θ high-temperature in-situ measurements were performed using Anton-Paar HTK-1200 chamber.

XRD high-temperature chamber

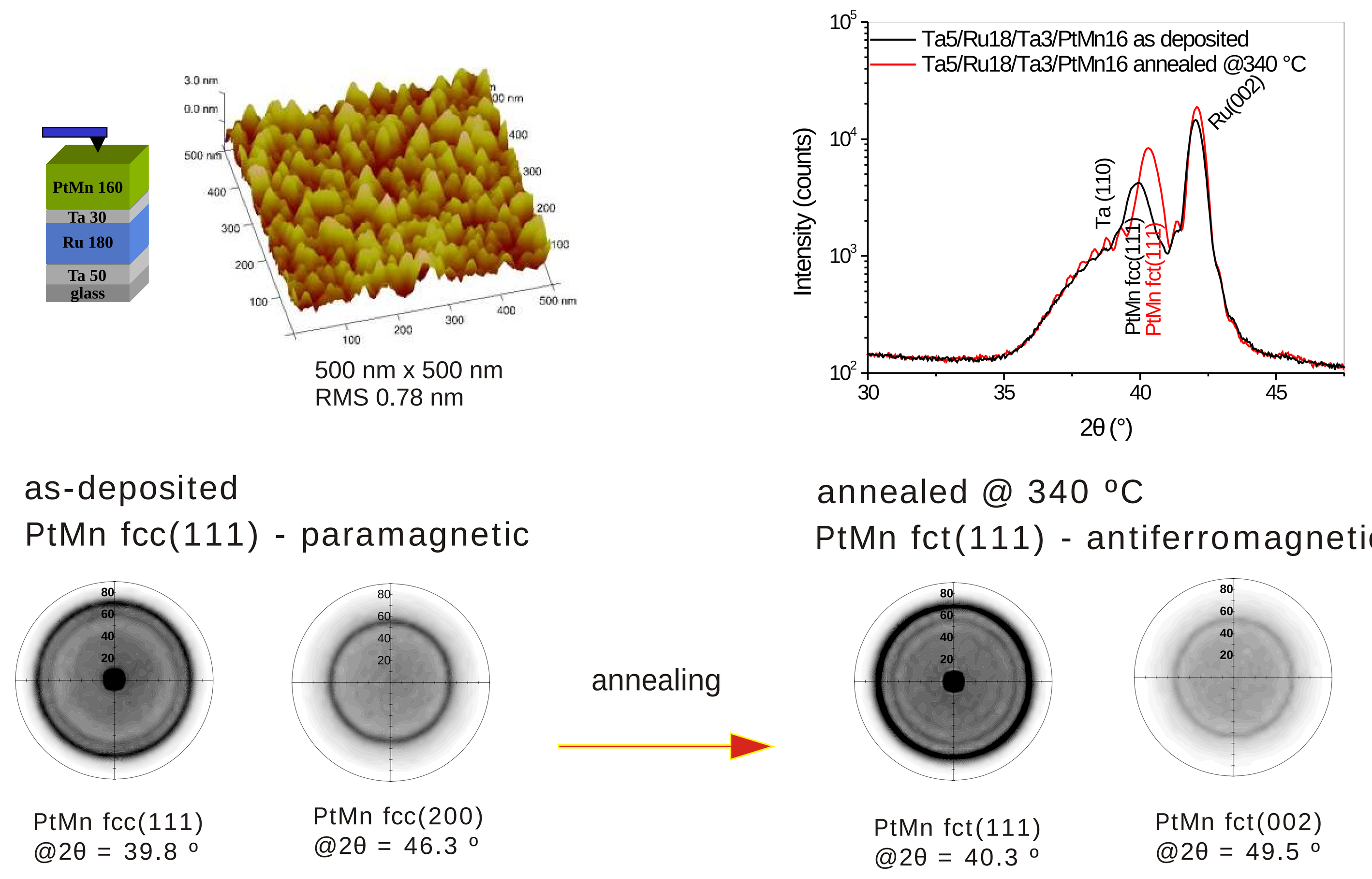
Anton-Paar HTK-1200



Buffer layers: texture vs.roughness

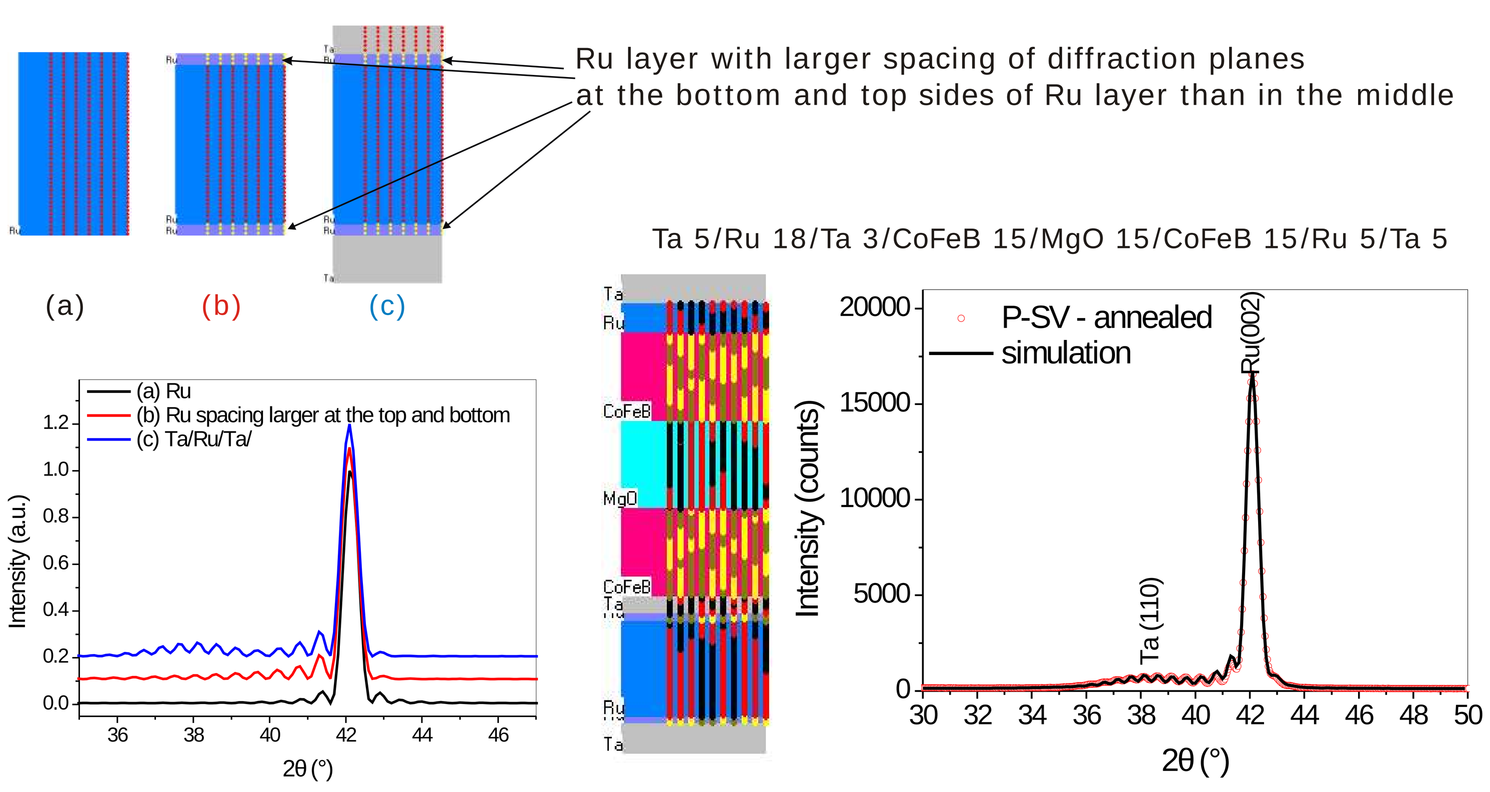


PtMn: texture vs.roughness

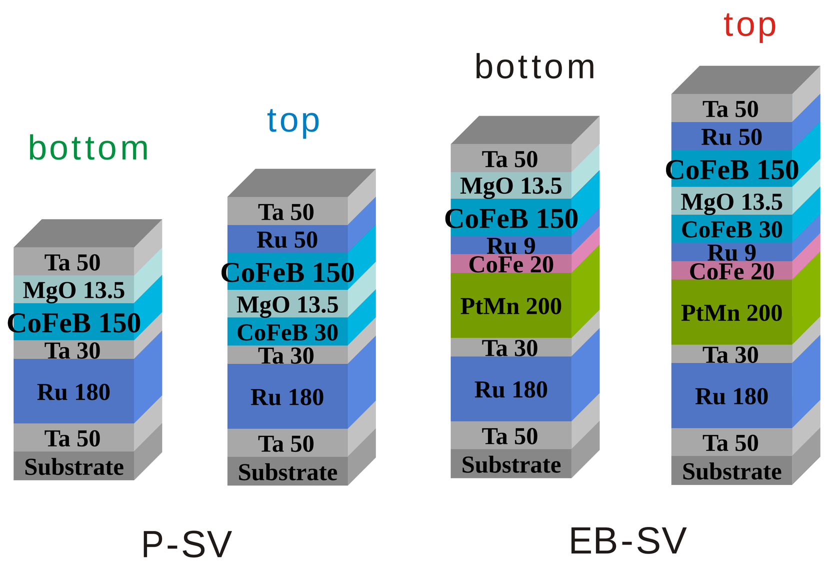


Simulation of θ-2θ profiles

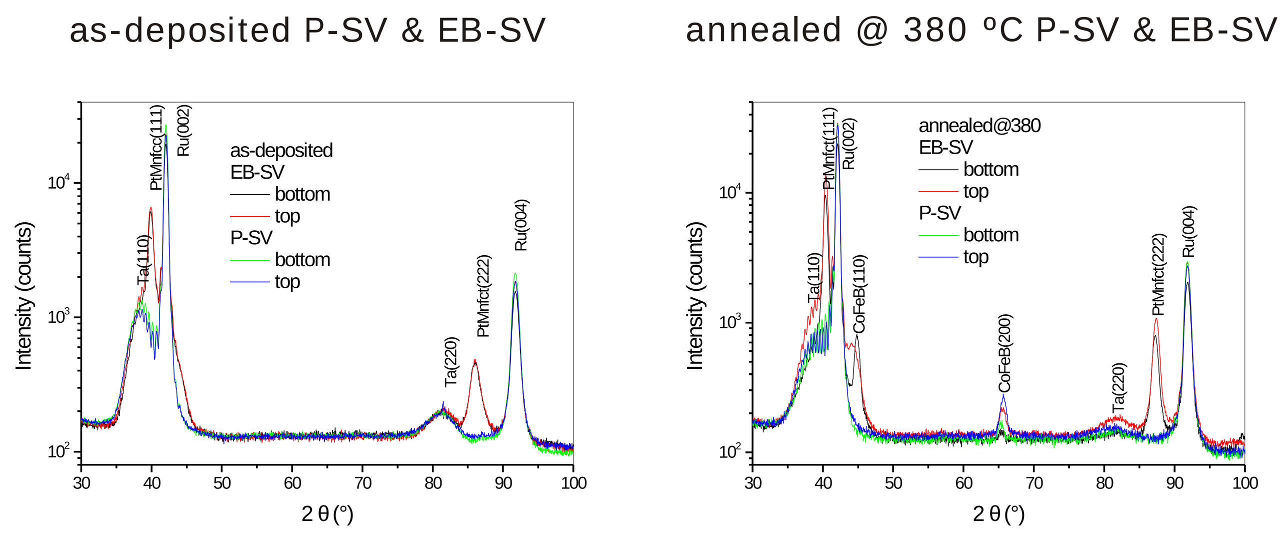
calculation from kinematical diffraction theory



Samples structure

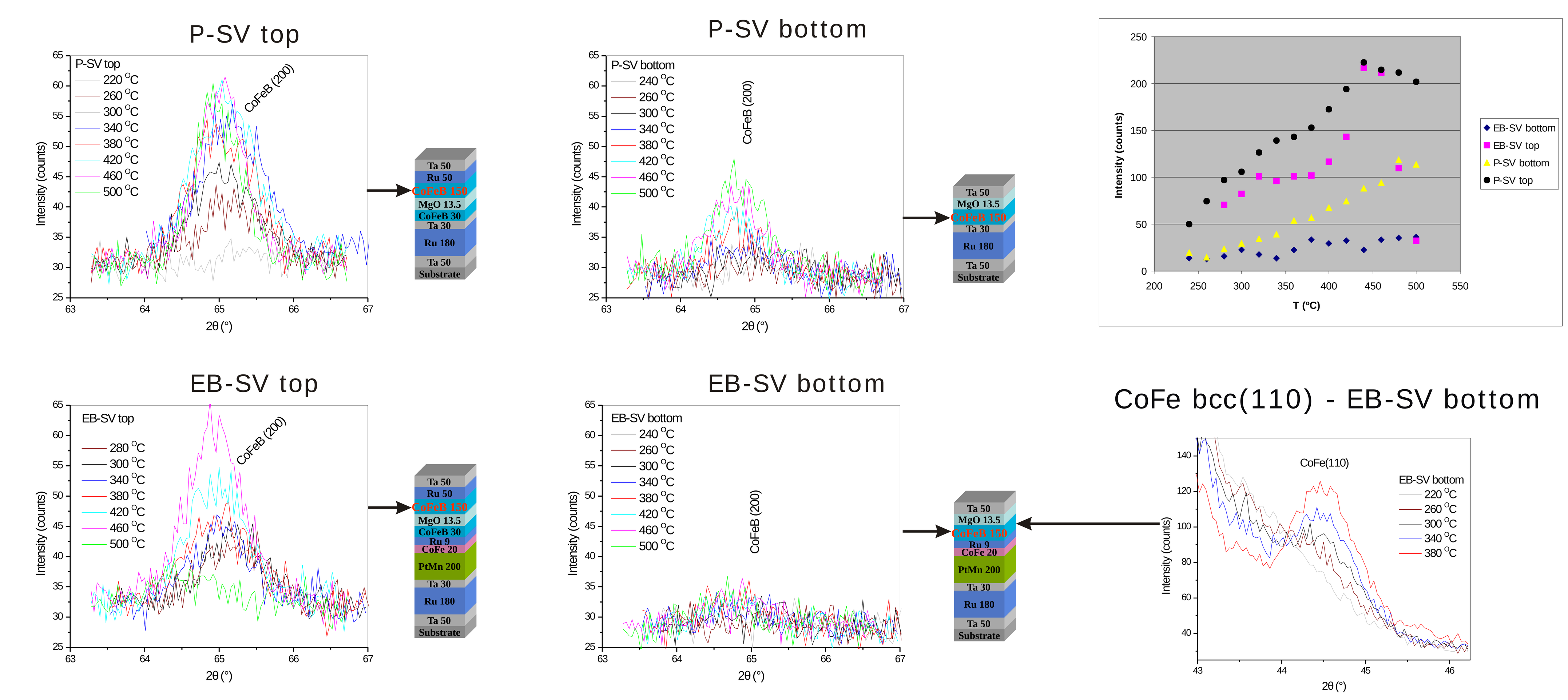


XRD θ-2θ

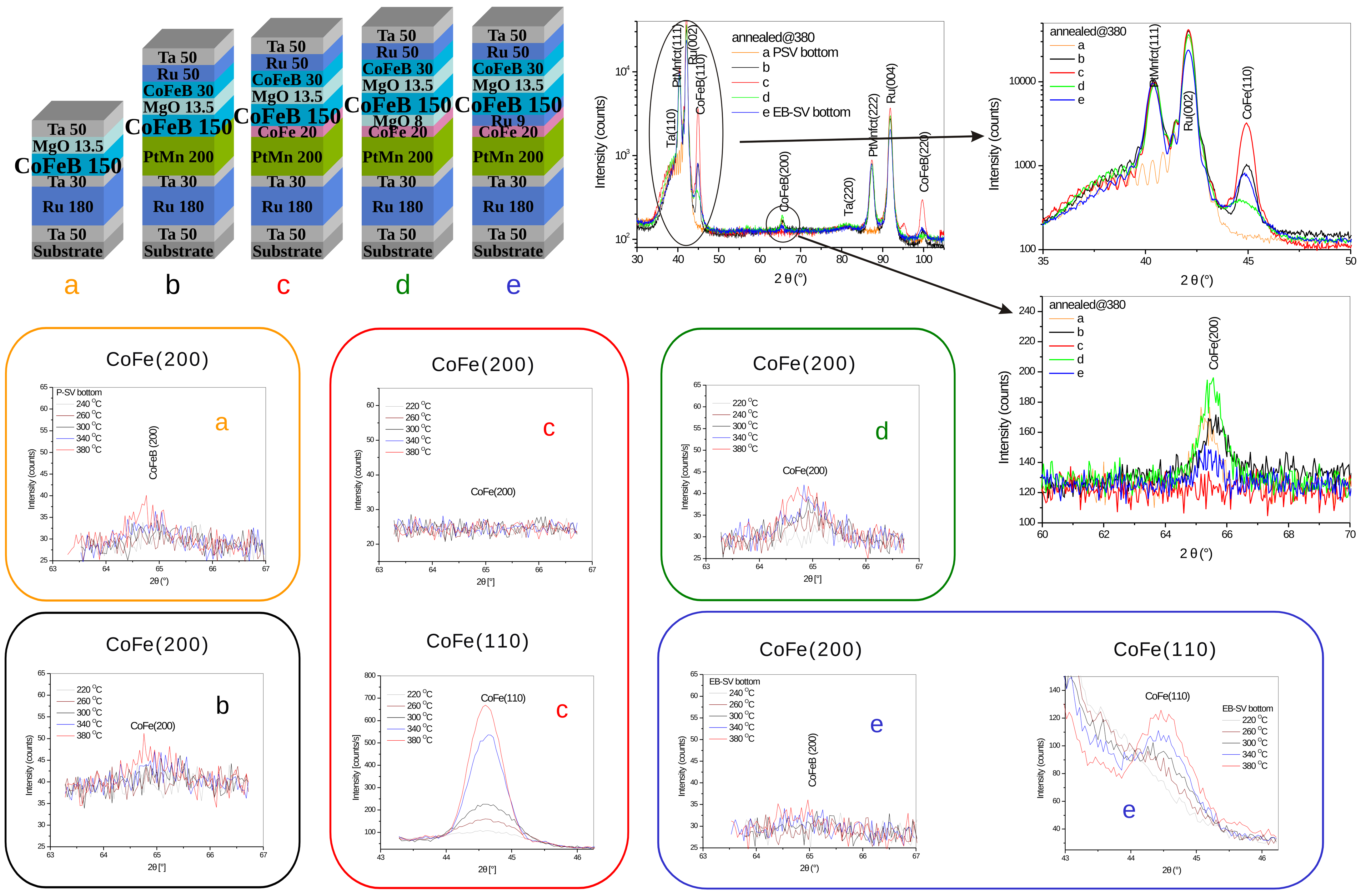


Crystallization asymmetry of CoFeB

high-temperature θ-2θ XRD measurements at position of CoFe(200)



The influence of underlayer on CoFeB crystallization



Conclusions

In the Ta/Ru/Ta buffer layer system the bottom Ta layer was amorphous, Ru was strongly textured in [002] direction and the top Ta layer was crystalline and smoothed the Ru layer. PtMn layer in EB-SV sample was strongly textured and transformed after annealing from paramagnetic fcc(111) to antiferromagnetic fct(111) phase. Textured growth of PtMn induced high roughness.

The amorphous CoFeB layers crystallized after annealing to bcc (200)- or (110)-oriented texture depending on material of underlayer. In both EB-SV and P-SV junctions crystallization of CoFeB in (200)-oriented texture was stronger for the top than for the bottom layer. The bottom CoFeB layer in P-SV crystallized better in (200)-oriented texture than in EB-SV.

It was found that CoFeB, deposited on thin 9 Å Ru underlayer, crystallized predominantly in direction [110] of bcc CoFe and weakly in [200]. The replacement of thin Ru layer by MgO 8Å gave rise to crystallization in (200)-oriented texture. Ta and PtMn as underlayer caused crystallization of CoFeB in (200)-oriented texture. CoFe as underlayer gave rise to crystallization of CoFeB in a highly (110)-oriented texture.

In conclusion we can say that the same crystallographic orientations of CoFeB electrodes and MgO (100) barrier in the case of P-SV junction is the reason for significantly higher TMR ratio of P-SV than of EB-SV.

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