Ultrathin MgO films on Fe(001): growth, morphology and implementation in magnetic tunnel junctions

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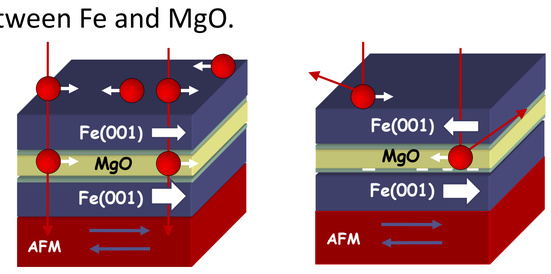
Motivation

Phenomena in the magnetic tunnel junctions:

❑**Tunneling Magnetoresistance (TMR)**
❑**Interlayer Exchange coupling (IEC)**

are directly dependent on the quality of the MgO tunnel barrier and the interfaces between Fe and MgO.

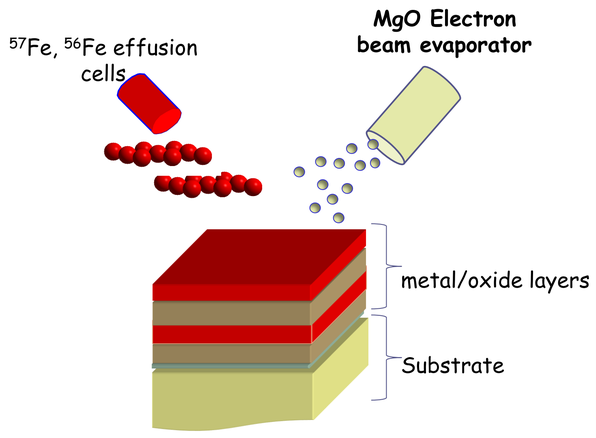


M. Mizuguchi et al. found that MgO barrieries thinner than 5ML were imperfect [1]. In the study of M. Klaua et. al. the monolayer of MgO was completed in the 3.8 ML film, showing nearly perfect layer- by layer growth of MgO onto Fe [2].

The aim of this study was to prepare and characterize ultrathin MgO layers on Fe(001) with the greatest attention paid on the continuity of MgO films.

Samples

❑UHV conditions, base pressure 10^{-10} mbar
❑Cleaved and polished MgO substrates
❑Molecular beam epitaxy

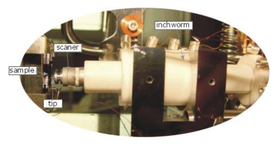


To enable MgO evaporation using EBV, MgO was encapsulated in tantalum foil.
In this setup, the foil is heated up by electrons and transfers the heat to MgO.

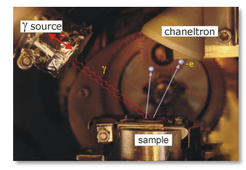
Experiment

Standard UHV sample characterisation methods: **Low Energy Electron Diffraction (LEED)** and **Auger Electron Spectroscopy (AES)** enabling growth investigation.
Additionaly:

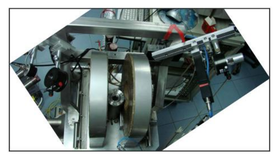
Scanning Tunneling Microscopy (STM)
❑ Morphology investigation
❑ Sensitive to electronic properties of the samples



Conversion Electron Mössbauer Spectroscopy (CEMS)
❑Probing of the hyperfine fields at the interfaces
❑Isotopic sensitivity (^{57}Fe)
❑Applicable to submonolayers and burried interfaces



Magneto-optic Kerr Effect (MOKE)
❑ Magnetic properites of the samples
❑ IEC investigation

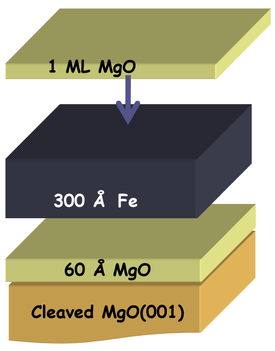


Results I: growth & morphology

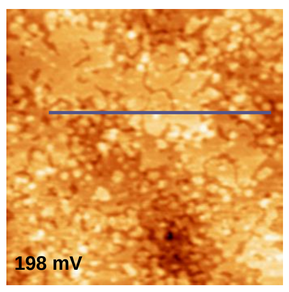
Does the morphology of Fe layer influence the quality of MgO deposited on it?

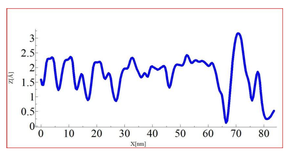
STM measurements were performed for different Fe layer preparation methods.
All MgO films were deposited at RT.

Fe: high deposition temp. (400 °C), No annealing

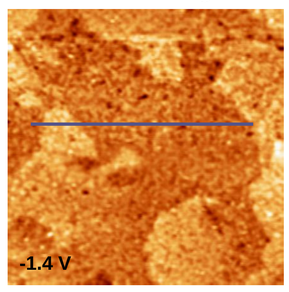


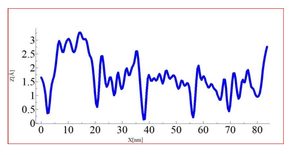
Fe surface



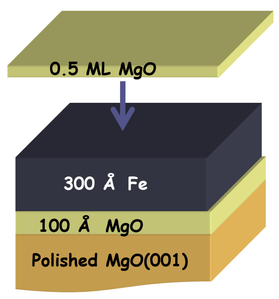


plus **1 ML** MgO

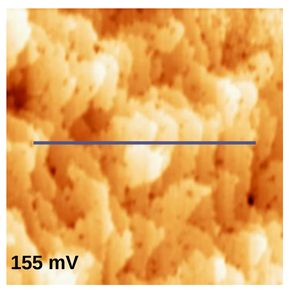


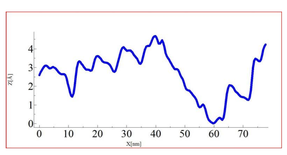


Fe: RT deposition, high annealing temp. (450 °C)

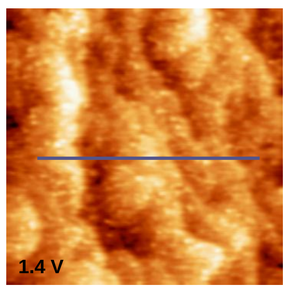


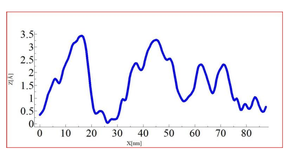
Fe surface



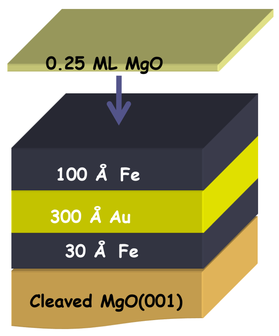


plus **0.5 ML** MgO

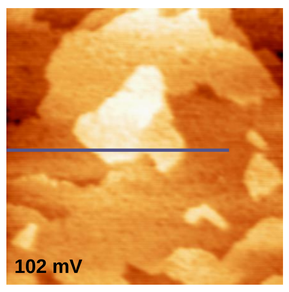


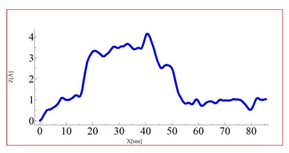


Fe: RT deposition onto Au buffer, high annealing temp. (450 °C)

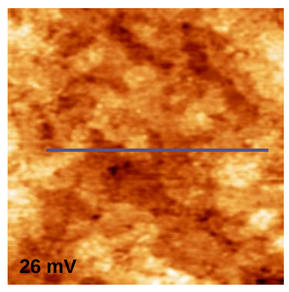


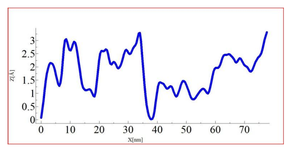
Fe surface





plus **0.25 ML** MgO



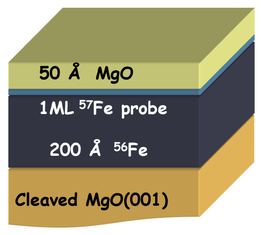


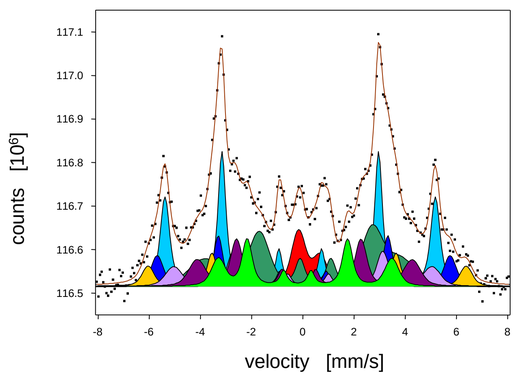
MgO as thin as 0.5 ML (~1 Å) seems to create a continous oxide layer.

All the showed STM scans are 100x100 nm.

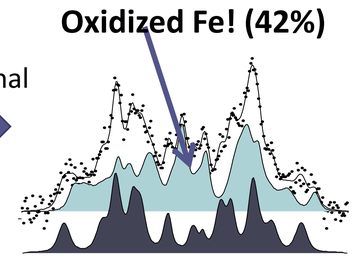
Is FeO layer formed when MgO is deposited on Fe?

CEMS measurement shows the chemical state of ^{57}Fe atoms located at the MgO/Fe interface





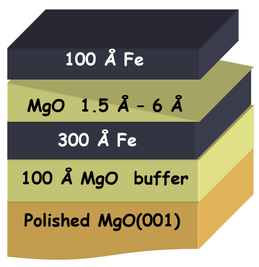
Minus bulk signal

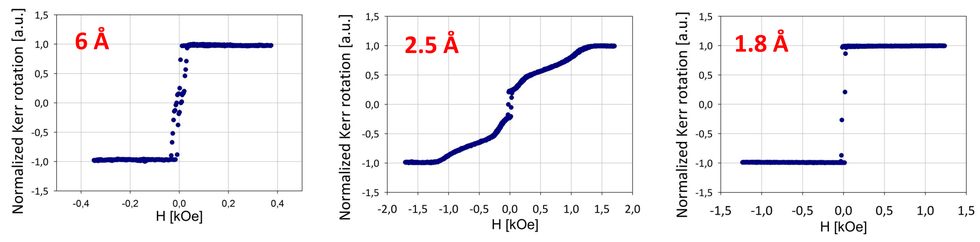


Fe oxide formation at the interface

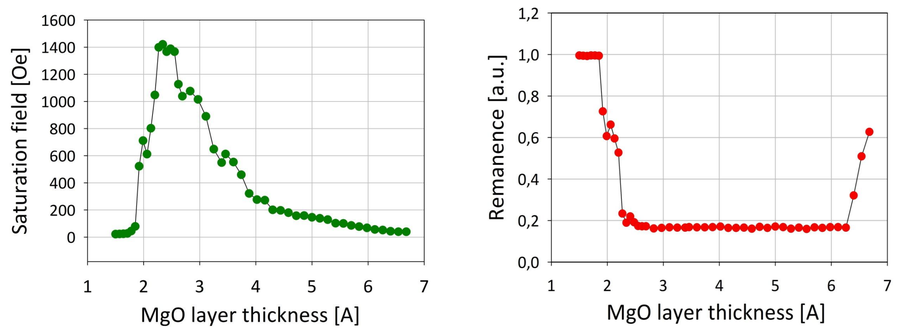
Results II: magnetism

IEC measurements for a wedged sample using MOKE :





Remanence and saturation fields derived from MOKE loops:



Antiferromagnetic coupling exists for two Fe layers separated by MgO barrier as thin as 2 Å.

Conclusions

❑Morphology of Fe layer does not influence directly the quality of MgO barrier.
❑Judging on STM, MgO as thin as 0.5 ML seems to create a continous oxide barrier.
❑CEMS measurements proves that almost 0.5 ML of Fe at the interface is oxidized in the form of FeO, which is consistent with previous studies [3].
❑IEC investigation using MOKE shows that 2 Å (1ML) MgO film creates a continous oxide barrier. Based on STM and CEMS results we can conclude that the continous oxide layer is composed of both MgO and FeO.

1. M. Mizaguchi et al., Appl. Phys. Lett. 88, 251901 (2006), 2. M. Klaua et al., PRB vol. 64 134411 (2001),
3. H. L. Meyerheim et al., PRB vol 65 144433 (2001), 4. I. Horcas et al, Rev. Sci. Instrum. 78, 013705 (2007)

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