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Dynamic of Defects in an Iron Monolayer on W (110)

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1. Introduction

Structural and dynamical properties of an iron monolayer on a W(110) substrate have been investigated with nuclear resonance scattering (NRS) in grazing incidence geometry. This method combines the high brilliance of a third generation synchrotron source and the excellent characteristics of Mössbauer Spectroscopy and is best suited to study structural and magnetic properties of materials as well as dynamics on an atomistic scale.

An iron monolayer is pseudomorphic with the W(110) substrate and shows exceptional thermodynamic stability up to 1100 K, as known from Auger Electron Spectroscopy (AES) [1]. Therefore high temperature investigations are possible.

Due to broken symmetry at the surface of an iron monolayer, an electric field gradient (EFG) exists and is large enough to follow its changes upon appearance of defects like vacancies or adatoms in the neighbourhood of Fe atoms. The extreme sensitivity of the EFG in an Fe monolayer to the coordination of the neighbour shells has been recently confirmed experimentally [2]. This feature has been also applied in the theory of diffusion in a two-dimensional system (surface) that has been recently elaborated [3]. The theory is based on the fact that diffusing atoms cause fluctuations in the nearest-neighbour shell of the Mössbauer nuclei involving relaxations of electric field gradient.

2. Experimental

The experiment was carried out at the nuclear resonance beamline ID18 at the European Synchrotron Radiation Facility using a recently constructed multifunctional ultra high-vacuum (UHV) system [4]. A monolayer of ^{57}Fe (nominal thickness 1.66 Å) was prepared by molecular beam epitaxy at a pressure below 10^{-10} mbar. A (1 × 1) LEED pattern registered after deposition confirmed a pseudomorphic growth of the monolayer.

For nuclear resonance scattering of X-rays we used monochromized synchrotron radiation to an energy bandwith of 0.75 meV at 14.413 keV and vertically focused to 7 μm. All spectra shown in Figure 1 were taken in grazing incidence geometry at the angle of 4.7 mrad. The spectrum registered at room temperature shows an exponential decay with only very small deviations being thus a proof for a practically undisturbed surface. At 570 K a beat pattern appears and becomes more distinct with increasing temperature suggesting the presence of defects. The process is reversible: lowering the temperature causes disappearance of beats.

Our tentative interpretation of the thermically activated, reversible process, that we observed in the spectra, is creation and movement of vacancies. Analysis of the spectra within a theory of electric field gradient relaxations upon Fe atoms diffusion via a vacancy mechanism [3] allowed us to derive vacancy concentration and atomic jump rates. From the temperature dependence we estimated the vacancy formation and migration energies.

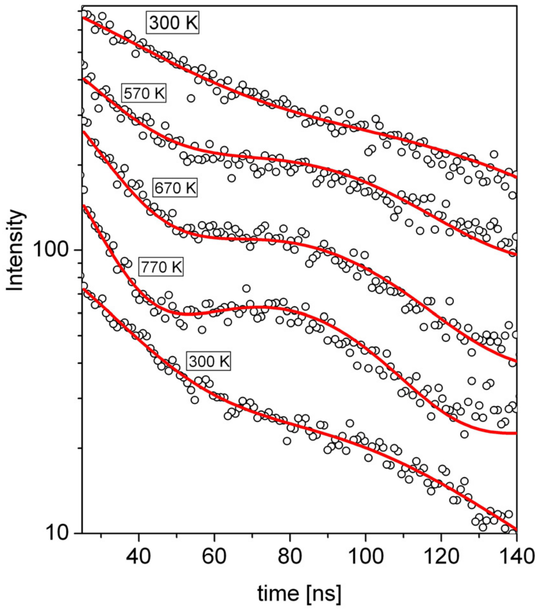

Fig. 1: The NRS time spectra of the Fe monolayer on W(110) registered at temperatures 300, 570, 670, 700, 300 K. For clarity, the spectra are shifted relatively to each other.

3. Conclusion

Nuclear resonant studies of an iron monolayer at elevated temperatures permitted to follow the relaxation of the electric field gradient upon creation of defects and their movements. The temperature dependence of vacancy concentration as well as the vacancy jump rate in an iron monolayer have been obtained.

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References

[1] P. J. Berlowitz, J.-W. He and D. W. Goodman, Surf. Sci. 231 (1990) 315.
[2] E. Partyka-Jankowska et al., Surf. Sci. 602 (2008) 1453-1457.
[3] G. Vogl, M. Sladecek, S. Dattagupta, Phys. Rev. Lett. 99 (2007) 155902.
[4] S. Stankov et al., Rev. Sci. Instrum. 79 (2008) 045108.