Publ. Astron. Obs. Belgrade No. 84 (2008), 197 - 200 *Contributed Paper*

SURFACE TEXTURE PARAMETERS IN OPTIMIZING MAGNETIC FORCE IMAGES

M. NENADOVIĆ[1], S. ŠTRBAC[2], Z. RAKOČEVIĆ[1]
[1]*INS Vinča, Laboratory for Atomic Physics, P.O.B. 522, 11001 Belgrade, Serbia*
[2]*ICTM-Institute of Electrochemistry, University of Belgrade, P.O.B. 815, 11001, Belgrade, Serbia*

Abstract. In this work, the optimizing conditions necessary for magnetic field gradient imaging using Atomic Force Microscopy (AFM) and Magnetic Force Microscopy (MFM) in a lift mode have been established. 55 nm thick Co thin film deposited on monocrystalline silicon substrate was used as a sample. The lift height dependence of various surface texture parameters: R_{sk} - the skewness, and R_{ku}- the kurtosis, have been determined. The results have shown that the influence of the substrate and its texture on the magnetic field gradient can be neglected for the lift height above 40 nm, and that the upper lift height limit corresponding to the height where magnetic field lines follow the shape of the field is 100 nm.

1. INTRODUCTION

Various parameters used to determine the real surface can be considered depending on the surface physical properties investigated for specific purpose (Dong et al. 2004). Real surface parameters involve: 3D Surface Texture Parameters, Stylus X and Stylus Y Surface Texture Parameters, S Parameters and Wear Surface Texture Parameters (Cohen 2002, *** 2007). Using a commercial Atomic Force Microscopy (AFM) has emphasized the importance of 3D surface topography and an advent of measurement and characterization of surface topography and magnetic field in three dimensions.

Magnetic images are very complex to define and we used an analogy with a surface 3D topography to obtain reproducible results in this field. Surface parameters used to define magnetic images have to be limited to statistic parameters only where z-axis represents the change in the cantilever oscillation phase due to the magnetic forces between the tip and the sample. Also, some preliminary physical conditions defined by the nature of the measured magnetic field have to be taken into account.

Ferromagnetic materials, bulk and thin solid films, all have magnetic domains whose spatial and surface distribution gives a magnetic field of a material with a given dimensions to be minimal, tending to zero in the case when there is no external magnetic field applied (Hubert and Schafer 2000). This suggests that the image of 3D magnetic field topography should have a Gaussian distribution without a pronounced high peaks and deep valleys. It should be symmetrical with no anomalies in surface height distribution. Taking into account these considerations it can be concluded that kurtosis parameter should have value of $S_{ku}=3$, while skewness parameter should be $S_{sk}=0$.

Magnetic Force imaging is a secondary imaging mode derived from TappingMode AFM that maps the magnetic field gradient on the sample surface. For magnetic imaging mode of an AFM for each scan line, two successive scans were performed. The topography was acquired in the main scan by standard tapping mode AFM, while for MFM imaging, the tip is subsequently retraced in lift mode at a certain tip-sample distance (lift height). Changing the lift height it is possible to follow the changes in the magnetic field, i.e. to acquire the magnetic field gradient. Accordingly, the chosen lift height affects the quality of MFM images, what was the aim of these investigations.

2. EXPERIMENTAL PROCEDURE

Co thin films on Si (100) substrate were prepared by e-beam evaporation at the TESLA facility (Bibic et al. 2002). The substrates were cleaned by means of standard procedure, rinsed in diluted HF and in deionized H_2O. Prior to deposition they were sputter-cleaned with a high-intensity 1,5 keV Ar ion beam. The pressure in the chamber during deposition was maintained 1×10^{-6} mbar, and the Co deposition rate at 0,5 nm/s. The IONAS implanter was used for ion irradiation. A sample area of 1×1 cm^2 was implanted homogeneously at a beam current of 2,5 μA/cm^2. The Co/Si layers were irradiated to (5, 10, 15) $\times$ 10^{15} ions/cm^2 with 250 keV Xe at 550 °C.

The imaging of the topography and magnetic domains was performed with scanning probe microscopy (SPM) Quadrex Multimode IIIe (Veeco Instruments), operated under ambient conditions. The topography was acquired in the main scan by standard tapping mode AFM using MESP tip. For MFM measurements, the tip is subsequently retraced in lift mode using lift height values of: 10, 20, 40, 60, 80, 100, 150, 200, 300, 400 and 1000 nm, with the aim to establish the optimum lift height range for the best image quality. The surface roughness average, the skewness and kurtosis were estimated in the dependence of the lift height, using the subprogram packages of the SPM.

3. RESULTS AND DISCUSSION

Characteristic AFM/MFM images of thin solid Co films are shown in Fig. 1. The image on the left side represents the topography of the surface and it was the same for all measurements for a given place on the surface. The image on the right side represents the magnetic field gradient which varied depending on the lift height. White areas on the image represent the repulsive forces between the tip and the sample, while dark areas represent the attractive forces.

From the estimation of kurtosis and skewness parameters we tried to find out an optimal range for the lift height. On Figure 2, the kurtosis vs. lift height is shown. In the range of the statistical error of measurements it can be seen from Fig. 2 that the symmetrical distribution of the magnetic field is obtained for images acquired for the lift heights ranging from 40 to 300 nm. A huge asymmetry obtained for the lift heights from 10 to 40 nm can be explained by the influence of the sample being close to the tip for MFM measurements (Naves and Andrade 1999). For lift heights set at

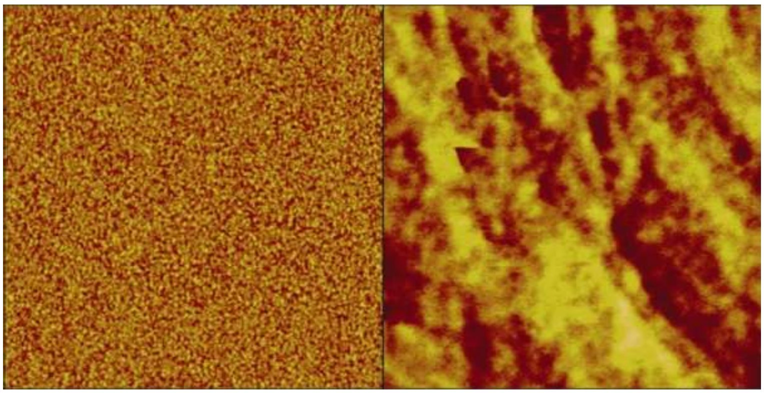
a)  b)

Figure 1: SPM images ($5\mu \times 5\mu$) of 55 nm thick Co thin film: a) AFM image of surface topography; b) MFM image of the same area for the lift height of 60 nm.

300 nm and above, MFM images are in the domain of the noise and their adequate interpretation is not possible.

In order to discuss the anomalies of MFM images, the dependence of the skewness parameter as a function of the lift height is presented in Fig. 3. In the range of statistical error, the value of the skewness parameter of S_{sk}=0, have MFM images acquired for the lift heights from 40 to 100 nm. In the range from 100 to 300 nm, the anomalies of MFM images are found which could be a consequence of the decrease in the magnetic field intensity and consequently its equalization.

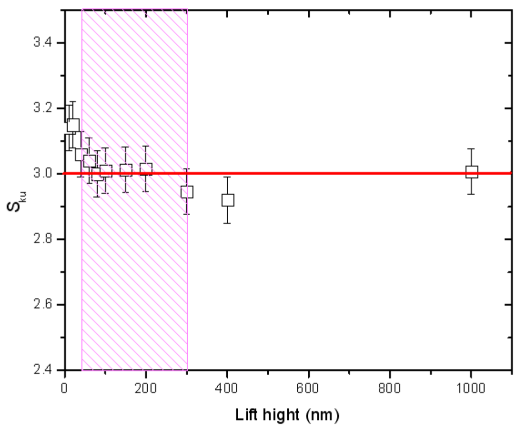


Figure 2: Kurtosis as a function of the lift height.

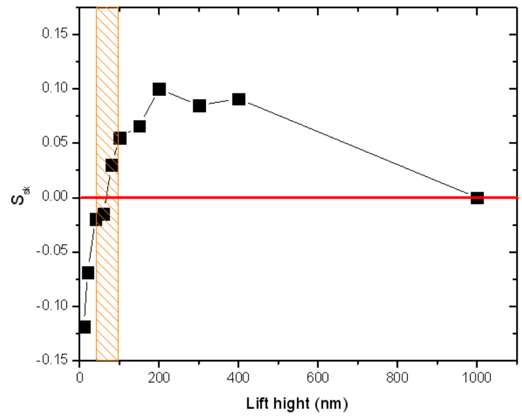


Figure 3: Skewness as a function of the lift height.

4. CONCLUSION

The obtained results have shown that surface texture analysis is very complex. There are many parameters which need to be involved. We have got values for R_{sk} and R_{ku} as a function of the lift height. The optimal ranges are estimated for each measurement.

References

***: 2007, Metro Pro Surface Texture Parameters, Zygo Corporation.

Bibic, N., Dhar, S., Lieb, K. P., Milosavljevic, M., Schaaf, P., Huang, Y.-L., Seibt, M., Homewood, K. P., McKinty, C.: 2002, *Surface and Coatings Technology*, **158**, 198.

Cohen, D. K.: 2002, Glossary of Surface Texture Parameters, Michigan Metrology, LLC.

Dong, W. P., Sullivan, P. J., Stout, K. J.: 1994, *Wear*, **178**, 29.

Hubert, A., Schafer, R.: 2000, Magnetic domains: the analysis of magnetic microstructures, Springer-Verlog Berlin Heidelberg New York.

Naves, B. R. A. and Andrade, M. S.: 1999, *Appl. Phys. Lett.*, **74**, 2090.