Oblique angle deposition of nickel thin films by high power impulse magnetron sputtering

H. Hajihoseini [1], M. Kateb [1], S. Ingvarsson [1], J. T. Gudmundsson [1,2]

[1] Science Institute, University of Iceland, Dunhaga 3, IS-107 Reykjavik, Iceland; hah107@hi.is (H.H.)
[2] Department of Space and Plasma Physics, School of Electrical Engineering and Computer Science, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden.

Introduction

HiPIMS operation is characterized by a pulsed high peak power in the range of several kW/cm^2 and consequently a high plasma density of up to 10^{19} m^{-3} in the cathode target vicinity, which is up to three order of magnitude higher than in dcMS [1].

Oblique deposition, sometimes referred to as glancing angle deposition (GLAD), is known as a PVD technique which leads to a film texture with low density and columnar grain growth which is elongated in the direction of the incoming flux [2].

By employing an ionized deposition flux in the GLAD, the angular distribution of deposited material can be influenced [3].

We studied the microstructure and magnetic properties of Ni films deposited by dcMS and HiPIMS under varying tilt angles.

Experimental findings

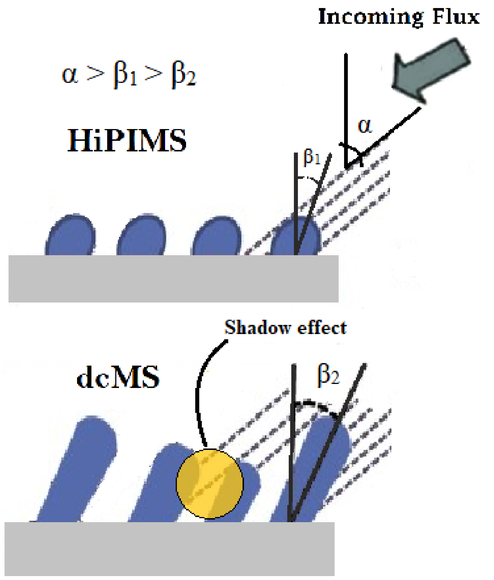

Figure 1: The schematic of oblique angle deposition using HiPIMS and dcMS methods and its effect on the microstructure of deposited film.

Deposition setup

We have deposited 50 nm thick Ni films under various tilt angle ranging from 0° to 70°.

All the films are deposited at working pressure of 0.6 Pa and average power of 150 W using HiPIMS and dcMS methods.

Silicon substrate used for deposition and the substrate holder was grounded during the growth.

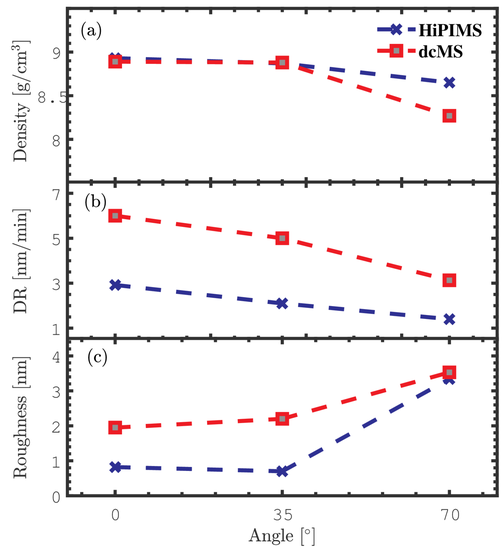

Figure 2: (a) Film density, (b) deposition rate, and (c) surface roughness of nickel films deposited by HiPIMS and dcMS. The data was extracted from XRR measurements. All films are deposited at 0.6 Pa working pressure, 150 W average power. In the HiPIMS case we used a pulse length of 200 μs and a repetition frequency of 100 Hz.

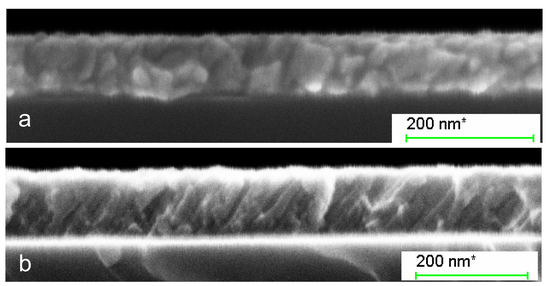

Figure 3: Cross sectional SEM image of the nickel films which are deposited by (a) HiPIMS, and (b) dcMS methods at 70° substrate tilt angle, at 0.6 Pa, and 150 W power.

Thin film structure

The HiPIMS deposition leads to denser film, with smoother surface and 50% lower deposition rate.

The obliquely deposited HiPIMS film are significantly more uniform (around 40%) in terms of thickness.

Figure 4 shows the dcMS deposited film exhibits inclined columnar growth with column length extending through the entire film thickness. In contrast, the HiPIMS deposited film shows grains that are smaller than the film thickness.

The inclined grain growth is more pronounced in dcMS deposited film.

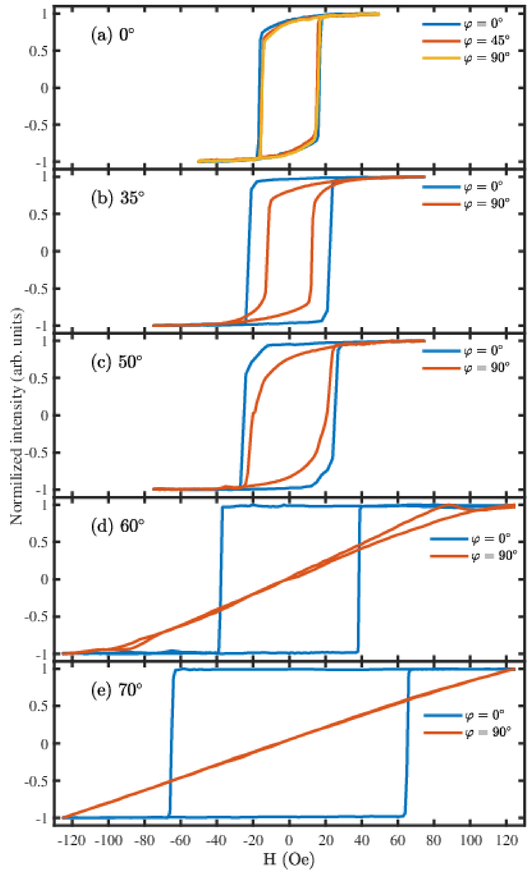

Figure 4: MOKE loops of nickel films which are deposited by HiPIMS, at various tilt angles ranging from 0° to 70°, at 0.6 Pa working pressure, and 150 W average power. Each figure shows the in-plane angle of the applied magnetic field with respect to the incoming flux direction.

Magnetic properties

Both deposition methods result in in-plane isotropic magnetic behavior at small tilt angles while larger tilt angles result in uniaxial magnetic anisotropy.

The easy axis of uniaxial anisotropy is aligned with the direction of depositing flux.

The transition to uniaxial anisotropy accrues at around 35° for the dcMS and around 60° for the HiPIMS deposition.

The difference in transition tilt angle is because of more inclined columnar growth in dcMS deposition.

The HiPIMS deposited films are magnetically softer than dcMS deposited films for otherwise same deposition conditions.

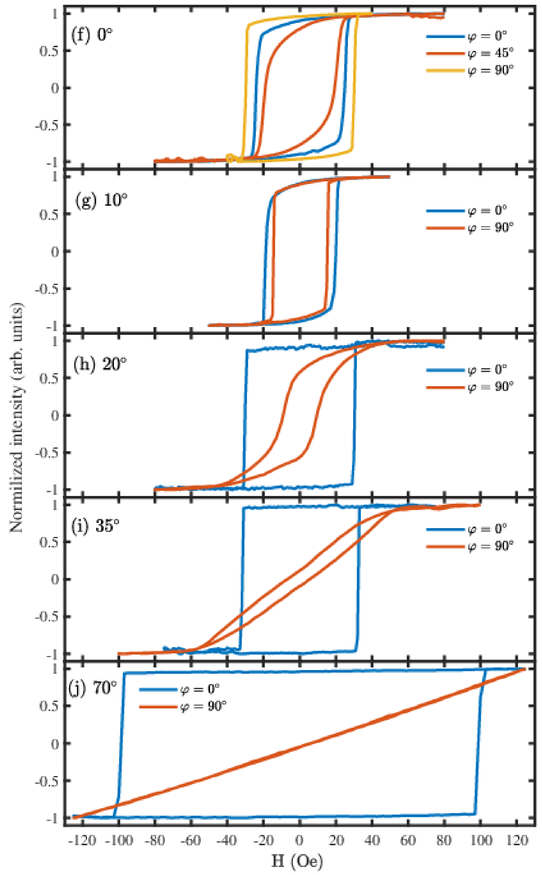

Figure 5: MOKE loops of nickel films which are deposited by dcMS, at various tilt angles ranging from 0° to 70°, at 0.6 Pa working pressure, and 150 W average power. Each figure shows the in-plane angle of the applied magnetic field with respect to the incoming flux direction.

Conclusions

- The HiPIMS oblique deposited Ni films exhibit better quality in terms of density, surface roughens and thickness uniformity than corresponding dcMS deposited films.
- The HiPIMS process can suppress the inclined columnar growth induced by oblique angle deposition.
- The HiPIMS deposited Ni films are magnetically softer then dcMS ones due to smaller grain size.
- HiPIMS is a promising deposition method for coating on objects with complex geometries.

[1] J. T. Gudmundsson et al. J. Vac. Sci. Technol. A, **30** (2012) 030801.
[2] M. Hawkeye et al. J. Vac. Sci. Technol. A, **25** (2007) 1317-1335.
[3] S. M. Rossnagel, J. Vac. Sci. Technol B, **16** (1998) 2585-2608.