Surface processes of energetic metal ions on HiPIMS target materials

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Abstract: The maintenance of glow discharges sensitively depends on secondary electron emission of surfaces. Ion-induced secondary electron emission coefficients for metal ions interacting with metal surfaces are measured in a particle-beam experiment. The coefficients are calculated by comparing the emitted electron current to the total ion current impinging on the targets.

Keywords: particle beam experiment, ion-induced secondary electron emission, HiPIMS.

1. Introduction

In glow discharges the generation of secondary electrons play an important role for the ignition and maintenance of the plasma. The impinging of primary plasma particles such as ions, electrons, photons and metastables on surfaces cause emission of secondary electrons. The secondary electron emission coefficient γ (SEEC) depends on the chemical state of the surfaces and is defined as ratio between secondary electron current and incident ion current. In high power impulse magnetron sputtering (HiPIMS) plasmas the bombardment of the metal target with plasma ions and self-sputtered metal ions is crucial for the discharge regime. The different discharge modes (metallic and reactive mode) sensitively depend on the target surface processes [1]. Here, knowledge about the interaction of metal ions with metal surfaces is important. Metal ions with different mass and charge effect and contribute to the secondary electron yield. For separately analysing the influence of different metal ions and oxides to the target a particle beam reactor with a metal ion beam source is applied and the γ-coefficients measured. The γ-coefficients of some metals were already published in literature and measured by different techniques [2,3,4]. The applied techniques though were rather indirect as they measured the SEEC directly in the plasma. Moreover, energy dependence is missing. However, the here presented experiment enables the determination of SEECs of metal ions and their oxides with energy dependence (20-20keV).

2. Experimental

The study of ion-induced secondary electron emission coefficients (SEEC) is performed in an ultra-high vacuum (UHV) particle beam reactor (base pressure 10^{-5} Pa) (Fig. 1). Metal ions and molecules are generated in an ion beam source. The source is based on an inductively coupled plasma (ICP) discharge which is fed with argon and operated with RF power. A metal target inside the ICP is sputtered and generates metal atoms and ions. By negative electrically biasing the target, the sputter rate inside the discharge is increased and thus the metal ion output rises. Metal ions are extracted out of the ICP, pass a Wienfilter and are decelerated to a set energy. By this, single and multiple ionized metals can be chosen. This ion beam with mass and energy selection is sent to a metal target surface in the vacuum chamber, where sputtering takes place. For both sputter targets, inside the ICP and the vacuum chamber, aluminium, cupper and titanium is used. Moreover, by operating the ICP with oxygen or nitrogen as fed gas metal molecule oxides and nitrides are produced.

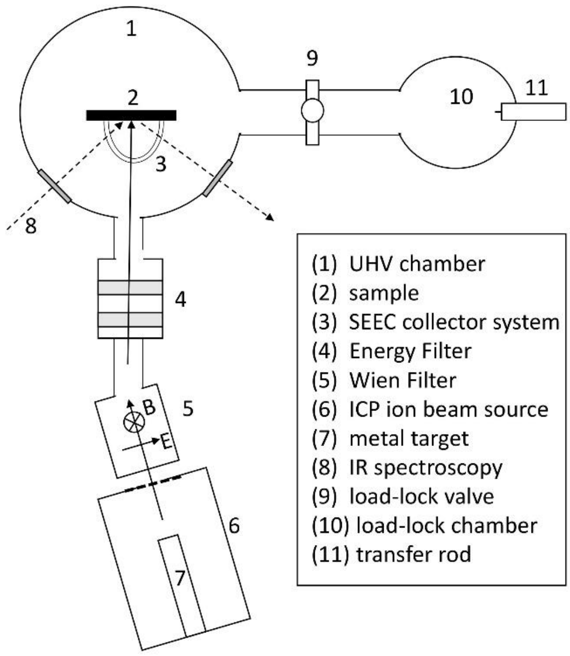

Fig. 1. Schematic top view of particle beam experiment.

For determination of the SEECs a collector system (Fig. 2), based on current measurements, is used as already described in [5]. Basically, this system consists of three electrodes namely screening (grounded), collector (positive biased) and holder (grounded) which all can be independently biased. The ion beam passes the two semicylindrical coaxial electrodes screening and collector before reaching the sample holder. During sputtering at the sample surface secondary electrons are emitted. By comparing the electron current at the collector $I_{current}$ to the total ion current at the sample I_{sample}, the SEEC is calculated:

$$\gamma = \frac{I_{collector}}{I_{sample} - I_{collector}} \quad (1)$$

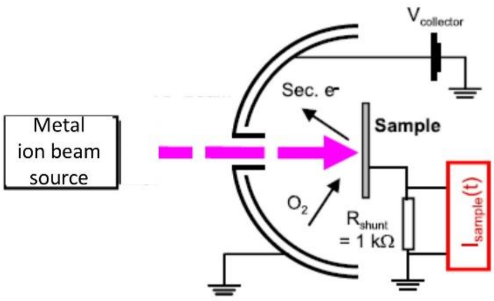

Fig. 2. Schematic top view of the SE-collector.

Moreover, in-situ infrared spectroscopy (IR) is applied for monitoring chemical modifications of the metal surfaces in the vacuum chamber

3. Previous Measurements

The ion-induced γ-coefficient for argon ions was measured by means of particle beam experiment for different metals and their oxides (Fig. 3) [6]. The values are consistent with literature [7,8]: γ rises with increasing ion energy and is higher of oxide surfaces. The higher γ-value for oxides is higher due to different energy dissipation mechanisms. When ions penetrate into metals they dissipate their energy easily by excitation of free electrons. Due to the efficient dissipation less energy is left for generation of SEEs. In contrast, the impinging ions loose less energy to covalent binding in oxides. Hence, more energy is available for release of electrons.

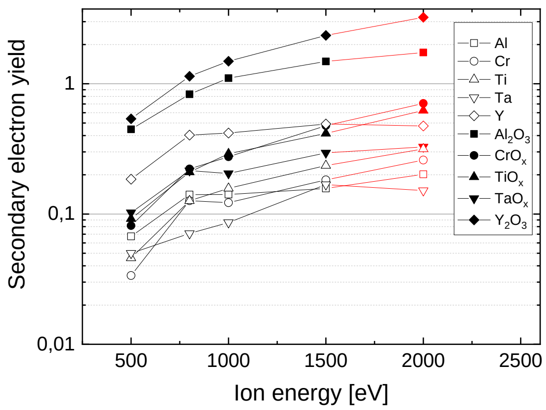

Fig. 3. Energy dependence of SEEC for Al, Cr, Ti, Ta and Y and their oxides

4. Outlook

We are presenting SEECs in dependence of the ion energy of commonly used HiPIMS target materials such as aluminium, copper and titanium. For proof of concept and verification of the experimental results the SEECs will be compared to calculations based on formula of Yamamura [9].

5. Acknowledgement

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6. References

[1] A. Hecimovic et al., J. Phys. D: Appl. Phys. **51** 453001.
[2] D. Depla et al., J. Appl. Phys. **101**, 013301 (2007).
[3] D. Depla et al., J. Phys. D: Appl. Phys. **41,** 202003 (2008).
[4] D. Depla et al.Plasma Sources Sci. Technol. **10** 547 (2001).
[5] A. Marcak et al., Rev. Sci. Instrum. **86**, 106102 (2015).
[6] C. Corbella, Rev. Sci. Insturm. **84**, 103303 (2013).
[7] R.A. Baragiola et al., Reactive Sputter Deposition (Springer-Verlag, 2008).
[8] A.V. Phelps et al., Plasma Sources Sci. Technol., **8**, R21 (1999).
[9] Y. Yamamura, Atomic data and nuclear data tables **62**, 149-253 (1996).