Controlling the Electron Density with the Multipole Resonance Probe During a Sputter Process

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1. Introduction

Plasma sputtering processes are used for the deposition of ceramic layers such as aluminium oxide (Al2O3). During reactive sputtering, the reactive gas reacts with the metal target surface. In case the reactive gas flow is too high, the target becomes covered with compound material. The covering decreases the sputter rate and increases the secondary electron emission. Both parameters show a non-linear hysteresis effect for a variable reactive gas flow [1]. This leads to process instabilities. From an industrial point of view, the sputter rate should be as high as possible. Consequently, a process control is necessary. Until today, research has focused on stabilizing the deposition of certain ceramic layers on a substrate by detecting a spectral line of the sputtered target material as an indicator for the sputter rate used as the controlled process variable. Thereby a coupling between plasma and substrate is not considered. This work deals with the control of a reactive sputter process for the deposition of ceramic layers (Al2O3) in a multi-frequency capacitively coupled plasma (MFCCP) based on plasma parameters. A young diagnostic method is used to assess the electron density: The multipole resonance probe (MRP) based on on the principle of active plasma resonance spectroscopy measures plasma parameters by analysing a typical resonance frequency.

2. Multipole Resonance Probe

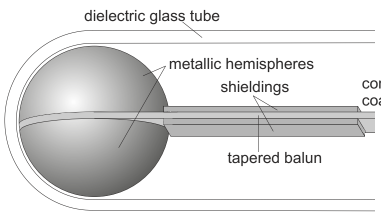

Fig. 1: *Schematic of the MRP. The head consists of two metallic hemispheres, a tapered balun transfers the coaxial signal into a symmetric signal.*

In preceding publications, the new diagnostic probe system MRP was presented [2,3]. It bases on the principle of active plasma resonance spectroscopy (APRS) and exploits the capability of plasmas to resonate near the electron plasma frequency. After coupling an rf-signal into the plasma, the system response can be evaluated. The mathematical model can use the electrostatic approximation of Maxwell equations and the cold plasma approximation because of the symmetric electrical and geometrical design. The schematic of the probe is shown in fig. 1.

The dielectric glass tube surrounding the probe makes the system insusceptible to dielectric coatings [4]. The electron density n_e can be calculated from the measured resonance frequency f_{res} [3]. As shown in fig. 2, f_{res} also shows a hysteresis effect in the reactive sputter process as a result of a non-constant plasma.

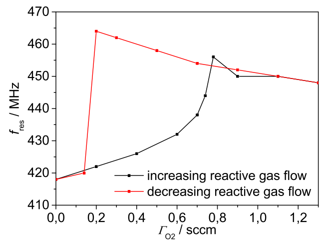

Fig. 2: *Hysteresis curve of the resonance frequency* f_{res} *during reactive sputtering for a variable oxygen flow* Γ_{O2}.

3. Control System based on the MRP

A control system with a simple PI-controller is used to stabilize the process (fig. 3). The MRP measures with a network analyser (NWA) the resonance frequency, a proportional plus integral controller implemented in a software determines the voltage required for a mass flow controller (MFC) to adjust the oxygen flow. With this control system it is possible to stabilize the process in an optimal working point.

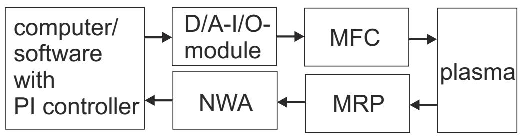

Fig. 3: *Block diagram of the control system.*

References

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[3] M. Lapke *et al. Plasma Sources Sci. Technol.* **20** 042001
[4] T. Styrnoll *et al.* 2014 *Plasma Sources Sci. Technol.* **23** 025013

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