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Correlation of III/V semiconductor etch results with physical parameters of high-density reactive plasmas excited by electron cyclotron resonance

Gerhard FRANZ[1], **Ralf MEYER**[2] and **Markus-Christian AMANN**[2]

[1] Munich University of Applied Sciences, Dep. 06 34 Lothstrasse, Munich, Bavaria, D-81730, Germany
[2] Walter Schottky Institut, Technische Universität München Am Coulomwall, Garching, Bavaria, D-85748, Germany

E-mail: gerhard.franz@hm.edu

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Abstract

Reactive ion etching is the interaction of reactive plasmas with surfaces. To obtain a detailed understanding of this process, significant properties of reactive composite low-pressure plasmas driven by electron cyclotron resonance (ECR) were investigated and compared with the radial uniformity of the etch rate. The determination of the electronic properties of chlorine- and hydrogen-containing plasmas enabled the understanding of the pressure-dependent behavior of the plasma density and provided better insights into the electronic parameters of reactive etch gases. From the electrical evaluation of $I(V)$ characteristics obtained using a Langmuir probe, plasmas of different compositions were investigated. The standard method of Druyvesteyn to derive the electron energy distribution functions by the second derivative of the $I(V)$ characteristics was replaced by a mathematical model which has been evolved to be more robust against noise, mainly, because the first derivative of the $I(V)$ characteristics is used. Special attention was given to the power of the energy dependence in the exponent. In particular, for plasmas that are generated by ECR with EM modes, the existence of Maxwellian distribution functions is not to be taken as a self-evident fact, but the bi-Maxwellian distribution was proven for Ar- and Kr-stabilized plasmas. In addition to the electron temperature, the global uniform discharge model has been shown to be useful for calculating the neutral gas temperature. To what extent the invasive method of using a Langmuir probe could be replaced with the non-invasive optical method of emission spectroscopy, particularly actinometry, was investigated, and the resulting data exhibited the same relative behavior as the Langmuir data. The correlation with etchrate data reveals the large chemical part of the removal process—most striking when the data is compared with etching in pure argon. Although the relative amount of the radial variation of plasma density and etch rate is approximately $\pm 5\%$, the etch rate shows a slightly concave shape in contrast to the plasma density.