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Modelling gas discharges: from the magnetron to HIPIMS

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Our goal is to assess whether the time-dependent behaviours observed in gas discharges can be reproduced with a very simple mathematical model. In particular, we want to understand the current response to applied voltage using the fewest assumptions possible. We are interested in gas discharges generally, with HIPIMS as a special case.
We would like to reproduce the range of V-I characteristics observed in the literature such as a stable discharge displaying a current plateau resulting from a constant applied voltage, a current peak resulting from a decreasing applied voltage or pulse, a current peak followed by a plateau, consistent with argon depletion, and finally a current that increases unbounded with time.
Here we present a simple mathematical model of a time-dependent plasma glow discharge, based on an electric circuit. The script, written in MATLAB, inputs a given voltage-time trace that is applied to the plasma, and calculates the resultant current, comprising both the ion current from glow to cathode and the secondary electron current from cathode to the glow. The model takes into account the resistance from the plasma itself, as well as an additional resistance inherent in the electronics of an experimental system.
The script is able to reproduce HIPIMS behaviours from the literature, and we predict the classic I=V^n relationship for the stable plateau. We also predict the existence of stable discharges at very low current densities. We present an analysis of the effects of various parameters, noting which parameters are essential to cause a discharge to be stable, and identifying possible explanations for experimental results seen in the literature.
The model is deliberately kept simple and flexible, with a number of approximations. Users can adjust key parameters to tailor the model to suit a specific scenario, including the secondary electron emission, ionisation probability, loss factors, and ion mass. It is hoped the model will prove useful to the HIPIMS community, being robust and flexible enough to accurately model the physics of a variety of glow discharges, and providing insight into observed behaviours.

Keywords
model
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