化学反応プラズマ放電の電流—電圧特性モデリング及び超伝導窒化チタンニオブ（NbTiN）薄膜作製における応用

Modeling of Current-Voltage Characteristics of DC Reactive Sputtering and Its Application to Superconducting NbTiN Thin Film Deposition

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Reactive sputtered NbTiN thin films are utilized in superconducting electromagnetic wave detectors especially for those applications at THz frequency (10^{12} Hz) range owing to the higher energy gap of NbTiN than that of Nb, which is more conventionally applied at millimeter waves and microwaves. Optimization of the reactive sputtering process for high-quality NbTiN films, however, is an incomplete attempt due to insufficient understanding of the highly nonlinear process. In particular, the current-voltage characteristics (IVCs) of reactive magnetron plasma discharge remains not being quantitively studied and the underling physics is not fully unveiled.

In this work, a technique of numerical modelling of IVCs of reactive magnetron plasma discharge has been developed. The method is devised based on well-accepted equilibrium equations that describe the steady state of reactive plasma sputtering process. This technique allows an analytical expression of IVCs with a pair of parametric equations, which is convenient in computation. This approach is self-complete as unknown material-dependent parameters can be determined by curve-fitting of measured IVCs. By using this IVC model, the dependence of plasma discharge parameters on discharge current, voltage and other control parameters can be systematically studied, and the simulation results provide clear guidelines in optimization of the plasma process for desired film quality and insightful understanding of experimental phenomena. The plausibility of this method and the physical insights it reveals are demonstrated by applying it to a realistic case of superconducting NbTiN film deposition.

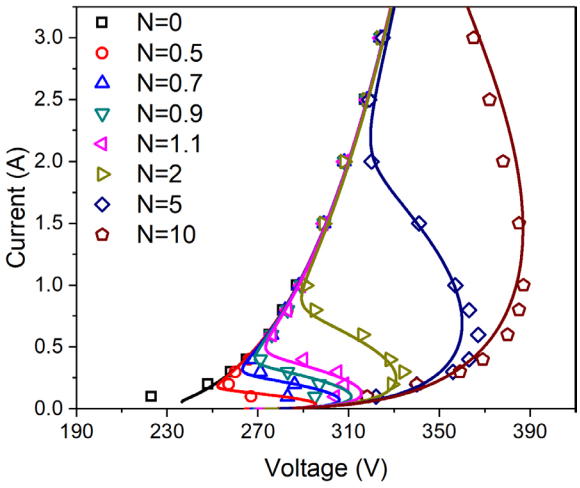

Fig. 1. IVCs corresponding to different N_2 flow rate (N in unit of sccm). The comparison is made between stepwise measured IVCs (dots) and simulated IVCs (lines) by using the model established in this work. The experiment was done with Ar flow rate 50 sccm and total pressure of 0.5 Pa.