Current-voltage-time characteristics of the reactive Ar/N₂ high power impulse magnetron sputtering discharge

F. Magnus, O. B. Sveinsson, S. Olafsson and J. T. Gudmundsson

1. Introduction

High power impulse magnetron sputtering (HiPIMS) is an emerging ionized physical vapour deposition technique (IPVD) [1]. By pulsing the sputtering target with high power (~1 kW/cm²), short duration pulses, a high ionization of the sputtered species is obtained, without significant target heating.

HiPIMS has been shown to have several advantages over conventional dc magnetron sputtering (dCMS) including increased film density, lower roughness, increased reactivity at low temperatures and better step coverage [1]. The aim of this study is to examine the current-voltage-time (I-V-t) characteristics of the reactive Ar/N₂ HiPIMS discharge with a Ti target and compare them to the non-reactive case.

We study the effect of pulse repetition frequency and discharge voltage on the I-V-t characteristics.

2. Experimental setup

UHV chamber (base pressure 4×10⁻⁶ Pa) with circular, planar, balanced magnetron.

3 inch diameter titanium target.

Square voltage pulse, 400 μs long.

Pulse repetition frequency varied in the range 10–80 Hz.

Ion flux at substrate determined by measuring the current from the negatively biased substrate to ground (Fig. 1).

3. The Ar discharge

For low voltages (up to 600 V) the current waveforms can be described by three distinct regions:

I. Plasma initiation and a current maximum → gas compression
II. A decay to a minimum → rarefaction
III. A steady state regime that remains as long as the discharge voltage level is maintained → sustained self-sputtering

At higher voltages (650 V and above) the plateau current increases rapidly and the waveform becomes unstable.

At highest voltages self-sputtering runaway occurs (pulse is cut short to maintain stability).

Consistent with results of Anders et al. [2].

The current waveform is not affected by the pulse repetition frequency in the Ar discharge (Fig. 3).

This means that the average power can be varied independently of the peak power and without changing the discharge properties.

4. The Ar/N₂ discharge

The current waveforms in the reactive Ar/N₂ discharge (Fig. 4) show the same general features as in the non-reactive Ar discharge.

Self-sputtering runaway occurs at lower voltages.

The discharge current is highly dependent on pulse repetition frequency in the Ar/N₂ discharge (Fig. 5).

Current increases as frequency is lowered to target nitridation.

The self-sputtering phase outgrows the initial current peak.

5. Conclusions

The reactive Ar/N₂ HiPIMS discharge is highly frequency dependent, unlike the non-reactive discharge.

The discharge current increases with decreasing frequency due to target nitridation. The increase in current is a result of the increased secondary electron emission yield of the nitride target during the self-sputtering phase.

The increase in current is reflected in an increase in the ion flux arriving at the substrate.

References