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The evolution of the IEDF in a low pressure HIPIMS discharge

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Using an energy-resolved mass spectrometer the evolution of the ion energy distribution function (IEDF) at a substrate in a high-power impulse magnetron sputtering (HIPIMS) plasma has been measured at low operating pressures. The plasma was maintained using a low-power DC power supply as a pre-ionizer in conjunction with a conventional HIPIMS power supply, allowing reduced times between the initiation of the HIPIMS pulse and plasma ignition. As a result, the stable HIPIMS discharge can be operated at the working pressure down to 0.08 Pa with a typical pulse width, repetition rate and power density of 100 μs, 100 Hz and 500 Wcm^{-2}, respectively. Time-averaged IEDF measurements at a sampling mass spectrometer orifice position (14 cm from a carbon target surface) showed two distinct energy peaks one at low energy (0.5 eV) and the other at high energy (10 eV) for the detected species Ar^{+}, Ar^{2+} and C^{+}. The origin of these two peaks can be revealed using a time-resolved acquisition technique. It was found that the high energy peak (corresponding with an effective stopping voltage of 10 V) was created during the on-time phase of HIPIMS pulse while the low energy peak dominated the IEDF during the off-time. Increase of the operating pressure to 0.53 Pa results in the depletion of intensity and energy of the energetic peak. A long mean free path which is comparable with the mass spectrometer orifice-target distance when operating at the low pressure gives rise to an energetic population transporting ballistically to the instrument orifice. This suggests that forming well-structured films may be achieved in the condition of the collision-free operation.

Keywords
high-power impulse magnetron sputtering (HIPIMS)
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Ballistic transport
Time-resolved diagnostics