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HiPIMS induced high-purity Ti3AlC2 MAX phase coating at low-temperature of 700℃

Reference
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Introduction

Currently, a significant challenge lies in lowering the formation temperature of Ti-based MAX phase while maintaining high-purity crystalline quality. This challenge is crucial for enabling widespread applications on substrates sensitive to temperature changes. The presented findings offer a straightforward method to produce high-purity Ti_3AlC_2 MAX phase coatings at low temperatures using HiPIMS (High Power Impulse Magnetron Sputtering) technology. Langmuir probe by Impedans evaluated the plasma discharge characteristics between HiPIMS and DCMS (Direct Current Magnetron Sputtering) and highlighted the advantages of HiPIMS technology over traditional Magnetron systems.

Experimental setup

Ti-Al-C coatings were deposited to Ti-6Al-4V substrates using a magnetron sputtering system equipped with both High Power Impulse Magnetron Sputtering (HiPIMS) and a DC power supply. The experimental setup is illustrated in Figure 1. The average target power, employing both DCMS (Direct Current Magnetron Sputtering) and HiPIMS deposition modes, was set at 2 kW. The HiPIMS pulse frequency and pulse-on time of the power supply were consistently maintained at 500 Hz and 100 μs, respectively. To transform the initially deposited Ti-Al-C coatings into crystalline MAX phase coatings, an annealing process was conducted at 700 °C under a vacuum of 2 × 10−3 Pa. In characterizing the plasma discharge in HiPIMS and DCMS modes, a Langmuir single probe (Impedans Ltd, ALP-150) made of tungsten wire with a diameter of 0.25 mm and a length of 5 mm was employed, as depicted in Figure 1.

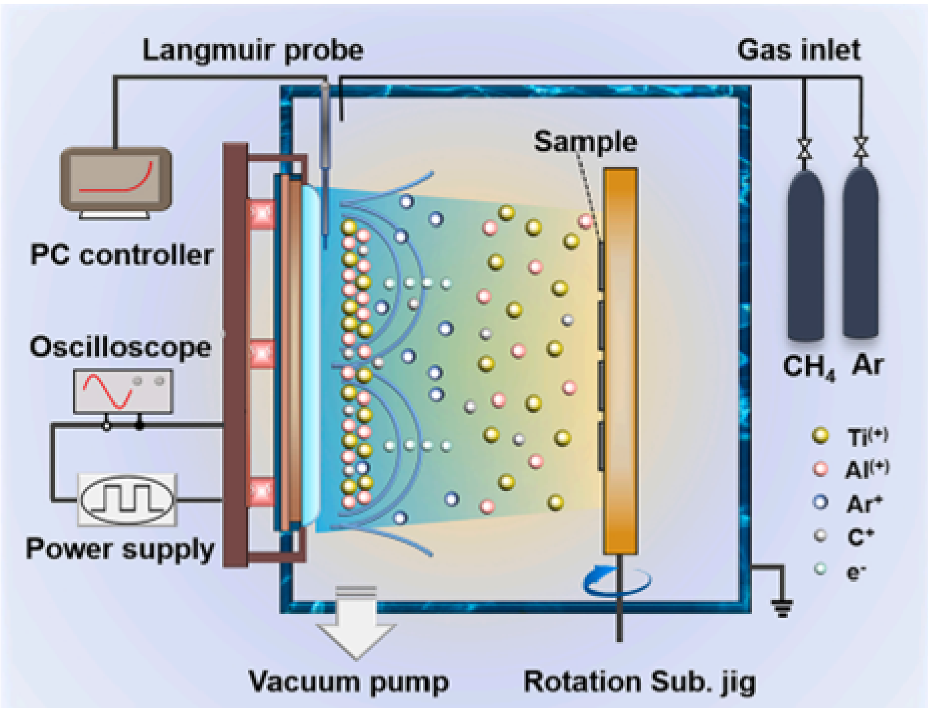

Figure 1 Schematic diagrams of the HIPIMS/DC magnetron sputtering system.

Results

Figure 2 illustrates the typical Langmuir I-V discharge curves for various sputtering methods in both High Power Impulse Magnetron Sputtering (HiPIMS) and Direct Current Magnetron Sputtering (DCMS) processes. As anticipated, the HiPIMS mode exhibited an order of magnitude higher plasma ion density and electron count compared to the DCMS mode. Furthermore, the distribution function of HiPIMS displayed an extended tail in the range of 20–25 eV, as depicted in Figure 2(b). This elevated energy played a pivotal role in facilitating the excitation and ionization of both the target material and gas precursors, thereby significantly influencing the distinct coating growth observed between HiPIMS and DCMS modes.

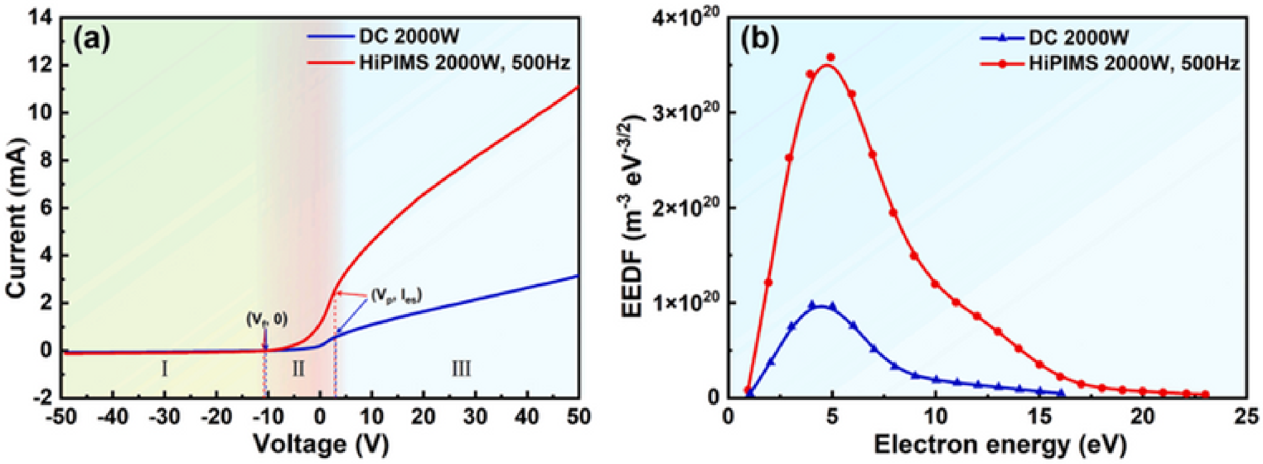

Figure 2 (a) I-V discharge curves of HiPIMS mode and DCMS mode during sputtering, (b) EEDF results of second derivative from I-V curves

Summary

The findings indicated that the High Power Impulse Magnetron Sputtering (HiPIMS) technique enhanced both the concentration of ions and the kinetic energy of the sputtered plasma in comparison to Direct Current Magnetron Sputtering (DCMS). This enhancement resulted in a denser, smoother, and microscale cluster-free morphology, in contrast to the amorphous structure observed in DCMS as-deposited coatings. The HiPIMS coating, subjected to annealing at 700 °C for 90 minutes, exhibited the Ti3AlC2 MAX phase, while the annealed DCMS coating showed Ti2AlC. This suggests that the HiPIMS technique allows for the synthesis of high-purity Ti3AlC2 MAX phase coatings at a lower temperature, possibly below the previously reported range of 800–1100 °C.

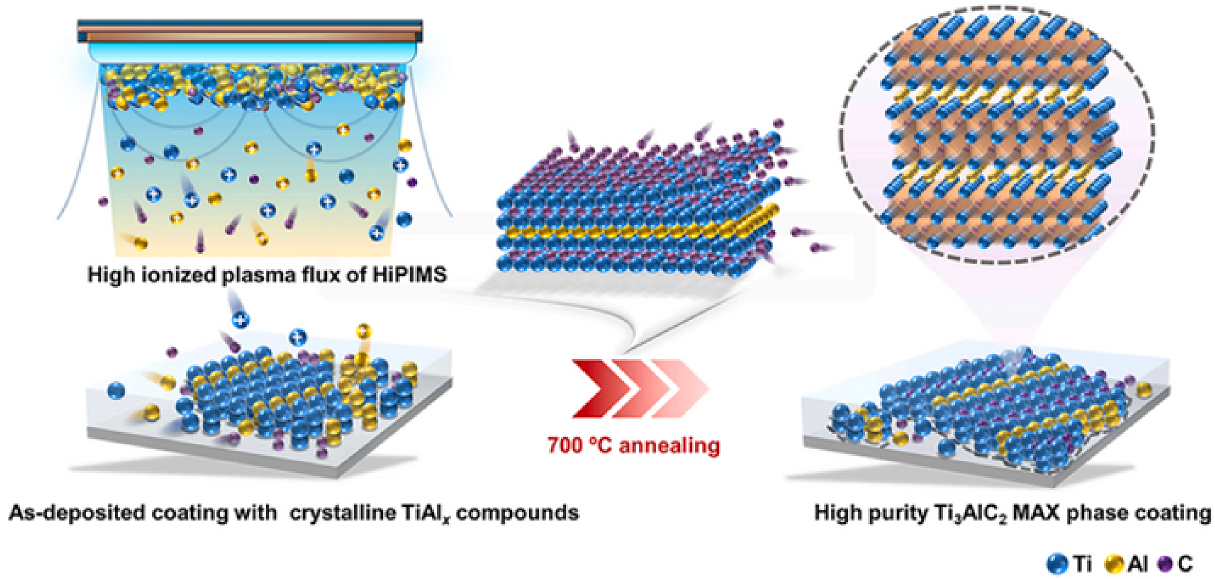

Figure 3 Schematic illustration for low temperature synthesis of HiPIMS induced Ti3AlC2 MAX phase coating.