

---

# Fracture Toughness and Durability of HiPIMS-Deposited Hard Coatings

Jon Molina-Aldareguia<sup>\*†1,2</sup>, Arley García Carrero<sup>2,3</sup>, Jose Antonio Santiago<sup>3</sup>, Pablo Diaz-Rodriguez<sup>3</sup>, Miguel Monclús<sup>2</sup>, Ivan Fernandez<sup>3</sup>, Álvaro Guzmán-Bautista<sup>1</sup>, Christoph Kirchlechner<sup>4</sup>, and Subin Lee<sup>4</sup>

<sup>1</sup>Universidad Politécnica de Madrid – Spain

<sup>2</sup>Institute IMDEA Materials [Madrid] – Spain

<sup>3</sup>Nano4Energy S.L.U. – Spain

<sup>4</sup>Karlsruhe Institute of Technology = Karlsruher Institut für Technologie – Germany

## Abstract

The High-Power Impulse Magnetron Sputtering (HiPIMS) technique enables the deposition of coatings with high hardness, low defect densities, and uniform, conformal coverage over complex 3D geometries, meeting the strict tolerances required in micromachining applications. High-speed machining (HSM) applications demand not only high hardness but also sufficient fracture toughness, which is critical for maintaining the structural integrity of both bulk and coated engineering components. However, these mechanical properties are often antagonistic, particularly in materials capable of plastic deformation, where high hardness typically correlates with lower fracture toughness. This study aims to systematically evaluate the fracture toughness and machining performance of AlTiN- and TiN-based coatings doped with Si, deposited by HiPIMS using different process parameters. Micro-fracture toughness was assessed on freestanding films using single cantilever bending tests, effectively minimizing residual stress and substrate interactions to obtain precise KIC values. Crack formation at the cutting edge of a 0.4 mm diameter microdrill was observed using FIB, while the composition of the coatings was determined by GDOES. Additionally, XRD was employed to analyze grain growth texture and peak shifts, enabling the evaluation of biaxial stresses. The AlTiSiN coatings exhibited a hardness of 35 GPa, while TiSiN coatings reached 40 GPa. Fracture toughness ranged from 1.78 MPa·√m to 2.2 MPa·√m, depending on the HiPIMS parameters used. In micromachining tests on the TiAl6V4 alloy, the coatings allowed continuous micro-milling to be extended from 40 minutes to over one hour. These findings link toughness values, stress reduction, and crack formation at the cutting edges with tool durability in machining applications.

---

\*Speaker

†Corresponding author: jon.molina@imdea.org