

FEMS 2025 EUROMAT

18th European Congress and
Exhibition on Advanced Materials and
Processes

Granada, Spain
14 – 18 September 2025

Mechanical properties and adhesion of $W_{1-x}Al_xB_{2+z}$ coatings

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The quest for advanced materials with outstanding properties has brought tungsten borides into the spotlight, thanks to their exceptional hardness, thermal stability, and resistance to wear. The crystallographic structure of these materials is crucial in shaping their physical, mechanical, and antioxidation behavior. Notably, borides doped with aluminium have emerged as a standout option, exhibiting excellent mechanical and antioxidation characteristics [1]. These materials hold significant potential for use as protective coatings that can remain stable under high-temperature conditions.

To achieve the desired material structure, a novel magnetron deposition technique was used, integrating direct-current magnetron sputtering (DC) with High Power Impulse Magnetron Sputtering (HiPIMS). The films were deposited using two distinct targets: AlB_2 (DC) and $WB_{2.5}$ (HiPIMS). Mechanical testing demonstrated exceptional hardness (~30 GPa for aluminum doping below 10% atomic). As the aluminum content in $W_{1-x}Al_xB_{2+z}$ coatings increased, a slight decrease in density and hardness was observed.

The experimental findings were compared with theoretical values derived from DFT calculations. All $W_{1-x}Al_xB_{2+z}$ structures examined using DFT were confirmed to be both mechanically and thermally stable. The experimentally measured hardness values surpassed those predicted by DFT, highlighting the notable impact of aluminum doping.

Due to the use of hard coatings mixed with a soft substrate, it is important to achieve good adhesion. Coatings were applied to nitrided steel QR90 with tungsten interlayer. For this purpose, the films were subjected to two methods of adhesion measurement: scratch testing and laser spallation.

Funding: This work was funded by the National Science Centre (NCN, Poland) Project number:2022/47/B/ST8/01296.

References

- [1] B. Wicher, O. V. Pshyk, X. Li, B. Bakhit, V. Rogoz, I. Petrov, L. Hultman i G. Greczynski, „Superhard oxidation-resistant $Ti_{1-x}Al_xB_y$ thin films grown by hybrid HiPIMS/DCMS co-sputtering diboride targets without external substrate heating,” Elsevier, Volume 238, 2024.