

HARDNESS AND WEAR PROPERTIES OF ALD HfO₂ LAYERS ON AZ31 ALLOY

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Exceptional mechanical properties of Mg and its alloys (lightness, great strength-to-weight ratio) allow them to be used in a variety of applications, including automobile and aviation industries, consumer electronics, biomaterials. However, the poor resistance of magnesium to corrosion and wear significantly limits and complicates its use. One of the ways to improve both corrosion performance and wear resistance of magnesium alloys is to coat their surface with chemically inert, mechanically hard oxides. Hafnium oxide (HfO₂) is considered as a promising candidate for this purpose [1, 2]. Atomic layer deposition (ALD) is the most suitable modern method to deposit thin oxide layers of a predictable thickness.

In this work, magnesium alloy AZ31 (Mg-3Al-Zn) was coated with HfO₂ layers of different thicknesses. The growth rate of HfO₂ (nm/cycle) was evaluated. Samples were tested as deposited and after annealing in nitrogen atmosphere at 350 °C for 5 hours. All samples were tested for hardness and wear with nanoindenter.

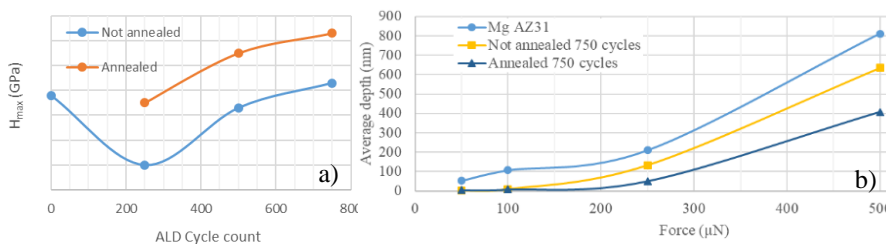


Fig. 1. Hardness of AZ31 alloy coated with HfO₂ coatings of various thickness (a) and average wear depth of uncoated and 750-cycle ALD coated AZ31 samples (b).

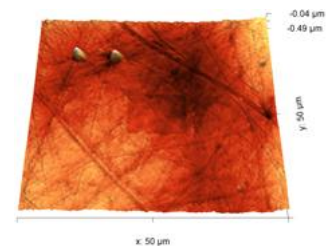


Fig. 2 SPM image of a wear trace on AZ31 alloy coated with 750 ALD cycles of HfO₂.

ALD growth of HfO₂ at 200 °C reactor temperature was determined to be linear in the region from 0 to 45 nm and the growth rate was calculated to be ~0.091 nm/cycle.

The surface hardness of AZ31 with natural oxide/hydroxide layer was better than that of samples with HfO₂ coatings of 250 and 500 ALD cycles. HfO₂ coating of 750 ALD cycles was already harder than natural oxide: ~4.3 GPa, compared to ~4 GPa for uncoated AZ31. The annealing improved hardness of the samples up to ~6.3 GPa for 750 cycle ALD coating.

Wear tests showed that HfO₂ coatings provided additional wear resistance for AZ31 samples compared to natural oxide/hydroxide layer. At 100 μN load, the annealed and not annealed samples with 750 cycle ALD coating, showed significant wear resistance with wear depth less than 15 nm. At higher loads some wear reduction effect was found which increased with the coating thickness. Hardness and wear resistance of all samples increased with annealing.

References

1. M. Li, Z. Jin, W. Zhang, Y. Bai, Y. Cao, W. Li, D. Wu, A. Li. *Sci. Rep.*, 9:10438 (2019); doi.org/10.1038/s41598-019-47049-z.
2. L. Staišiūnas, K. Leinartas, E. Juzeliūnas, D. Bučinskienė, A. Grigučevičienė, P. Kalinauskas, A. Selskis, S. Stanionytė. *Surf Coat Technol.*, 397 (2020) 126046; doi.org/10.1016/j.surfcoat.2020.126046.