Workshop »Coatings for Tools & Components«

Modulus and yield strength measurements of ultra-thin ALD coatings in a thickness range between 5 nm and 100 nm

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In the last years the interest in industrial solutions for Atomic Layer Deposition (ALD) is increasing. ALD is one of the best techniques to produce conformal thin films on curved surfaces and in holes. It is widely used in semiconductor industry. The global ALD equipment market is expected to reach 8.2 billion Dollar in 2026, growing by 28 % every year. However, the mechanical properties of ALD coatings are often not well known due to the low thickness of the layers which is typically only a few nanometres. Conventional nanoindentation techniques are not able to resolve the properties of such thin layers.

In the present work we apply a technique for the measurement of the Young's modulus of ultra-thin films that was already introduced in 2004 for DLC coatings on silicon single crystal [1]. It is based on fully elastic indentations with a spherical indenter and the fit of the load-displacement curve with an extended Hertzian contact model that is considering the substrate influence. Preconditions of the method are a high enough film hardness and a very smooth surface. The method is applied to Al_2O_3 coatings on Si (100) substrates with thicknesses between about 5 nm and 100 nm.

Additionally, the yield strength of some coatings is derived from high resolution scratch tests in combination with the von Mises stress calculation based on the measured moduli. Using a pre- and post-scan during a scratch test with low forces and a spherical tip, the elastic plastic transition can be detected. The maximum von Mises stress along the depth axis obtained from the critical force at the transition point and the calibrated tip radius corresponds to the yield strength of the coating material when it is softer than the silicon substrate.

Modulus and yield strength can then be used to optimize the coatings according to the requirements of the application. This is especially interesting for a combination of ALD and PVD techniques for tools and components.

[1] T. Chudoba, M. Griepentrog, A. Dück, D. Schneider, F. Richter; J. Mater. Res., 2004, 19, 301-314.