Young's modulus measurements on ultra-thin coatings

T. Chudoba[a,d], M. Griepentrog[b], A. Dück[b], D. Schneider[c], F. Richter[d]

[a] ASMEC (Advanced Surface Mechanics), D-01454 Rossendorf, Germany
[b] Federal Institute for Materials Research and Testing, Unter den Eichen 87, D-12200 Berlin, Germany
[c] Fraunhofer Institute for Materials and Beam Technique, Dresden
[d] Chemnitz University of Technology, Institute of Physics, D-09107 Chemnitz, Germany

Abstract

The determination of the mechanical properties of ultra-thin coatings becomes more and more important due to the increasing number of applications of such films. However, an accurate mechanical testing of coatings with a thickness down to some nanometers is still a challenge, despite the improvements of existing measurement techniques.

Nanoindentation is an often-used mechanical nano-probe. Using the conventional test method with a sharp Berkovich indenter the problem of the substrate influence on the result arise with decreasing film thickness. Therefore it is nearly impossible to measure the modulus of films with a thickness less then 100-200nm. The problem can be overcome by using spherical indenters in combination with an analytical solution for the Hertzian contact of coated systems. It allows a separation of film and substrate properties from the load-displacement curve of the compound. Indentation measurements were done at a 44 nm TiN film and at DLC coatings in the thickness range between 4.3 nm and 125 nm on Si substrates. Several corrections were applied to obtain wholly elastic force-displacement curves with high accuracy. It is shown in more detail how zero point and thermal drift corrections are used to obtain statistical depth errors below 0.2nm.

Laser-acoustic measurements based on ultrasonic surface waves were chosen as a second method, which is also able to measure the Young's modulus in this thickness range. Although the indentation technique is a local probe and the laser-acoustic technique gives an integral value for a surface range of some millimeters the results agree well for the investigated samples. In contrast to that it was impossible to get the correct Young's modulus by conventional indentation measurements with Berkovich indenter, even for ultra low loads.