Determination of mechanical film properties of a bilayer system due to elastic indentation measurements with a spherical indenter

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Abstract

A recently developed theoretical model represents the generalization of the indentation of a sphere into an infinite homogeneous halfspace to the problem of a Hertzian load acting on an a halfspace covered with one or more films having different elastic properties. The model allows the analytical calculation of the complete elastic stress field and the deformations within the films and the substrate.

Some results of the model shall be confirmed by nanoindentation experiments using an UMIS-2000 nanoindenter into Si_3N_4/SiO_2 and SiO_2/Si_3N_4 double layers on BK7 glass and Si (100) single crystal. The materials used allow accurate measurements due to their homogeneous, amorphous structure as well as low surface and interface roughness. After the determination of the instrument compliance and the real, depth dependent indenter radius the measured load-depth data are compared with calculated results. It is shown that measurement results can be correctly interpreted by the model. The onset of plastic deformation is investigated for the same samples by multiple partial unloading experiments with a 4µm diamond sphere. The critical load at which

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a first deviation from a wholly elastic response occurs is used for a stress calculation with the model. The mechanical behavior of the different film combinations is interpreted by means of the von Mises comparison stress. The measured results together with the analytical modeling allow an optimization of the thickness and modulus of the individual layers to get a maximum mechanical stability.