HARDNESS AND ELASTIC MODULUS OF SPUTTERED SILICON NITRIDE THIN FILMS.

M. Vila and C. Prieto.
Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas, Cantoblanco. 28049-Madrid (Spain).

D. Cáceres.
Dep. Física, Escuela Politécnica Superior, Universidad Carlos III de Madrid, Avda. Universidad, 30. 28911-Leganés (Spain).

The use of mechanically resistant coatings is a common practice in many industries. Hard films deposited by physical vapour deposition (PVD) and chemical vapour deposition (CVD)[1] techniques have been widely applied in recent years[2] to produce transparent and hard coatings.

Silicon nitride thin films are excellent coatings because of their transparency up to the UV region and because of their high predicted hardness,[3]50.3 GPa for crystalline and 31.5 GPa for amorphous films. These films are commonly prepared by CVD techniques and contain relatively high amounts of hydrogen, which can lead to a degradation of films in subsequent high temperature processing steps.[4] Therefore, sputtering is an interesting thin film preparation technique for all silicon nitride applications where low process temperatures are desired, low hydrogen contents in the films are required (because no hydrogen content is obtained), or where the stoichiometry of the films should be controlled [5] for example to obtain higher hardness of the film.[6]

Silicon nitride thin films have been prepared by reactive sputtering from different sputtering targets and using a range of Ar/N_2 sputtering gas mixtures. The hardness and the Young's modulus of the samples were determined by nanoindentation measurements as it can be shown in Fig.1. Depending on the preparation parameters, the obtained values were in the ranges 8-23 GPa and 100-210 GPa, respectively.

Additionally, Fourier Transform Infrared Spectroscopy (FTIR), Rutherford Backscattering Spectroscopy (RBS) and X-ray diffraction (XRD) were used to characterize different types of bonding, atomic concentrations and structure of the films to explain the variation of mechanical properties. The hardness and Young's modulus were determined as a function of film composition and structure. Additionally, the deposited film hardness and elastic modulus could be predicted on the basis of a model that assumes a serial coupling of the elastic components corresponding to the Si-O and Si-N bonds present in the sample. This model provides two limits for hardness and Young's modulus corresponding to pure silicon oxide and silicon nitride amorphous materials. The validity of this model was demonstrated by the observed linear behaviour of the elastic compliances and inverse hardness vs. the oxygen content in the samples. This also permitted a prediction of the hardness and Young's modulus values of an oxygen free silicon nitride amorphous film by linear extrapolation. Finally, conditions giving the hardest amorphous silicon nitride film are presented.

References:

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Figures:

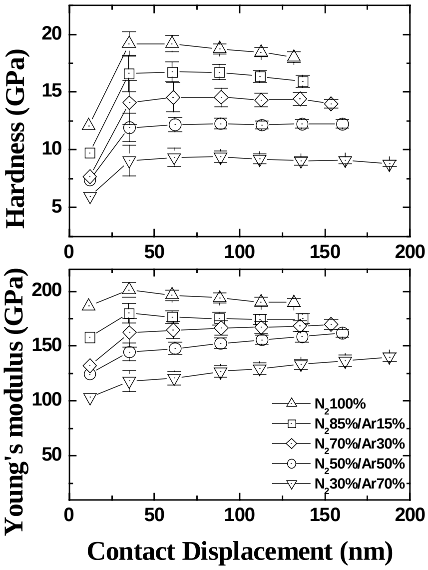

Fig.1. Hardness and Young's modulus vs. indentation contact displacement for silicon nitride films prepared from the pure Si target.