OPTICAL BEHAVIOUR OF THIN FILMS OF VARIABLE OPTICAL CONSTANTS

BY

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ABSTRACT

The purpose of this study was to examine the detailed optical behaviour of homogeneous and inhomogeneous films of variable optical constants obtained by codeposition and multilayer techniques.

Discrete and restricted values of the refractive index of the presently available bulk optical materials present a serious limitation on the usefulness of these materials for optical coatings. This limitation can be overcome by utilizing (a) the atom-by-atom condensation feature of the growth of vapour deposited thin films which allows the homogeneous mixing of different materials irrespective of their solubility restrictions, and/or (b) small step thickness multilayers of component materials. This feature of codeposition of different materials has been used to form mixed optical materials of variable refractive index, the variation being determined by the composition of the ingredients. Measurements of the optical constants of these films prepared by coevaporation of a mixture of ZnS and MgF_2 of various compositions have been made in the spectral range 2000-7000 A^{o}. The values of the optical constants of mixed films at any wavelength lie between the values of the optical constants of pure ZnS and MgF_2

films. The refractive index of the mixed films closely obeys Lorentz-Lorenz relation at wavelengths at which absorption is small. The fundamental absorption edge of the mixed films shifts from that of MgF_2 to ZnS continuously but nonlinearly on increasing the concentration of ZnS in MgF_2. The fundamental absorption edge of the mixed films follows $(h\nu - E_g)^2$ relation indicating indirect optical transition, in sharp contrast to the direct optical transition observed in bulk ZnS.

The equivalent homogeneous films of variable refractive index have been prepared by depositing alternate layers of different materials of small step thicknesses. The variation of the equivalent refractive index with composition of the multilayer films of ZnS-MgF_2, ZnS-Na_3AlF_6, Ge-ZnS and ZnS-MgF_2-SiO prepared by depositing alternate layers of different materials has been investigated. It has been established that, for small ($\lesssim \lambda/30$) step thicknesses of component layers, the multilayer films are optically equivalent to homogeneously mixed films of the same materials of corresponding relative compositions. Further, the results show that the indices of the multilayer films of ZnS-MgF_2, ZnS-Na_3AlF_6 and ZnS-MgF_2-SiO are in good agreement with the values predicted on the basis

of the Lorentz-Lorenz theory. The refractive index of Ge-ZnS multilayer films is in agreement with the Drude theory.

Gradient index (the refractive index varying continuously along the normal to the film surface) films have been prepared by depositing alternate layers of two materials of different refractive indices. The optical behaviour of the gradient index films of ZnS-MgF_2 combination has been investigated. The results show that, for small (much less than the wavelength of light used for the measurements) step thicknesses of each layer, the gradient-index multilayer film behaves like an inhomogeneous film. Periodically stratified medium obtained by depositing a number of identical gradient-index ZnS-MgF_2 multilayer films behaves like a band reflecting filter. The band reflectance increases with the number of periods and tends to nearly 100% for twenty periods. Further, the reflectance band is observed to shift towards longer wavelengths. The reflectivity of the stratified medium has been calculated theoretically by assuming that the gradient-index film is made of a stack of homogeneous films. The experimental and theoretical results have been compared and discussed.

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