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New Quaternary Sb-Se-Ge-In Chalcogenide Glasses: Linear and Nonlinear Optical Properties

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Chalcogenide glasses find extensive applications in infrared (IR) devices and optical communication. Optical parameters of $Sb_{10}Se_{65}Ge_{25-y}In_y$ thin films, deposited by the thermal evaporation technique, have been analyzed using ultraviolet–visible-near IR spectroscopy. The transitions in the forbidden gap are indirect. The effect of indium (In) alloying on the nonlinear optical parameters has been studied. A shift in optical absorption edge towards higher wavelength shows that the width of the localized states changes, which affects the optical parameters of the system. The high nonlinearity of these glasses makes them suitable for optical regeneration and Raman amplification.

Key words: Chalcogenides, thin films, optical properties

INTRODUCTION

Ultrafast all-optical switching devices play an important role in the field of signal transmission requiring high speeds and bit rates.[1] Silica glass optical fibers have low loss and high interaction length, which makes them favorable for fiber communication.[2,3] However, the low nonlinear refractive index of silica requires a high switching power and a very long length of fiber.[3] Chalcogenide glasses have nonlinearity several orders greater than silica[4] and thus ultrafast response time.[4] SbSeGe materials are promising for use in infrared (IR) optical fibers not only due to their high transparency in the IR region but also because of their wide bandgap, low material dispersion, low light scattering, and long-wavelength multiphonon edge.[5,6] For 25 at.% Ge alloying in $Sb_{10}Se_{90-x}Ge_x$ glass alloys, an optimal glass-forming composition is obtained with minimum light scattering losses.[7,8] However, a composition with higher percentage of Ge also becomes more prone to crystallization.[9] Therefore, the Ge concentration has been reduced in $Sb_{10}Se_{65}Ge_{25}$ by alloying with indium (In). It has been reported that In addition increases the dark conductivity due to an increase in the number of defect states[10] and decreases the thermal activation energy[11] of the system. Glasses with In content are promising for nonlinear applications and are suitable for optical devices.[12] Therefore, In has been chosen as an additive because, being a metal, it is expected that it may decrease the bandgap of the material.[13] Also, In-Se binary glassy alloys are interesting materials for solar cell applications.[14] Currently, In-based chalcogenides have attracted significant attention due to their potential applications in smart digital electronic devices.[15] These devices rely upon nonvolatile memory that uses the reversible phase transition of chalcogenide resistors.[15] So, In has been chosen as a dopant to study its effect via optical transmission measurements.

In the present study, an effort has been made to study the effect of increasing In concentration on the linear and nonlinear optical properties of $Sb_{10}Se_{65}Ge_{25-y}In_y$ (y = 0, 3, 6, 9, 12, 15) glasses. Replacement of In by Ge, with a higher density, may increase the linear refractive index (n) and hence the nonlinearity of the glasses. The refractive index (n) and extinction coefficient (k) have been evaluated using Swanepoel's envelope method.[16] The optical bandgap (E_g^{opt}) has been correlated with the absorption coefficient (α) and oscillator energy (E_0). The ratio of the charge carrier concentration to the

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