Available online at www.sciencedirect.com
ScienceDirect
Thin Solid Films 515 (2007) 7603 – 7606
thin solid films
www.elsevier.com/locate/tsf

Study of Ge_YSi_{1-Y}:H films deposited by low frequency plasma

L. Sanchez [a], A. Kosarev [a,*], A. Torres [a], A. Ilinskii [b], Y. Kudriavtsev [c], R. Asomoza [c], P. Roca I. Cabarrocas [d], A. Abramov [d]

[a] National Institute for Astrophysics, Optics and Electronics, Tonantzintla, Puebla, 72840, Mexico
[b] Instituto de Fisica, Benemerita Universidad Autonoma de Puebla, Apdo. Postal J-48, Puebla, Pue., C.P. 72570, Mexico
[c] CINVESTAV-IPN, Av. IPN #2508, D. F. 07360, Mexico
[d] LPICM, Ecole Polytechnique, Palaiseau-Cedex, France

Available online 18 January 2007

Abstract

In this work, we report a study of the optical properties measured through spectral transmission and spectroscopic ellipsometry in Ge:H and Ge_YSi_{1-Y}:H ($Y \approx 0.97$) films deposited by low frequency (LF) PE CVD with hydrogen (H) dilution. The dilution was varied in the range of $R = 20$ to 80. It was observed that H-dilution influences in a different way on the interface and bulk optical properties, which also depend on incorporation of silicon. The films with low band tail characterized by its Urbach energy, E_U, and defect absorption, α_D, have been obtained in Ge:H films for $R = 50$ with $E_U = 0.040$ eV and $\alpha_D = 2 \times 10^3$ cm^{-1} ($h\nu \approx 1.04$ eV), and in Ge_YSi_{1-Y}:H films for $R = 75$ with $E_U = 0.030$ eV and $\alpha_D = 5 \times 10^2$ cm^{-1} ($h\nu \approx 1.04$ eV).

Keywords: Germanium; Silicon; Plasma processing and deposition; Optical properties; Amorphous materials

1. Introduction

Germanium–silicon films deposited by plasma are very attractive as materials because its optical gap is narrower than that for silicon films. They are also completely compatible with the standard silicon CMOS technology. These films can be used for different device applications i.e., solar cells [1] detectors [2], micro-bolometers [3], etc. However growth, structure and electronic properties of these films have been significantly less studied in comparison with silicon films. Typically RF glow discharge at a frequency $f = 13.56$ MHz is used for its deposition. Dalal [4] has reported that deposition conditions providing higher ion bombardment during growth, resulted in good quality Ge:H and Ge_YSi_{1-Y}:H films. These conditions can also be reached in a low frequency (LF) discharge. Growth and properties of Ge_YSi_{1-Y}:H films deposited by LF PE CVD have been reported in Refs. [5,6]. In the latter, the effect of argon (10:1) and hydrogen (20:1) dilution has been studied over the entire range of Ge concentrations. The deposition and study of nano-crystalline films by LF discharge with a very high degree of hydrogen dilution (from 170:1 to 400:1) have been reported in Ref. [7]. Also, the morphology and some electronic properties of LF PECVD films have been reported in Refs. [8,9].

The goal of this work is to study optical properties of germanium–silicon films deposited by LF PECVD with hydrogen dilution in the range of $R = 20$ to 80.

2. Experimental

The Ge:H and Ge_YSi_{1-Y}:H films were deposited by LF PECVD at a substrate temperature of $T_s = 300$ °C and discharge frequency $f = 110$ kHz from SiH_4 and GeH_4 feed gases diluted with hydrogen. Hydrogen dilution defined as $R = Q_{H2}/[Q_{SiH4} + Q_{GeH4}]$, where Q_{H2}, Q_{SiH4}, and Q_{GeH4} are the gas flows of hydrogen, silane and germane, respectively, was varied in the range of $R = 20$ to 80. The Ge_YSi_{1-Y}:H films were deposited with a fixed flow of $Q_{SiH4} = 25$ sccm and $Q_{GeH4} = 25$ sccm. The composition of the films was studied using secondary ion mass spectroscopy (SIMS). The spectral dependence of the optical absorption coefficient, $\alpha(h\nu)$, was calculated from optical transmission $T(h\nu)$ measurements (with a “BRUCKER”

* Corresponding author. Tel./fax: +52 222 266 3100x1409/+52 222 247 0517.
E-mail address: akosarev@inaoep.mx (A. Kosarev).

0040-6090/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2006.11.100

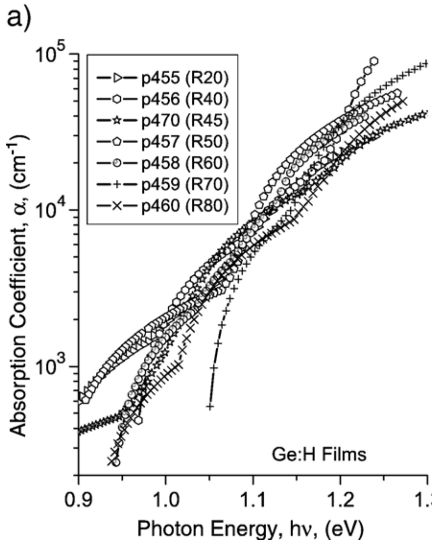

Fig. 1. Spectral dependence of optical absorption coefficient α(hν) for different hydrogen dilution R for a) Ge:H and b) Ge_YSi_{1-Y}:H, Y=0.97, films.

spectrophotometer model Vector-22) using the model described in Ref. [10] for obtaining the set of optical parameters. Spectroscopic ellipsometry measurements were performed in the hν=1.0–4.5 eV photon energy range.

3. Results

3.1. Optical characteristics obtained by spectral transmission, T(hν), measurements

Fig. 1 shows the spectral dependence of the absorption coefficient, α(hν), for the Ge:H and Ge_YSi_{1-Y}:H films deposited in the aforementioned hydrogen dilution range. α(hν) was determined from spectral transmission $T(\lambda)$ measurements. The α(hν) curves demonstrate significant effect of hydrogen dilution on the spectral dependence of the optical absorption, dependence which is related to density of states in the films. The three main regions in α(hν) spectra of Fig. 1, are due to: a) band-to-band transitions that correspond to the transitions from valence to conduction band; b) transitions related to valence and conduction band tails and c) defect related transitions. It should be noted that in non-crystalline materials there is no un-ambiguous definition of optical gap, in contrast to crystalline semiconductors. There are several definitions for optical gap and conventionally Tauc optical gap, E_g, is used among others. In this work, in order to characterize optical properties we have used the following parameters: E_{03} and E_{04} energies corresponding to $\alpha=10^3$ cm^{-1} and $\alpha=10^4$ cm^{-1}, respectively, $\Delta E=E_{03}-E_{04}$ is the energy characterizing the slope of α(hν), the refraction index for long wavelengths, n_∞, the Tauc optical gap, E_g, and the Urbach energy,

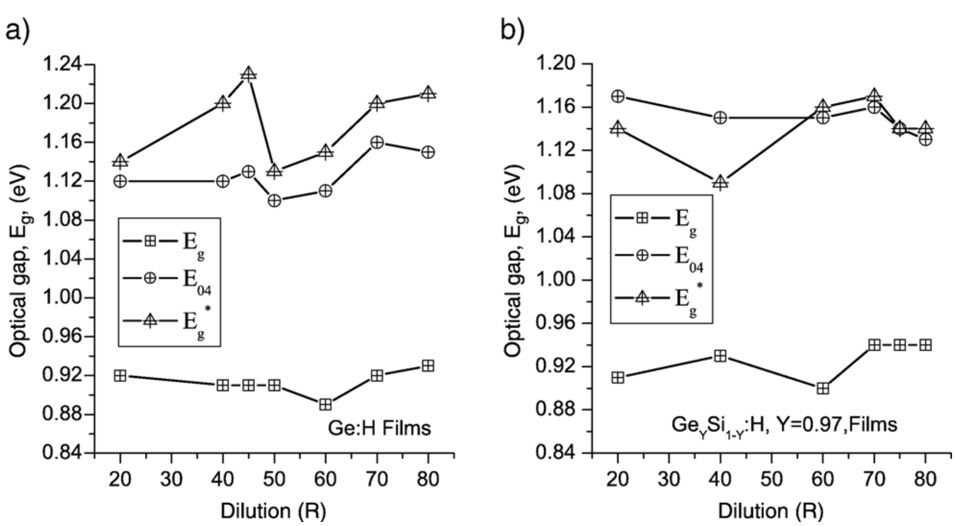

Fig. 2. Optical gaps, E_g and E_g^* determined from spectroscopic ellipsometry and spectral transmission measurements, respectively, and the energy, E_{04}, as function of H-dilution for a) Ge:H and b) Ge_YSi_{1-Y}:H films. Solid line is a guide to the eyes.