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a-Si:H crystallization from isothermal annealing and its dependence on the substrate used

M. Rojas-López^{a,*}, A. Orduña-Díaz^a, R. Delgado-Macuil^a, V.L. Gayou^a,
M. Bibbins-Martínez^a, A. Torres-Jácome^b, C.G. Treviño-Palacios^b

^a CIBA-Tlaxcala, Instituto Politécnico Nacional, Tepetitla, Tlax. 90700, Mexico

^b INAOE, Tonantzintla, Puebla, Pue. 72000, Mexico

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ABSTRACT

We present hydrogenated amorphous silicon (a-Si:H) films which were deposited on two different substrates (glass and mono-crystalline silicon) after an isothermal annealing treatment at 250 °C for up to 14 h. The annealed amorphous films were analyzed using atomic force microscopy, Raman and FTIR spectroscopy. Films deposited on glass substrate experienced an amorphous–crystalline phase transition after annealing because of the metal-induced crystallization effect, reaching approximately 70% conversion after 14 h of annealing. An absorption frequency of the TO-phonon mode that varies systematically with the substoichiometry of the silicon oxide in the 1046–1170 cm⁻¹ region was observed, revealing the reactivity of the film with the annealing time. For similar annealing time, films deposited on mono-crystalline silicon substrate remained mainly amorphous with minimal Si-crystalline formation. Therefore, the crystalline formations and the shape of the films surfaces depends on the annealing time as well as on the substrate employed during the deposition process of the a-Si:H film.

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1. Introduction

Hydrogenated microcrystalline silicon ($\mu\text{c-Si:H}$) is a material used in the electronic industry and in solar cells manufacturing technology as top contact layer in hydrogenated amorphous silicon (a-Si:H) [1,2]. However, the tendency towards cost reduction in the photovoltaic industry has led to the development of the so-called thin film silicon technology. Among the different possible morphologies, a material that presents very promising features is nanocrystalline silicon (nc-Si:H), which consists in an aggregate of crystallites with sizes in the order of few tens of nanometers embedded in an amorphous matrix [3]. One of the most commonly used techniques to prepare $\mu\text{c-Si:H}$ films has been plasma enhanced chemical vapor deposition (PECVD) [4]. Nevertheless, metal-induced crystallization (MIC) effect has also been used to crystallize a-Si:H films at relatively low temperature [5]. It is known that the solid phase crystallization (SPC) temperature of a-Si:H can be lowered adding metals such as aluminum, nickel or palladium [6]. When these metals are used, crystalline silicon grains formation of micrometric size has been observed with considerable grain

growth. In these grains the internal structure changes from the amorphous to crystalline structure resulting in a metal-induced phase transition. This transformation has been investigated using aluminum among other metals [7–10]. In this work we have studied the effect of the substrate used to grow the films, particularly glass or c-Si, on the morphological and vibrational properties of a-Si:H films processed by MIC.

2. Film growth and characterization

The a-Si:H films were grown using conventional radio frequency PECVD at 13.56 MHz in an AMP 3300 PECVD system, on glass and mono-crystalline silicon substrates, at 270 °C. The source gases used are SiH₄ electronic grade and PH₃ 1% diluted in H₂. All samples were cleaned by standard techniques previous to the deposition. The glasses were introduced in the system when the pressure in the chamber was pumped down to a base pressure of 5×10^2 Pa. The $R_p = \text{PH}_3/\text{SiH}_4$ flow ratio was maintained constant at the pressure of 6×10^4 Pa and 60 sccm total flow. The power density was 45 mW/cm². Later the a-Si:H films were subjected to MIC process by aluminum evaporation on the amorphous surface and then applying an isothermal heating during few hours. After annealing, the aluminum was removed from the samples employing a chemical solution. Growth and preparation of the samples can be found in detail elsewhere [8]. Atomic force microscopy (AFM) was used to observe superficial morphology of the crystallized sam-

* Corresponding author at: Instituto Politécnico Nacional, Biotechnology, Carretera estatal Santa Ines Tecuexcomac-Tepetitla, Km. 1.5 Tepetitla, 90700 Tepetitla, Tlaxcala, Mexico. Tel.: +52 248 4870765; fax: +52 248 4870766.

E-mail address: marlonrl@yahoo.com.mx (M. Rojas-López).