Materials Research Bulletin 49 (2014) 71–75

Contents lists available at ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Fabrication and electrical properties of polycrystalline Si films on glass substrates

Shi-hua Huang [a,*], Jian Liu [a], Wei-ke Jing [a], Fang Lu [b], Gu-jin Hu [c,**]

[a] Department of Physics, Zhejiang Normal University, Jinhua 321004, China
[b] Surface Physics National Key Laboratory, Fudan University, Shanghai 200433, China
[c] National Laboratory for Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China

ARTICLE INFO

Article history:
Received 23 September 2012
Received in revised form 21 August 2013
Accepted 24 August 2013
Available online 6 September 2013

Keywords:
A. Semiconductors
D. Microstructure
D. Electrical properties

ABSTRACT

Al-induced a-Si crystallization process has been used to prepare polycrystalline Si (pc-Si) thin films on glass substrates. It has been found that the glass/Al/Al_2O_3/a-Si multilayer could be transformed into the structure of glass/Si/Al_2O_3/Al via a thermal treatment at 500 °C for 5 h. The Si layer in the glass/Si/Al_2O_3/Al system is in the polycrystalline state and exhibits a high crystallographic quality, a dense and continuous surface morphology, an average grain size of ~18 μm, a ~2.6×10^{19} cm^{-3} hole concentration and a ~24.2 $cm^2/V\,s$ hole mobility. The crystallographic quality and electrical performance of the pc-Si film can be further improved by increasing crystallization time and temperature. The obtained pc-Si material may be a suitable candidate for the solar cells.

1. Introduction

Comparing with amorphous Si (a-Si) and microcrystalline Si, the major advantages of polycrystalline Si (pc-Si) are high carrier mobility and stable energy conversion efficiency [1]. Now, much attention has been paid to the pc-Si thin films grown on transparent substrates due to their potential applications in microelectronic and optoelectronic devices such as thin film transistors, displays and solar cells.

Generally, thermal treatment temperature of the pc-Si films on glass could not exceed 600 °C owing to softening of glass. Thus, it is very difficult to obtain high quality pc-Si materials below 600 °C. Recent years, a two-step approach had been proposed to overcome this issue [2–4]. However, in this processing route a thin pc-Si seed layer is required to induce pc-Si epitaxial growth besides a long annealing time and small average grain size [2–4].

Very recently, the atom-exchange process based on Al-induced crystallization (AIC) had attracted a special attention because of its ability to obtain large-area and preferred-orientation pc-Si thin films at 570 °C [5–10]. In this technique, to grow continuous pc-Si films a thin layer of Al_2O_3 acting as the semi-permeable barrier is introduced to form the geometrical structure of glass/Al/Al_2O_3/a-Si. The multilayer stack of Al/Al_2O_3/a-Si is then transformed into the glass/pc-Si/Al_2O_3/Al by annealing treatment. Nast et al. not only investigated in detail the effect of processing parameters on formation of pc-Si films but also obtained the pc-Si thin films with an average grain size of ~13 μm [9].

In this work, we report the low temperature fabrication of pc-Si films with large grain size and high carrier mobility and the dependence of microstructure and electric properties of the pc-Si films on the crystallization temperature and time. It has been found that high quality pc-Si thin films could be grown by annealing the Al/Al_2O_3/a-Si multilayer stack at 500 °C for 5 h. These pc-Si films can be used as solar cell materials.

2. Experimental procedure

Corning glass (code 1334) with a softening point of ~660 °C was used as substrate, and was cleaned by acetone, ethanol, and distilled water in sequence. Prior to deposition, the sputtering chamber was pumped down to a base pressure of 4×10^{-5} Pa. Argon gas was used as working gas, and the sputtering pressure was fixed at 2.0 Pa. The sputtering power density was 1.24 W/cm^2. Firstly, a layer of Al film was deposited on glass at room temperature by DC magnetron sputtering, and then it was exposed to air to form a thin layer of Al_2O_3 used as diffusion barrier. The oxidation time was about 24 h. Secondly, the a-Si layer was deposited on the oxide layer by plasma-enhanced chemical vapor deposition (PECVD) at a depositing rate of 0.4 nm/s to form the structure of glass/Al/Al_2O_3/a-Si. Both the a-Si and Al layers thicknesses were taken as 500 nm according to the criterion suggested by Nast and Wenham for obtaining a continuous pc-Si

* Corresponding author.
** Corresponding author. Tel.: +86 021 25051872; fax: +86 021 65830734.
E-mail addresses: huangshihua@zjnu.cn (S.-h. Huang), hugj@mail.sitp.ac.cn (G.-j. Hu).

0025-5408/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.materresbull.2013.08.049

layer [11]. Finally, the as-prepared glass/Al/Al_2O_3/a-Si multilayer stack was cut into slices with nearly equal sizes, and these slices were annealed in Ar ambient to get the desired samples. The heating rate was 10 °C/min, and each sample was cooled down to room temperature naturally. For simplicity, the slices annealed at 500 °C for 10, 20, 60, and 300 min were remarked as specimens A, B, C, and D, respectively, and those slices annealed at 150 and 300 °C for 300 min were denoted as samples E and F, respectively. In addition, for comparison we also prepared the sample G by annealing the glass/a-Si at 500 °C for 5 h.

The microscopic analysis technique was used to characterize the microstructure of the formed Si films. The distribution of Si, Al, and O elements together with the film thickness were measured by secondary ions mass spectrograph (IMS-6F, Cameca). The Raman scattering spectra were recorded on a micro-Raman setup (Renishaw 2000) in backscattering configuration. X-ray diffraction (XRD) analysis was carried out on a Philips PW 3040/60 diffractometer using Cu Kα radiation. The morphology of pc-Si films was examined by a transmission optical microscope (Shanghai Changfang Optical Instrument Co., Ltd. CMM-80E). The electric property was evaluated by Hall measurement system (HMS-5000, ECOPIA).

3. Results and discussion

Fig. 1(a)–(c) shows the Al and Si elements' secondary ions mass spectra of specimens A, D, and the as-grown Al/Al_2O_3/a-Si multilayer, respectively. The inset in Fig. 1(c) represents the oxygen distribution in the Al_2O_3 interlayer. From the inset it can be seen clearly that the oxygen distributes primarily in a ~10 nm thin layer centered at 502 nm. Its peak position has hardly changed before and after annealing, but for samples A and D the peak height

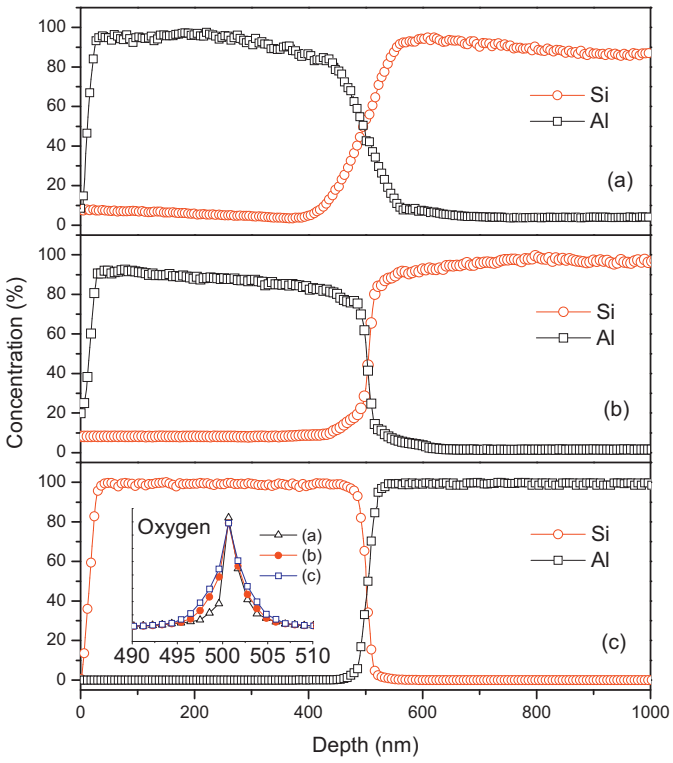

Fig. 1. Secondary ion mass spectra for sample A (a), sample D (b), and for the as-deposited Al/Al_2O_3/a-Si (c). The inset shows the oxygen distribution within the Al_2O_3 interlayer before and after annealing.

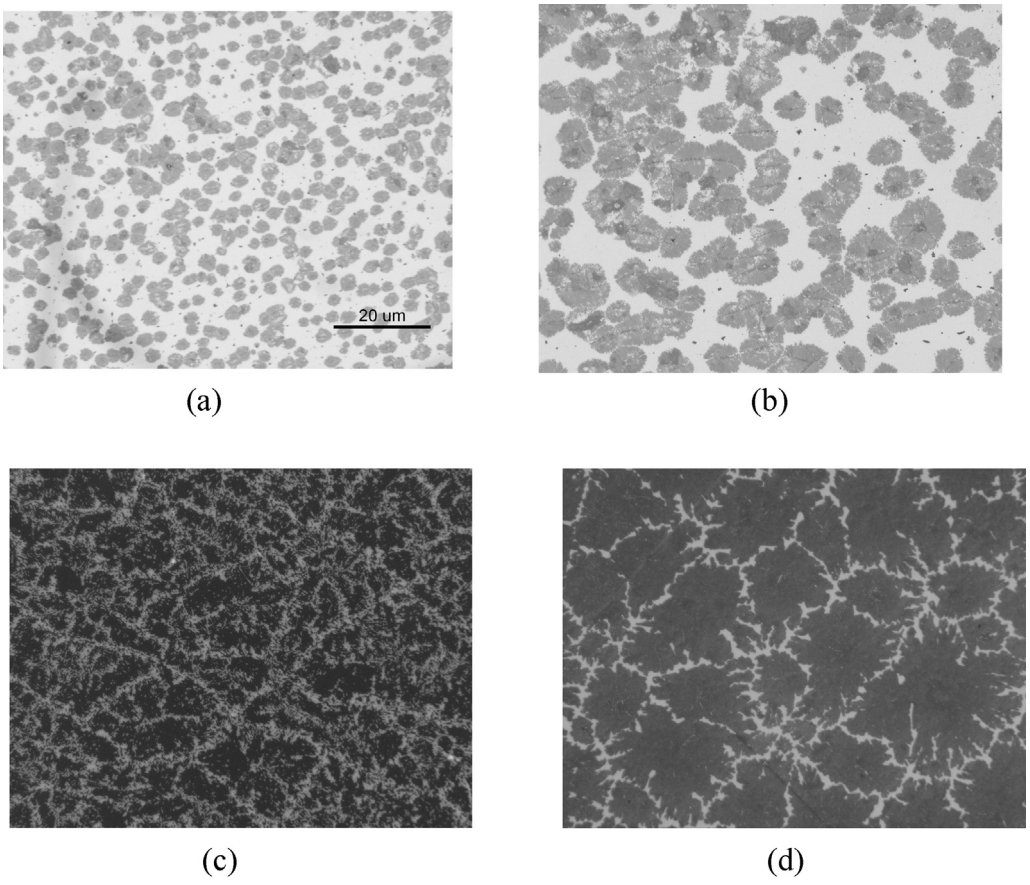

Fig. 2. Optical microscope images. (a), (b), (c), and (d) correspond to specimens A, B, C, and D, respectively.