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$CHClF_2$ gas mixtures to activate all-sputtered CdS/CdTe solar cells

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ABSTRACT

Solar cell production process entirely based on sputtering deposition is considered the most suitable for industrial applications. Based-CdTe solar cells need activation treatment usually performed by $CdCl_2$ saturated solution bath followed by high temperature annealing. Liquid, flammable and toxic reagents need special care in industrial processes. In this work, alternative activation treatments based on controlled gaseous atmospheres with Ar-O_2-$CHClF_2$ and Air-$CHCl_2$ for all-sputtered CdTe solar cells were studied. Finished devices were compared to cells activated by $CdCl_2$ saturated solution. The all-sputtered (glass/ITO/ZnO/CdS/CdTe) structures were characterized before and after the activation processes byX-ray diffraction and field emission scanning electron-microscopy. Solar cells were characterized by external quantum efficiency and current density-voltage curves. An efficiency of 11% was achieved for the solar cell activated with Ar-O_2-$CHClF_2$ gas mixture, achieving values of V_{oc} = 0.797 V and J_{sc} = 25.4 mA/cm^2. The quantum efficiency was around 90% in the 580–830 nm range.

1. Introduction

CdTe solar cells are growing in importance due to constant efficiency improvement (www.firstsolar.com/en/About-Us/Research, 2016; Rusell et al., 2015) as compared to first and third generation solar cells. In CdS/CdTe solar cells, the CdTe layer can be deposited by Close Space Sublimation (CSS) (Flores-Mendoza et al., 2011), Vapor Transport Deposition (VTD) (Ren et al., 2015) and Sputtering (Hernández-Contreras et al., 2002). However, ITO and CdS are usually deposited by sputtering, hence to design an 'all-sputtering' production process would make it simpler and cheaper. Moreover the sputtering technique allows low temperature deposition of the CdTe on the glass/ITO/ZnO/CdS stack, avoiding changes of its optical and electrical properties during its deposition (Plotnikov and Compaan, 2007). Usually, to improve the solar cell efficiency, sputtered-CdTe and CSS-CdTe solar cells are activated by wet process using saturated $CdCl_2$-MeOH solution (Plotnikov et al., 2009, 2013, 2010; Moutinho et al., 1998). However, wet process presents some drawbacks for large area applications. Particularly, it is difficult to homogeneously distribute chlorine on the CdTe surface due to the interaction of the liquid with the CdTe. Moreover, $CdCl_2$ is toxic and a chemical treatment for final disposal is required, therefore, the solar cells production costs increases. For these reasons, researchers have proposed different activation processes (Major et al., 2014; Drost et al., 2015; Major et al., 2015; Williams et al., 2015), most of them based on non-toxic liquid solutions, which usually are deposited on the samples surface or evaporated. On the other hand, Romeo et al. (2006) proposed a gaseous activation treatment which avoids liquid solutions and improves the activation homogeneity for large area applications. Additionally, the gaseous activation presents an important advantage: the amount of chlorine can be controlled by gases partial pressure in the treatment atmosphere. The chlorination process reported in Romeo et al. (2006) was performed by annealing the sample at 400 °C in Ar-$CHClF_2$ atmosphere into a quartz tube for 30 min. The mentioned process has been successfully modified adding oxygen in the vacuum chamber to activate the CSS-CdTe solar cells, achieving efficiencies above 14% (Rios-Flores et al., 2011; Rejon et al., 2013). It is reported that oxygen plays an important role in $CHClF_2$ decomposition (Gong-Liang et al., 1996) and p-type doping of CdTe promoting the intermixing formation (Razykov et al., 2011; Albin et al., 2002).

The aim of this work is to study the all-sputtered CdS/CdTe solar cells activated with $CHClF_2$ gas mixtures. Particularly, the activation cases of Ar-O_2-$CHClF_2$ and Air-$CHClF_2$ were analyzed. Morpho-

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Full Length Article

Structural and photoluminescent properties of a composite tantalum oxide and silicon nanocrystals embedded in a silicon oxide film

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ABSTRACT

Tantalum oxide crystals encrusted in a silicon oxide matrix were synthesized by using a hot filament chemical vapor deposition system (HFCVD). A solid source composed by a mixture in different percentages of Ta_2O_5 and silicon (Si) powders were used as reactants. The films were grown at 800 °C and 1000 °C under hydrogen ambient. The deposited films were characterized by X-ray photoelectron spectroscopy (XPS), high-resolution transmission electron microscopy (HRTEM) and photoluminescence (PL) at room temperature. From the XPS results it was confirmed the formation of a mixture of Tantalum oxide, silicon oxide and Si nanoparticles (Ta_2O_5-SiO_2-Si(nc)) as seen from the Si (2p) and Ta (4f) lines corresponding to Si^+ and Ta^+ states respectively. Ta_2O_5 and Si nanocrystals (Si-NCs) embedded in the silicon oxide films were observed on HRTEM images which corroborate the XPS results. Finally the emission properties of the films exhibited a broad band from 400 to 850 nm caused by the independent PL properties of tantalum oxide and Si-NCs that compose the film. The intensity of the emissions was observed to be dependent on both temperature of deposition and the ratio Ta_2O_5/Si, used as initial reactants. Results from this work might supply useful data for the development of future light emitter devices.

1. Introduction

Recently, nanocomposites are of interest in both, scientific and technological issues due to its novel properties that can be applied in several science and technology fields. In electronic technologies the nanocomposites has been applied in photo catalysis [1,2], solar cells [3,4], gas sensors [5,6], electronic and optoelectronic devices [7,8]. This because, many electronic devices are based on silicon, this material is the most widely studied and it is very important in microelectronics industry. However, crystalline silicon is unsuitable for light emission in the visible range due to its indirect band-gap. Recently, several alternatives are being investigated to overcome this limitation; silicon nanocrystals (Si-NCs) embedded in a SiO_2 matrix is one of them [9,10]. Visible PL at room temperature has been observed in this type of materials and although the origin of that PL still in debate two mechanisms has been proposed to explain those emissions. First of one is the recombination of electron-hole pairs in Si-NCs. An enlargement of the optical band-gap of Si-NCs due to quantum effect is carried on as the size of such Si-NCs is of the order of Bohr radius. The observed emissions are in the range of 570–645 nm. The other effect is concerned to the oxygen related defects in the interface of Si-NCs–SiO_x that introduces radiative recombination centers. The wavelength emission depended on the type of defect introduced but commonly that is in the range of 415–540 nm. Silicon nanoparticles doped with erbium, Ytterbium, boron and phosphorous having SiO_2 as a host, have been grown to improve the PL properties of that material and it was observed a shift emission length from red to near infrared region [11–14]. ZnO:Si nanocomposite and ZnO/porous silicon as nanocomposites and structures have also been fabricated to produce white light [15–17].

On the other hand, tantalum oxide is a material that due to its interesting properties, such as high dielectric constant (~23), good dielectric breakdown strength and a direct band-gap of 4.2 eV, can be applied in the present semiconductor technology. Moreover, this material has been used as gate dielectric layer in metal-oxide semiconductor devices (MOS) in order to replace SiO_2 [18–20]. Under properly conditions, tantalum oxide exhibits light emission properties that make it suitable to develop light emitters and other optoelectronic devices. The existence of oxygen vacancies in the tantalum oxide matrix seems to be responsible for high intensity emissions observed in those oxides.

Both of them, SiO_2-Si-NCs and Ta_2O_5, can be deposited on

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