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Multilayer Si/Ge thin films with quantum confinement effects for photovoltaic applications

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ABSTRACT

Multilayer thin films of Si and Ge were grown by e-beam evaporation and resistive heating techniques. Each Si-layer has a thickness of 15 nm and that of Ge is 20 nm. In this way, three sets of multilayer structures with 2, 4 and 6 layers of Si and Ge in an alternative way were deposited on glass substrates. Structural and electrical properties of these multi-layer films were studied using Raman spectroscopy, Rutherford backscattering, Fourier transform infrared spectroscopy, and electrical resistivity measurements. Raman spectra of these multilayer thin films exhibit peaks shift towards lower wavelength (in comparison with bulk Ge) demonstrating that the films consist of nanostructures and also represent quantum confinement effect in Ge. The quantum confinement effect increases with the increase in number of layers. Raman spectra also reveal the formation of silicon oxide and germanium oxide. FTIR spectroscopy also confirms the presence of oxides in these multilayer films. The layer thickness and composition was determined using Rutherford backscattering spectroscopy. The DC-conductivity measurement of Si/Ge multilayer thin films shows gradual increase in conductivity with the increase in number of layers. These multi-layer Si/Ge films show high electrical conductivity in comparison with pure Ge and Si films due to the SiGe alloy phase formed at the interface during deposition. These investigations suggest that Si/Ge multilayer thin films with quantum confinement effects can be used for solar cells.

1. Introduction

Thin films fabricated in the form of multi-layers at nanometer scale give unusual properties due to their reduced dimensions. The properties of multi-layer films strongly depend on its thickness. An extremely thin film/layer is characterized by a high surface-to-volume ratio, and its small size perpendicular to the film giving rise to quantum confinement of electrons. Novel properties can also be obtained in rather thicker nanostructured films composed of multi-layers, nanoclusters, nanocomposites, etc., by interfacial phenomenon and quantum confinement effects. Nanostructured semiconducting materials, particularly 2-D thin films are of prime importance due to their structure dependent optical and electrical properties such as absorption, transmission, conductivity, mobility, etc. that can be used to design and create new generation of electronic devices predominantly photovoltaic [1–9].

The concept of tandem thin film photovoltaic (third generation photovoltaics) possessing cascading band gaps and exploiting quantum confinement effect has become the focus of research nowadays. The high efficiency of third generation photovoltaic is due to the reduction in loses by absorption of wide spectrum of solar radiation by different semiconductor absorber stacked over each other in decreasing band gap order [1,2,10]. Quantum confinement has noticeable effect on the structural, electrical and opto-electronics properties of the nanomaterials or nanostructured thin films causing size-tunable properties [1–3].

Ge has a Bohr radius of 25 nm while Si has 5 nm. The larger Bohr radius of Ge in comparison with Si makes it easier to tune the electronic properties of Ge and consequently, exhibits more prominent quantum confinement effects. The indirect band gap of silicon is about 1.1 eV, while Ge has 0.67 eV at room temperature. Ge (containing nanoparticles) in the Si matrix shifts the absorption edge of germanium towards higher energies subject to the particle size [11]. This effect can be used to increase the conversion efficiency of these Si/Ge films for solar devices. Nevertheless, the ability to deposit multi-layer films using PVD techniques with nanoscale precision is of prime importance for the fabrication of photovoltaic device. In this respect, it is worthwhile to fabricate the multi-layer

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