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Gap states density measurement in copper oxide thin films

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ABSTRACT

The density of gap states near the Fermi level have been measured in copper oxide (CuO) thin films deposited by spray pyrolysis technique. The measurement method is based on the exploitation of the current–voltage characteristics of the space charge limited current (SCLC) measured in a sandwich Au/CuO/Au structure. The measured gap states density is equal to 1.5×10^{14} cm^{-3} and 2.0×10^{14} eV^{-1} respectively in films prepared at 300 and 400 °C substrate temperature, while the defect position are located at 16 and 20 meV above Fermi level. The carriers mobility and concentration are also determined from SCLC, the obtained results are in good agreement with Hall effect measurement ones.

1. Introduction

A large research activity have been devoted to new materials investigation for low cost thin films solar cells. Generally solar cell device is based on pn homo-junction or an heterojunction between two semiconductors with different gaps. Thin films based heterojunction solar cells is formed with a stack of buffer layer (such as CdS or ZnS) and an absorber layer. The commonly used absorber layers are CuIn(Ga)Se, Cu_2ZnSnS_4, CuO and SnS films. The incident photons are wholly absorbed and converted to free carriers in this layer. Thereafter solar cells performance i.e photocurrent , open circuit voltage and efficiency are close related to the electronic properties of the absorber layer. The presence of electronic defects in the band gap is crucial and may be a serious drawback of cells conversion, they hinder photo-generated charges collection through their recombination. Therefore, determination of the density of states (DOS) localized in the material band gap is an ambitious task and their diagnostic is important for the study of material dedicated to photovoltaic conversion. Several techniques have been used for DOS measurement in semiconductors such as: field-effect measurements [1], capacitance measurements [2], space charge limited current (SCLC) [3], deep-level transient spectroscopy (DLTS) [4] and photoluminescence (PL) measurements [5]. Among these techniques the space charge limited conduction (SCLC) technique has been extensively used for measurement of the DOS for amorphous hydrogenated silicon (*a*-Si:H) [6], organic semiconductors [7] and nano-cluster carbon [8]. The experimental measurement requested by this technique is simple and easy , it needs less equipments by comparison to the other techniques. It is based only on the exploitation of the current–voltage characteristics. Copper oxide (CuO) has emerged as a promising material as absorber layer in solar cell [9,10]. CuO is a monoclinic semiconductor with an optical band gap ranged from 1.21 to 1.55 eV [11] which matches well with the solar spectrum and enjoys a high absorption coefficient in visible region which is suitable for solar energy conversion. Moreover, it is a p type semiconductor and is considered as a good partner to CdS or ZnS to form with an heterojunction necessary for thin films solar cells production [12]. On the other hand it is composed of inexpressive, no-toxic and available elements. To our knowledge no studies have been devoted to investigation of gap state density in CuO. The present work deals with the estimation of the density of localized state near the Fermi level and the carrier mobility in CuO thin films deposited by ultrasonic spray pyrolysis, using the space charge limited conduction (SCLC) measurements.

2. Experimental details

Copper oxide thin films have been prepared by ultrasonic spray pyrolysis. The precursor solution was prepared by dissolving 0.05 M copper chloride ($CuCl_2.2H_2O$) in distilled water. The precursor solution is sprayed, using an ultrasonic generator with a frequency of 40 KHz, in fine droplets of 40 μm diameter on heated glass substrate in ambient air. Films are formed by pyrolytic reactions. During deposition, the substrate temperature is kept at 300 and 400 °C. This temperature range is chosen to ensure a complete precursor decomposition and to avoid the presence of chloride in films network. Deposition time was fixed equal to 30 minutes.

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