Synthesis of Nanocrystalline Cu-In Chalcogenide Thin Films By Sequential Chemical Bath Deposition (S-CBD) Method

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Abstract

Nanocrystalline semiconducting materials are ideal systems for investigating the dependence of electrical transport, optical properties and mechanical properties on size and dimensionality. They are expected to play an important role as both interconnects and functional components in the fabrication of nanoscale devices. Nanocrystalline semiconducting materials have attracted steadily growing interest due to their fascinating properties, as well as their unique applications relative to their bulk counterparts. The ability to generate such structures is now central to the advance of many areas in modern science and technology.

Cu-In chalcogenide [$CuInX_2$ (X = S, Se and Te)] semiconductor materials have emerged as leading candidate in photovoltaic applications. Cu-In chalcogenide semiconductors are associated with their desirable and exceptional properties for terrestrial photovoltaic applications. They received attention due to their optical band gaps [$CuInS_2$ (Eg = 1.5 eV), $CuInSe_2$ (Eg = 1.1 eV) and $CuInTe_2$ (Eg = 0.9 eV)] are near optimum values for homojunction or heterojunction (with a wide band gap window layer) photovoltaic applications; the optical absorption coefficients are extremely high ($10^5 cm^{-1}$). All three appear to have a direct band gap, which minimise the requirements for minority carrier diffusion lengths. Both n-type and p-type materials can be produced, allowing homojunction formation as well as a variety of heterojunction types etc.

The growth mechanism of chemical bath deposition (CBD), also known as one step CBD, involves, formation of precipitate, growth of particles and growth of thin film. CBD synthesis is not economical as the precipitation in the solution and thin film deposition on substrate occur simultaneously. Precipitation formation is an undesirable, which can't be eliminated. The high percentage loss is not affordable and it stands out as an important disadvantage of CBD. Sequential CBD is mainly based on the adsorption and reaction of the ions from the solutions and rinsing between every immersion with deionised water to avoid homogeneous precipitation in the solution. Following the above-mentioned steps the maximum film thickness could be obtained.

In the present work, using S-CBD method deposition of CIX_2 thin films have been carried out by: 1) deposition of indium sulphide over copper sulphide (separate cationic precursors), and 2) simultaneous adsorption of Cu and In ions and their reaction with sulphur ions (combined cationic precursor). Semiconducting Cu-In chalcogenides ($CuInS_2$, $CuInSe_2$ and $CuInTe_2$) thin films have been deposited at room temperature. In order to obtain stoichiometric $CuInX_2$ (X = S, Se and Te) thin films, preparative conditions such as concentration, pH of cationic and anionic precursors, adsorption, reaction and rinsing time durations etc have been optimized. The characterization of the films have been carried out by means of X-ray diffraction (XRD), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), High Resolution Transmission Electron Microscopy (HRTEM), Rutherford back scattering (RBS), optical absorbance, electrical resistivity, Photoelectrochemical (PEC) measurement and thermoemf. The XRD, SEM, AFM and HRTEM study revealed that films are of nanocrystalline. The SEM showed films well covers the surface of the substrate. The optical absorbance of $CuInX_2$ film was found to be high (10^5 cm^{-1}). The films showed thickness dependent properties. The films showed p-type electrical conductivity and have photoactive in polyiodide electrolyte.