Crystallization Study of the $CuSbS_2$ Chalcogenide Material for Solar Applications

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Second generation thin-film chalcogenide materials, in particular CuInGa(S,Se)2 (CIGS) and CdTe, have been among the most promising candidates for large-scale PV manufacturing and are quickly becoming commercial products. These materials offer stable and efficient (above 10%) photovoltaic modules fabricated by scalable thin-film technologies and cell efficiencies above 20 % (CIGS). $CuSbS_2$ is a chalcogenide that was discovered in 1942 as a dark gray mineral in Morocco/Tunisia. $CuSbS_2$ is a relatively new material with little research published but is expected to be interesting for environmentally amenable solar cells, as its constituents are nontoxic and are relatively abundant in the earth's crust. $CuSbS_2$ thin films show p-type conductivity, a band gap of around 1.5 eV, which is ideal to achieve the highest solar-cell conversion efficiency, and a relatively high optical absorption in the visible light range. It also benefits from a low crystallization temperature of 250 ^{o}C, which allows easier synthesis for flexible solar cells.

Various techniques have been developed for synthesizing $CuSbS_2$ but to meet the goal of cost effective fabrication, suitable thin film in-line coating and processing techniques have to be realized. Among possible deposition methods, sputtering can provide good control on film composition at a relatively low cost and is suitable for large-area, continuous and multi-component deposition. This method is already an established technique for the preparation for thin films for magnetic, optical and contact applications. Annealing by rapid thermal processing is a method that significantly reduces the thermal budget of the sample as compared to conventional furnace annealing. In addition to production related issues, the principal advantages of low thermal budget processing is the minimization of interdiffusion and impurity diffusion from the substrate as well as better control of the process kinetics.

In this work, $CuSbS_2$ thin films were first deposited by RF magnetron sputtering at room temperature from a single ternary target on molybdenum coated substrates using a Kurt Lesker NANO-38 thin film deposition system. The films were annealed in a Jipelec JetFirst 100 bench top rapid thermal processor at 250, 300, 325 and 350 ℃ for 5 min; with a ramp rate of 50 ℃ per minute. The annealing was done without any toxic gases or reactive sulfur. The compositional and structural properties of the films were analyzed using EDX, SEM, XRD and Raman.$CuSbS_2$ films with good adhesion; good crystallinity and with no apparent sulfur loss can be achieved. Finally an in depth analysis of the crystalline phases formed was undertaken, and at higher annealing temperatures an antimony instability in the films has been identified.

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