VISIBLE AND X-RAY SPECTROSCOPY STUDIES OF DEFECTS IN CdTe

A. Gupta, A.D. Compaan, K. Price,[a] A. Vasko, K. Hinko,[b] X. Liu, M. Fritts, N. Leyarovska,*J. Terry#
Dept. of Physics, Univ. of Toledo, Toledo, OH 43606
* Illinois Institute of Technology, Chicago, IL 60616
#Univ. of Notre Dame, South Bend, IN

ABSTRACT

We have used electroluminescence (EL), photoluminescence (PL), and synchrotron x-ray fluorescence (XRF) to study some of the properties of defects related to Cu and Na in polycrystalline thin films of CdTe. Some samples were prepared by ion implantation of CdTe single crystals followed by thermal anneal to remove the damage. Others were prepared by magnetron sputtering on quartz or borosilicate glass followed by vapor $CdCl_2$ heat treatment. EL was studied from sputtered CdS/CdTe solar cell structures. We find that EL is very sensitive to defects induced by light soaking; ion implantation-induced damage can be annealed at 400 C to yield good PL; and synchrotron XRF shows the presence of substantial copper in films sputtered from nominally pure CdTe.

INTRODUCTION

Extrinsic defects such as Cu and Na can play important roles in thin-film polycrystalline solar cells. In CdTe, Cu is often used as part of a back contact preparation but Cu easily migrates to the CdS/CdTe junction region and into the CdS during processing and perhaps during cell operation.[1] Furthermore, its chemical state and electrical activity can be changed by moderate light soak and recovered again by subsequent heat treatments.[2] In this study we have used ion implantation with photoluminescence, electroluminescence, and x-ray fluorescence to improve our understanding of Cu and Na impurities in CdTe. 1) Photoluminescence was used together with ion implantation and annealing to help identify the role of defect states of Cu, Na and other impurities. 2) We have quantified the density of Cu in thin films of CdTe through the use of synchrotron x-ray fluorescence using x-ray energies slightly above the k-edge of Cu. We find significant densities of residual copper in films prepared by magnetron sputtering from high purity CdTe targets. 3) We have used electroluminescence from CdS/CdTe solar cells to track changes induced by light soak stress. We find that the EL signal is much more sensitive to stress-induced changes than is the J-V curve or cell efficiency.

PL FROM Cu ION IMPLANTED CdTe

Ion implantation is a convenient method of introducing calibrated quantities of known extrinsic impurities and has been used together with PL for studies in CdTe. Halliday, et al.,[3] have used samples lightly implanted ($\sim10^{15}/cm^3$) with a variety of species. We have implanted Cu into single crystal CdTe at higher doses to continue our PL studies of this important acceptor. In order to match the laser absorption length, we carried out the implantation at energies up to 440 keV (using Cu^{++}) to yield Cu densities of 1E16, 1E17 and 1E18 (Cu atom/cm^3). The projected range and the range straggling were calculated by the Monte Carlo program "Stopping and Range of Ion in Matter" (SRIM) [4,5] which is an extension of the familiar TRIM. At 440 keV the range and range straggling are $R+\Delta R=0.2068+0.0909$ μm. In order to achieve a uniform implant density, we used three energies, 440, 200, and 100 keV with fractional doses, respectively, of 78%, 14% and 8%. Fig. 1 shows the calculated Cu density vs. depth in CdTe.

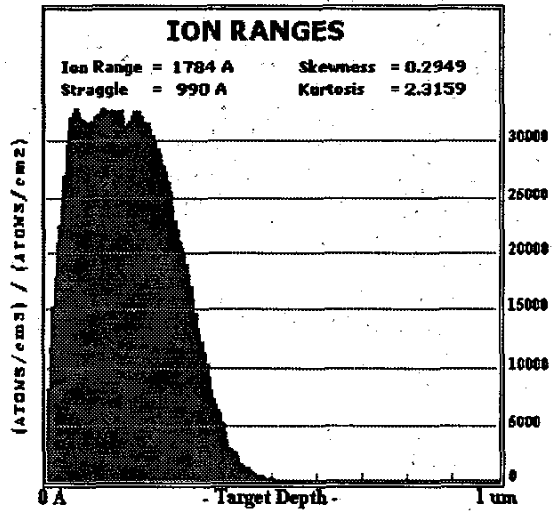

Fig. 1. SRIM-calculated Cu density vs. depth for a triple-energy implant in CdTe.

Our PL studies were done with the 488 nm line of an Ar ion laser to provide excitation depth ($1/\alpha = 0.2$ μm) nearly matching the projected range. The lowest density implant, 1×10^{16} cm^{-3}, shows additional PL bands even before annealing if a careful subtraction is done relative to the adjacent unimplanted region. The two heavier doses clearly show the influence of damage in quenching the PL signal from the implanted region.

0-7803-7471-1/02/$17.00 © 2002 IEEE