Application of X-ray Topography Techniques to the Study of Defects and Strain in Solar Materials

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Crystalline silicon photovoltaic (PV) modules are the predominant devices used in solar farms. The performance and lifetime of encapsulated silicon solar cells that constitute a module are a complex function of different variables from the manufacturing process and the module operational environment. Understanding the impact of various factors would greatly contribute to improving PV silicon-based renewable energy technologies. Among these factors, defects and strain in the silicon material play a critical role in determining the efficacy of the cells that make up the module. The application of X-ray topography can non-destructively provide information on the nature and distribution of structural defects such as dislocations, inclusions/precipitates, twins and low angle grain boundaries, etc. in the silicon material. Further by using a mesh/grid in the path of the incident/diffracted beam (i.e. X-ray reticulography) it is possible to trace the change in path of X-rays diffracted from for e.g. a strained region of crystal and quantitatively determine the full strain and thereby the stress tensor as a function of position inside the crystal. Thus, applying both X-ray topography and X-ray reticulography at each stage of the module manufacturing process enables understanding and lead to improved control of the processing sequence used to convert high purity silicon chunk into crystalline Si solar cells. Using the high intensity, broad energy range, high brightness and low divergent X-ray beam provided by a synchrotron source such as NSLS-II, we can rapidly and non-destructively image and characterize defects and strains at micron resolution. Direct imaging of the silicon material encapsulated in the cell will also allow in situ monitoring to study the generation, interaction and propagation of defects during device operation or for XBIC studies to identify performance limiting defects. In this presentation, an overview of X-ray topography and X-ray reticulography will be provided along with appropriate experimental results from packaged silicon devices and solar cells.