

Abstract

Amorphous and nano- or micro- crystalline silicon thin films are intensively studied materials for photovoltaic applications. The films are used as intrinsic layer (absorber) in p-i-n solar cells. As opposed to crystalline silicon solar cells, the thin films contain about hundred times less silicon and can be deposited at much lower temperatures (typically around 200 °C) which saves energy needed for production and makes it possible to use various low cost (even flexible) substrates.

However, these films have a complex microstructure, which makes it difficult to measure and describe the electronic transport of the photogenerated carriers. Yet, the understanding of the structure and electronic properties of the material at nanoscale is essential on the way to improve the efficiency solar cells.

One of the main aims of this work is the study of the structure and mechanical properties of the mixed phase silicon thin films of various thicknesses and structures. The key parameter of microcrystalline silicon is the crystallinity, i.e., the microcrystalline volume fraction. It determines internal structure of the films which, in turn, decides about many other properties, including charge transport and mechanical stability. Raman microspectroscopy is a fast and non-destructive method for probing the microstructure. The factors which can influence the measurement are considered for the case of silicon thin films. The method of crystallinity evaluation by the Raman microspectroscopy is described. It is also shown that Raman mapping can be done with very high resolution which sometimes can overcome the resolution limit due to optical diffraction.

The Raman spectroscopy can not only distinguish amorphous tissue from microcrystalline grains but it also provides information about local stress in the film, which has a special importance for the properties and stability of the films on flexible substrates. We introduced an original setup for the stress creation in which the silicon films were deposited on the AFM cantilevers and then bent by a micromanipulator to introduce an extrinsic stress. We demonstrated that the positions of the Raman peaks changed linearly with the applied stress both for amorphous and microcrystalline silicon and we were able to compare the same film in stressed and relaxed states.

Another aim of this work was the microscopic study of the charge transport in hydrogenated microcrystalline silicon with nanometer resolution. The final part of the thesis covers the results of the conductive atomic force microscopy (C-AFM) study. Thin films of microcrystalline silicon were studied both in coplanar configuration as well as in "sandwich" setup. Results of C-AFM made in ultra high vacuum and in ambient atmosphere are discussed and compared, including the local I-V characteristics. It was demonstrated that in ambient atmosphere (under which the silicon film is covered by a layer of native oxide and thin layer of condensed water) the C-AFM measurement itself may change the properties of measured sample due to the local anodic oxidation and charge trapping at the interface between silicon and its oxide. It was shown how both these processes can lead to artifacts which can fundamentally change character of the conductive maps, leading for example to the appearance of conductive rings at the grain edges. We have identified the neighboring line oxidation as the origin of this artifact which occurs even upon the first scan of a pristine surface. We also show how to avoid these artifacts. To support our conclusions the native oxide was stripped away by HF acid and we demonstrated that after the etching the character of maps of local currents measured in ambient air became comparable to the maps measured in ultra high vacuum.