TEM studies of PbS-ZnS quantum wells for solar cells

P. G. Schindler[1], N. P. Dasgupta[2], C. Rentenberger[1], T. Waitz[1], F. B. Prinz[2,3] and H. P. Karnthaler[1]

1. Physics of Nanostructured Materials, Univ. of Vienna, Boltzmanng. 5, 1090 Wien, Austria
2. Departments of Mechanical Engineering, Stanford University, Stanford, CA 94305, USA
3. Departments of Materials Science and Engineering, Stanford University, Stanford, CA 94305, USA

peter.schindler@chello.at
Keywords: photo voltaic, quantum well solar cells, cross-section TEM, PbS, ZnS

Research to maximize the efficiency of solar cells (SC) that can be used for photovoltaic power generation is a timely issue. SC based on Si technology use only a limited range of frequencies of the solar spectrum for energy conversion. To overcome this, different approaches can be used, e.g.: dye-sensitized solar cells, semiconductor sensitized solar cells and quantum confinement solar cells (QCSC). In QCSC, features with dimensions in the nm range open up the opportunity for band gap engineering by quantum effects. We report on a transmission electron microscopy (TEM) study of layers of ZnS and PbS deposited by atomic layer deposition (ALD) [1].

To prepare cross-section TEM samples the layered structures were glued together face to face to protect them using a two-component epoxy resin. The samples were cut with a diamond wire saw and mechanically polished finally using a 0.5 μm diamond paste and afterwards an alumina suspension. In a last step the wedge shaped TEM foils (having an extremely shallow angle) were softly polished with Ar^+ ions.

Fig. 1 shows a TEM image of the cross-sectioned multilayer structure on a substrate of amorphous quartz (on the right) with a layer of Pt followed by alternating layers of ZnS and PbS, finally ending with a layer of glue (on the left). At the bottom of Fig. 1 the intensity profile of the TEM image perpendicular to the layers integrated over about 80 nm is shown. The mass scattering contrast of the TEM bright-field image yields low intensity values for elements of high atomic numbers. The intensity profile is used to get an estimate of the thickness of the layers (from right to left): Pt (47±2 nm), ZnS (4.5±0.5), PbS (7.5±1.0), ZnS (11±2 nm), PbS (16±3 nm) and ZnS (11±3 nm).

Fig. 2 makes use of bright field diffraction contrast to get an estimate of the size of the larger grains of the PbS layers. The result is that their size is about corresponding to the thickness of the PbS layers. The roughness of the layers increases with distance from the Pt layer.

In the TEM image of Fig. 3 the atomic structures are resolved. Frequently moiré patterns are observed indicating that small grains (with sizes of a few nm) are present; some twin structures are observed (e.g. between b and c). For the calibration of the atomic structures, the lattice spacing 0.23 nm of (111) planes of Pt was used. Power spectra of local regions based on FFT were carried out to analyze the layers in detail. This leads to the result that the layers near a and c contain cubic ZnS whereas near b PbS is encountered.

Further studies are carried out to improve the structures by heat treatment and to analyze them by high angle annular dark field TEM methods.

1. N. P. Dasgupta, W. Lee, F. B. Prinz, Proceedings of the 34th IEEE Photovoltaics Specialists Conference, Philadelphia, PA, 2009, in press.
2. The authors (P.G.S., C.R., T.W., H.P.K.) acknowledge the support by the research project „Bulk Nanostructured Materials“ within the research focus „Material Science“ of the University of Vienna.

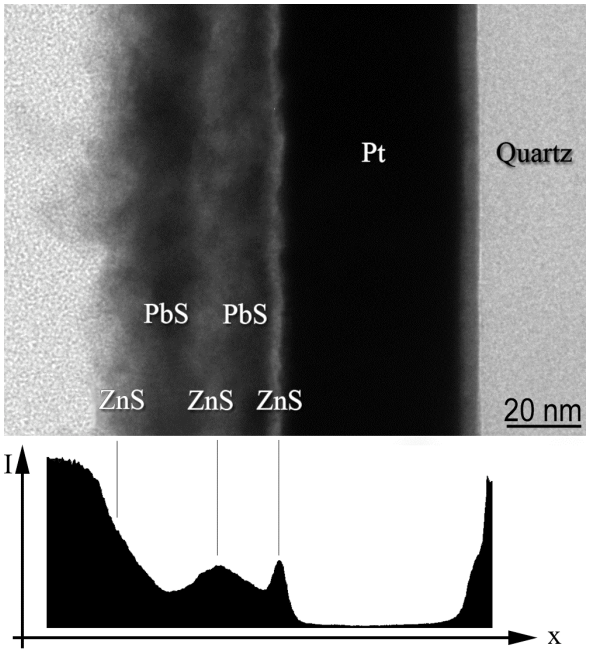

Figure 1. TEM image of cross-sectioned layer structure. The intensity profile of the mass contrast is used to estimate the thickness of the layers.

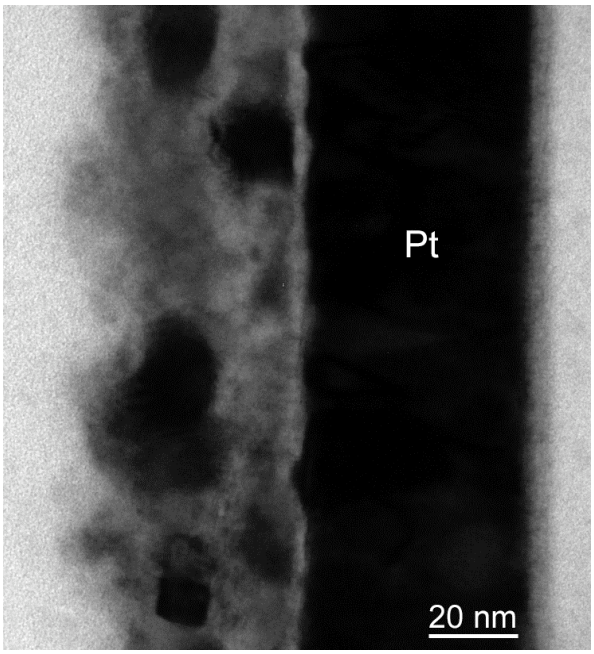

Figure 2. TEM bright field image; diffraction contrast is used to analyze the size of the large grains of the PbS layers showing that it corresponds to the thickness of the layers.

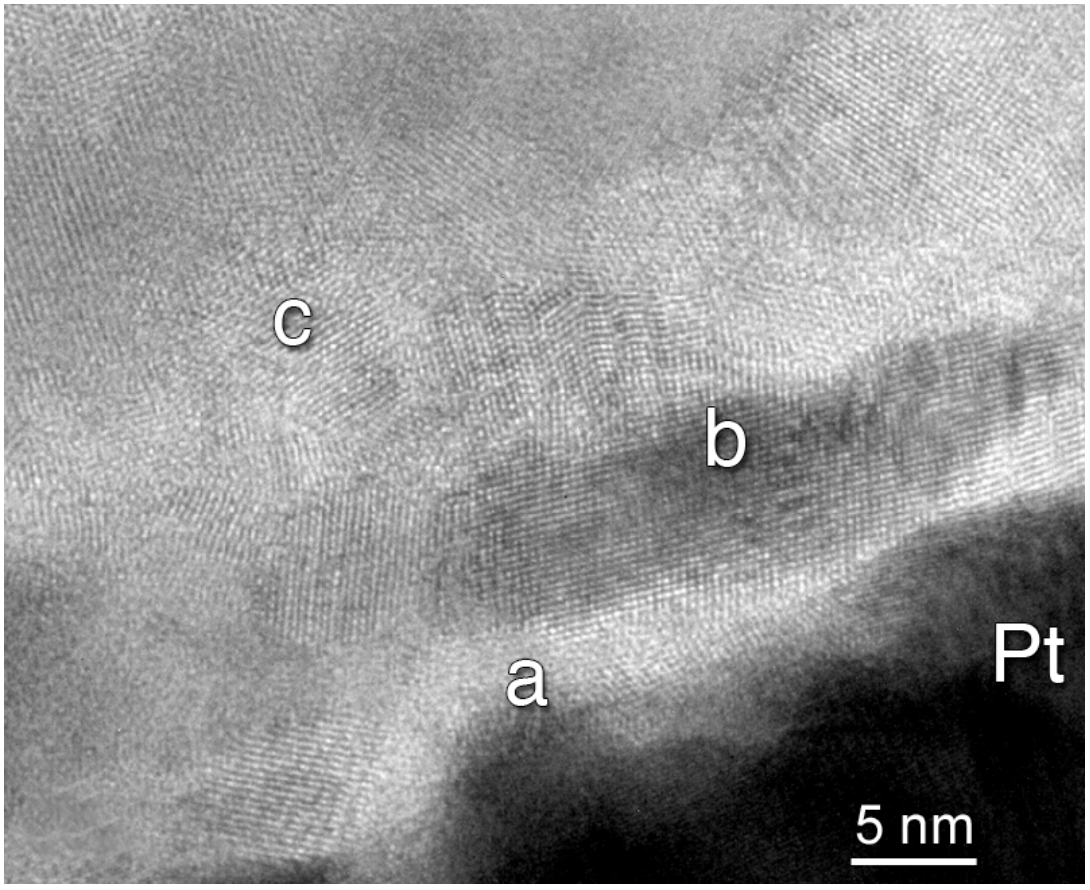

Figure 3. TEM structural contrast image; power spectra of local regions are used to identify the structures: the layers near a, b and c contain ZnS, PbS and ZnS, respectively.

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-607 , © Verlag der TU Graz 2009