PO1044

Combining a Magnetron Sputtering Plasma with an Electron-Cyclotron Resonance Plasma for the Deposition of $Cu(In,Ga)S_2$ Films

Thomas Welzel[1], Karl Barucki[2], Jonas Krause[1], Karsten Harbauer[1], Klaus Ellmer[1]

[1]Helmholtz-Zentrum Berlin, Berlin, Germany [2]IOT Innovative Oberflächentechnologien GmbH, Leipzig, Germany

thomas.welzel@helmholtz-berlin.de

Magnetron sputtering (MS) is widely used for the deposition of high-quality thin films, e.g. in photovoltaics, especially for the transparent conductive oxide front and the metallic back contacts. The reason is that moderate particle energies either obtained from the sputtering process or low-energy ion bombardment (below 50 eV) improve density and structural formation of the films at low substrate temperatures. The use of MS for the deposition of thin film absorber layers, e.g. $Cu(In,Ga)S(e)_2$ chalkopyrites is still a challenge because the essential opto-electronic properties can be perturbed by bombardment with high-energetic (above 100 eV) particles (atoms, ions). To overcome this problem, either the high-energetic bombardment – an intrinsic property of reactive MS – should be reduced or additional low-energy bombardment could be tried to anneal defects.
We have combined an MS system with a beamlike electron-cyclotron resonance (ECR) plasma with the primary intention to inject additional charge carriers in the magnetron plasma torus to reduce its impedance and hence the high energy of negative ions. The comparably high plasma density of the ECR plasma was additionally used to enhance the weak plasma in the substrate region by changing the direction of the ECR beam. Investigations with the ECR beam pointing differently into the magnetron target region showed that the target voltage reduction is generally insufficient with about 10% even if the ECR source is facing the target. A comparison of the simulated combined magnetic field and the plasma distribution revealed a strong magnetic shielding forming a separatrix between the magnetron and the ECR plasma. A reduction of the high ion energies is therefore not feasible. However, directing the ECR beam into the substrate region led to a significant improvement of solar cell efficiencies for $Cu(In,Ga)S_2$ absorber layers deposited with this plasma source combination. Possible reasons for this unexpected improvement are discussed.

Keywords
Magnetron Sputtering, ECR Plasma, Ion-Assisted Film Growth, Thin Film Solar Cells, Chalkopyrite Films