Applied Research Activities

Reactive Sputter Deposition of Zn-(IV)-Nitride films

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The class of Zn-IV-N_2 semiconducting thin films are attractive for novel opto- or power-electronic devices and for thin film solar cells, since their bandgap energies are widely tuneable (E_g =1 - 3 eV). Also, their base materials (zinc, tin, silicon, germanium) are abundant elements, and they can be prepared by reactive sputter deposition with non-toxic process gases (mixture of argon and nitrogen). Major challenges so far are: 1. Unintentional oxygen doping, 2. Defect formation due to energetic plasma species, 3. Adjustment and control of the layer growth. Plasma analysis and layer diagnostics are systematically used to develop a robust sputtering technology.

During reactive magnetron sputtering with rf-excitation, reactive nitrogen species are formed in the plasma, which are beneficial for the growth and the electronic properties of semiconducting polycrystalline Zn_3N_2 and $ZnSnN_2$ films, e.g., low carrier densities and high mobilities. Furthermore, the high plasma density during sputtering with rf-excitation allows for a reduction in substrate temperature (T<100 °C) for film deposition. During sputtering from zinc and tin targets in various nitrogen-argon gas mixtures, the ion energy distribution functions of positive ions as well as mass spectra for specified ion energies were measured in dependence of the plasma process parameter. We investigated the energy flux and the deposition rate using a combined plasma and deposition sensor.

Zn_3N_2 films were deposited onto glass substrates and silicon wafers in argon-nitrogen plasma without substrate heating. The optical and electrical properties of semiconducting Zn_3N_2 were examined. These films were polycrystalline n-type semiconducting materials (E_g =1.1 eV) with high electron mobilities (μ_e > 20 cm^2V^{-1} s^{-1}) and low carrier concentration ($n_e \approx 2 \times 10^{17}$ cm^{-3}). Increasing the substrate temperature leads to an unintentional doping of oxygen due to the residual gas in the vacuum chamber.

Nano-crystalline $ZnSnN_2$ films were grown by rf-sputtering from a zinc-target and tin-target in a reactive nitrogen plasma without substrate heating. These films were n-type semiconductors with low carrier densities, like $n_e \approx 5 \times 10^{16}$ cm^{-3} and had optical band gap energies of approximately 1.5 eV, which may be suitable for photovoltaic applications.