Plasma diagnostics in various configurations of reactive pulse magnetron sputtering systems used for thin film deposition of semiconductors

Z. Hubička, Institute of Physics Czech Academy of Sciences, Na Slovance 2, Prague 8, Czech Republic

Recently, pulsed reactive sputtering has emerged as a highly promising deposition technology for the production of semiconductor thin films. A major advantage of this approach is its strong compatibility with industrial-scale manufacturing. Various binary and ternary semiconductor oxide thin films have recently been intensively investigated for applications in gas sensors, photonic sensors, and photoelectrochemical cells for solar water splitting and hydrogen production. Plasma parameters in the reactive sputtering process play a key role in determining the final quality of the semiconductor material. The most critical parameters include the electron temperature, plasma density, ion flux density at the substrate, and the degree of ionization of the sputtered particles. Reactive magnetron sputtering systems operating in different pulse modes (HiPIMS, MF), as well as combinations of these techniques with RF ECWR plasma, have been used for the deposition of various semiconducting oxides such as ZnO, WO_3, Fe_2O_3:Sn, Cu_xWO_4, and $CuFeO_2$. The plasma parameters during film deposition were determined using an RF probe and a magnetized quartz crystal microbalance (QCM) with a biased electrode. The semiconducting properties of the films were characterized by measurements in a photoelectrochemical cell, Mott–Schottky analysis, and conductivity and photoconductivity measurements. High-quality oxide semiconductor films, including ZnO, WO_3, Fe_2O_3:Sn, Cu_xWO_4, and $CuFeO_2$, were successfully deposited under specific conditions of pulsed reactive magnetron sputtering. Optimal conditions were identified for each material. The influence of plasma parameters such as electron temperature, ion density, and the energy distribution functions of positive and negative ions on the resulting semiconductor properties was clearly demonstrated. It was found that these plasma parameters have a significant impact on the final semiconductor characteristics.