Abstract

Mono-gap solar cells, like commercial silicon solar cells, are unable to use the whole solar spectrum. In particular, photons with high energy have thermalization losses and photons with an energy lower than the bandgap energy can not be absorbed. Materials, which convert one UV photon into one or more visible photons, so called down-converters, or which convert two or more sub-bandgap photons into photons with an energy higher than the bandgap energy, so called up-converters, are of great interest for photovoltaic applications.

In this work new materials were investigated for their optical properties and their potential as down- or up-converters.

For down-conversion applications, barium chloride and barium bromide single crystals, as well as fluorozirconate-based (FZ) glasses, were doped with samarium. The glasses were additionally doped with bromide ions in order to initiate the formation of barium bromide nanocrystals in the glass upon thermal processing. Optical measurement techniques determined the divalent charge state of samarium in both single crystals. The FZ glasses show a different behavior: samarium enters the glass matrix either in its divalent or in its trivalent state. Fluorescence measurements indicate that during the annealing process Sm^{2+} ions enter the nanocrystals leading to enhanced fluorescence efficiency and to changes in the fluorescence lifetime.

For up-conversion applications, $BaCl_2$ single crystals, as well as FZ-based glassses, were doped with neodymium. Upon excitation at 796 nm, Nd^{3+}-doped $BaCl_2$ single crystals show several up-converted fluorescence bands in the visible spectral range, with the most intense bands at 530, 590, and 660 nm, in addition to the typical fluorescence bands in the infrared spectral range. The power dependence of the infrared fluorescence and of the two-photon up-conversion fluorescence intensities as well as the corresponding radiative lifetimes have been investigated.
An enhanced up-converted fluorescence in Nd^{3+}-doped fluorozirconate (FZ) glasses which were additionally doped with chlorine ions was found. Upon annealing between 240 and 290 °C, hexagonal phase $BaCl_2$ nanocrystals between 20 and 180 nm in diameter were formed in the glass. During thermal processing, some of the Nd^{3+} ions enter the nanocrystals leading to additional splitting of the up-converted fluorescence and infrared fluorescence spectra.

Nd-doped glass ceramics are useful as a model system, but are not applicable due to the excitation of the up-conversion at ~ 800 nm, which is light that can be absorbed by a silicon solar cell itself. However, erbium-doped FZ glasses were found to be more applicable systems for up-conversion-based silicon solar cells due to their excitation at 1540 nm. To show their potential the external quantum efficiency (EQE) of a commercial monocrystalline silicon solar cell with an Er-doped FZ glass on top of it was determined. For an excitation power of 18 mW at a wavelength of 1540 nm an EQE of almost 1.5 % was found for a 5 mol % Er-doped FZ glass.