Optical properties of epitaxial ZnO-ALD films implanted with Rare Earth

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Rare Earth (RE) doped semiconductor materials have been widely investigated because of their optical properties and possible application as fiber lasers and amplifiers, plasma displays, phosphors in fluorescence lamps and solar cells. The *RE4f* electron shell is highly localized, so the intra-shell transitions of *4f* electrons are only slightly affected by the host material, therefore the radiative efficiencies are almost temperature independent. Wide bandgap semiconductors are especially interesting as host materials, because they are expected to overcome the temperature quenching observed in other materials (e.g. in Si) and to promote effective resonant pumping of the *f* shell [1]. GaN and ZnO have been the most investigated semiconductors in this field. Both materials have a similar bandgap (about 3.4 eV at RT) and nowadays they compete with each other as the most promising new materials for optoelectronics. However, important advantages of ZnO are much higher exciton binding energy (60 meV vs. 24 meV) and availability of single crystal ZnO substrates. Additionally, the ZnO based technology is expected to be much cheaper than the GaN technology.
Epitaxial ZnO films were grown by Atomic Layer Deposition which is an inexpensive growth technology that can be applied in industry. The films were implanted with Yb, Pr or Dy ions to a fluence of $1x10^{15}$ at/cm^2. A considerable crystal lattice damage has been observed in the Rutherford Backscattering spectra and microscopic images after the implantation process [3-4]. As a result only a weak photoluminescence (PL) signal from ZnO:Yb, ZnO:Dy and ZnO:Pr layer was observed. It was found that annealing under oxygen or under ambient atmosphere at 800°C leads to ZnO crystal lattice recovery and activation of the band-edge and defect-related PL from the ZnO lattice as well as the RE-related emission. It is concluded that the intensity of the observed PL signal strongly depends not only on crystal lattice recovery, but on RE ions location in the ZnO lattice as well. Therefore, the parameters of used annealing processes play a crucial role in the obtained optical response from ZnO:RE films.

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