

Flame spray synthesis of amorphous Indium-Zinc Oxide (IZO) nanoparticles and their electrical and optical properties - towards an application in field effect transistors

D. Kilian¹, S. Polster², M.P.M. Jank^{2,3}, L. Frey^{2,3} and W. Peukert¹

¹Institute of Particle Technology, University of Erlangen, Erlangen, Bavaria, 91058, Germany

²Chair of Electron Devices, University of Erlangen, Erlangen, Bavaria, 91058, Germany

³Fraunhofer Institute for Integrated Systems and Device Technology, Erlangen, Bavaria, 91058, Germany

Keywords: flame spray pyrolysis, amorphous nanoparticles, mixed oxides, electronics

Presenting author email: daniel.kilian@lfg.fau.de.

As Flame Spray Pyrolysis (FSP) provides the possibility to mix a broad range of elements at the precursor stage it is one of the most suitable processes for designing new nanomaterials with tailor-made properties, e.g. needed for semiconductors.

One promising material class are amorphous transparent oxide semiconductors (AOS) based on ZnO for transparent (flexible) thin-film transistors (Nomura et al., 2004). The addition of indium, gallium or aluminium influences the band gap, defect density and amorphous state in a distinct composition range. The synthesis of AOS is often carried out by sputtering techniques, providing high device mobilities (Li et al., 2012) but also requiring costly vacuum equipment. Solution based routes like sol-gel processes are used but amorphous films are often not achieved (Lee, 2005). As FSP provides very short residence times, easy precursor mixing and the synthesis can be executed under atmospheric pressure it is a suitable and cost-effective process for the synthesis of AOS. In previous work (Height et al, 2006) the addition of Indium between 1 to 10 at.% to ZnO precursor led to ZnO nanorods, showing the influence of Indium on the morphology. To the best of our knowledge this is the only FSP-based synthesis of In-ZnO.

In this abstract we present our first results regarding the characterization of flame-made indium-zinc oxide nanoparticles towards an application as active layer in field effect transistors. The precursor composition is varied beginning with pure ethanolic zinc acetyl acetonate solution. The molar indium content is increased from 0.167, 0.348, 0.545 and 0.762 to pure ethanolic indium acetyl acetonate solution. The particles are collected by a filter unit and primary particle size, crystallinity and optical properties are analyzed by SEM, TEM, XRD, gas sorption and spectroscopic methods (PL, UV-VIS-NIR).

Table 1 and Figure 1a show basic results derived from XRD analysis of the final product as function of initial indium content in the precursor solution.

Table 1. Phase structure as function of indium content

mol. In content	phase composition
0.0	crystalline ZnO
0.167	mixed phase ZnO/In ₂ O ₃
0.348	mixed phase ZnO/In ₂ O ₃
0.545	amorphous/nanocrystalline
0.762	mixed phase ZnO/In ₂ O ₃
1.0	crystalline In ₂ O ₃

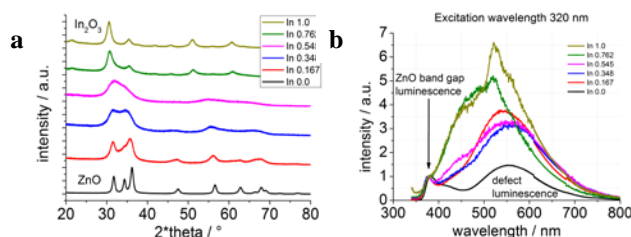


Figure 1. a) XRD patterns of the flame-made product powder. b) PL spectra of the product powder normalized to the intrinsic ZnO band gap emission at ~ 376 nm.

It can be seen, that FSP synthesis is suitable to control the phase composition by the indium content. The most promising composition for an application in flexible devices is a molar indium content of around 0.545. Since defects in the material play a major role in electronic applications regarding the charge carrier mobility and density the PL spectra of the product is depicted in Figure 1b. With increasing indium content the defect luminescence between 400 nm and 800 nm is increasing for the mixed oxide systems. This result can be explained by the increasing amorphous character with indium addition up to 0.545 mol % and is in good agreement with the XRD patterns. Furthermore, UV-VIS spectroscopy shows a shift in the absorption edge indicating the influence of the composition on the band gap (not shown here).

Based on these results and our experience in the fabrication of field effect transistors from nanoparticulate ZnO (Walther et al., 2010) we are convinced that In-ZnO is a very promising material for further improvement of the electronic device performance.

Nomura, K. et al. (2004) *Nature* **432**, 488 – 492.

Li, M. et al. (2012) *Jap. J. Appl. Physics* **51**, 1 - 5.

Lee, S.M. et al. (2005) *Thin Solid Films* **484**, 184 – 187

Height, M.J. et al. (2006) *Chem. Mater.* **18**, 572 – 578

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