DEVELOPMENT OF INDIUM FREE TCO INKS FOR PRINTING OF TRANSPARENT CONDUCTIVE COATINGS

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INTRODUCTION

Transparent conducting coatings (TCC) are widely used as transparent electrodes for displays, solar cells etc. The direct printing of transparent conductive oxide (TCO) coatings and patterns would be advantageous for a cost effective fabrication of many applications with TCO.

STATE OF THE ART

- Up to now mainly ITO (In_2O_3:Sn, tin doped indium oxide) is used, which is a high cost and rare material.
- ITO is deposited by vacuum techniques (e.g. sputtering)
- Patterning is a multi-step process (photolithography and etching processes) ➔ cost-intensive and waste of material.

OBJECTIVE

Development of novel indium-free TCO inks which can be

- deposited by direct printing process (gravure or ink-jet).

Alternative TCO materials will be tested and the properties of the coatings will be compared with ITO coatings of the INM [1,2,3]:

- ZnO:Al (AZO, aluminium doped zinc oxide)
- ZnO:Si (SZO, silicon doped zinc oxide)

EXPERIMENTAL

- Use of In-free TCO nanoparticles, fabricated by flame spray pyrolysis by an EU project partner (Lurederra, Tecnan).
- Dispersion of the TCO nanoparticles (AZO, SZO) in a solvent (Isopropoxyethanol) by using a suitable surface modifier
- Addition of an UV-curable binder [1,2]
- Deposition by spin-coating on glass and then curing by UV irradiation and various thermal treatments (250°C, 550°C in air and forming gas [N_2/H_2: 95%/5%])
- Gravure printing of the TCO inks on PET foil and UV treatment

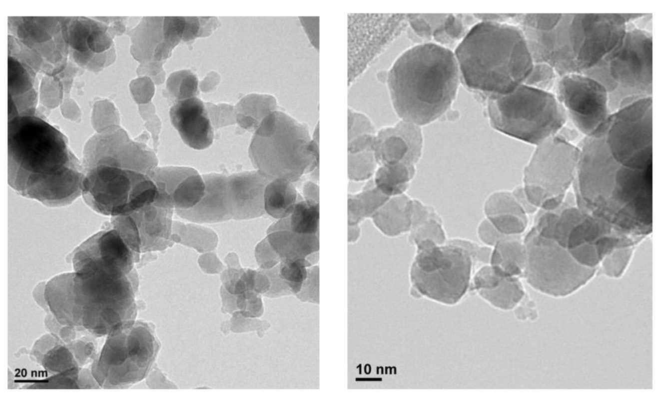

Fig. 1: TEM micrographs of AZO nanoparticles (LUR[4])

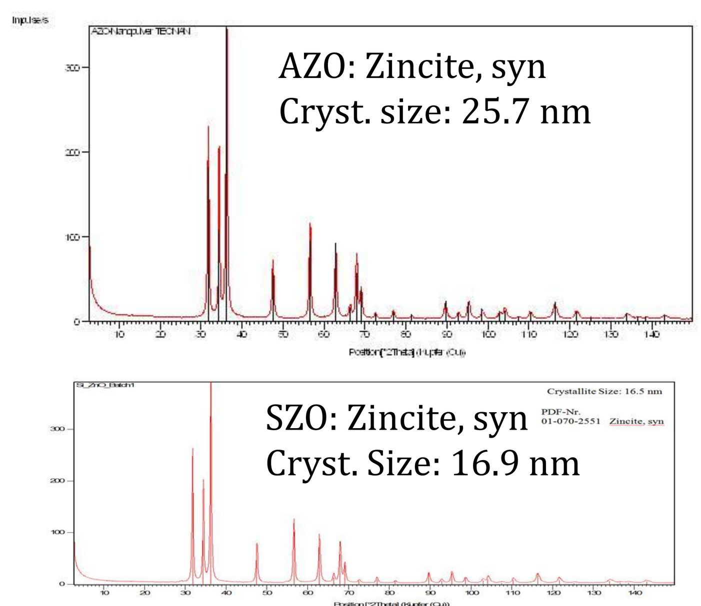

Fig. 2: XRD of AZO and SZO nanoparticles

Fig 3: Dispersion of SZO nanoparticles with different surface modifiers

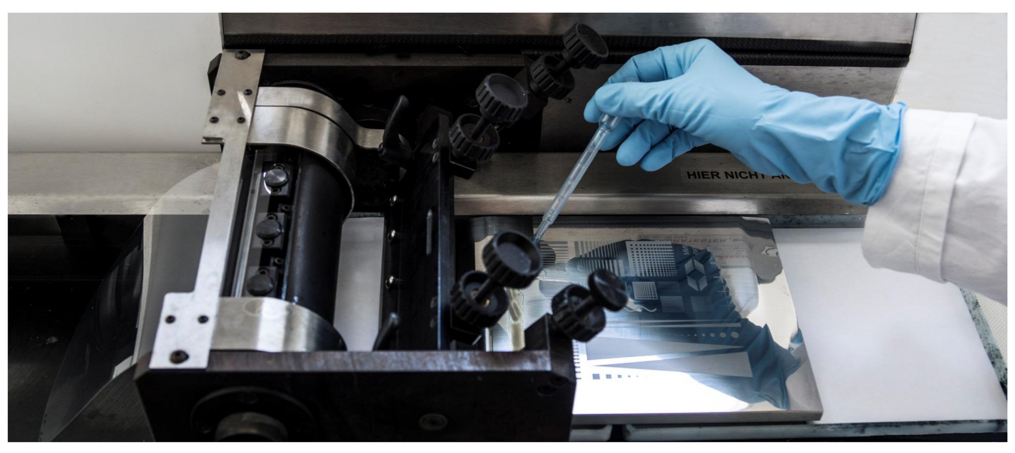

Fig 4: Gravure printer (Labratester, N. Schläfli AG, Switzerland)

RESULTS

Spin-coating on glass:

- After UV treatment: sheet resistance of AZO and SZO coatings not measurable: R/sq > 10 MΩ/sq (thickness up to 1 µm)
- Lowest resistivity after thermal treatment and post treatment under forming gas (FG, see table 1), but 3 to 4 orders of magnitude higher than that of ITO coatings.
- Total transmission of the AZO and SZO coatings in the visible range (with substrate): 80 to 89%, coatings are hazy
- UV-VIS-NIR spectra show, that the electron gas of the AZO coatings absorbs at higher wavelengths than that of the ITO coatings, which correlates with the higher resistivity (Fig. 5)

Gravure printing:

- AZO and SZO inks were gravure printed on PET foil
- R/sq after UV curing > 10 MΩ/sq, coatings are hazy
- Sheet resistance of printed ITO coatings: 3 to 5 kΩ/sq, ITO coatings are clear (haze < 1%, see table 1)

Table 1: Comparison of the electrical and optical properties of ITO and indium-free TCO coatings, prepared by spin-coating using ITO and new developed TCO inks, after UV treatment and additional thermal treatment

TCO	Thermal treatment after UV curing		Resistivity	Total Trans-mission	Haze
	Air [°C]	FG [°C]	[Ωcm]	[%]	[%]
ITO	550	250	0.016	92.7	0.43
AZO	550	250	202	89.1	16.1
AZO	550	500	14	88.7	16.4
SZO	550	250	50 to 129	80 to 84	17 to 44

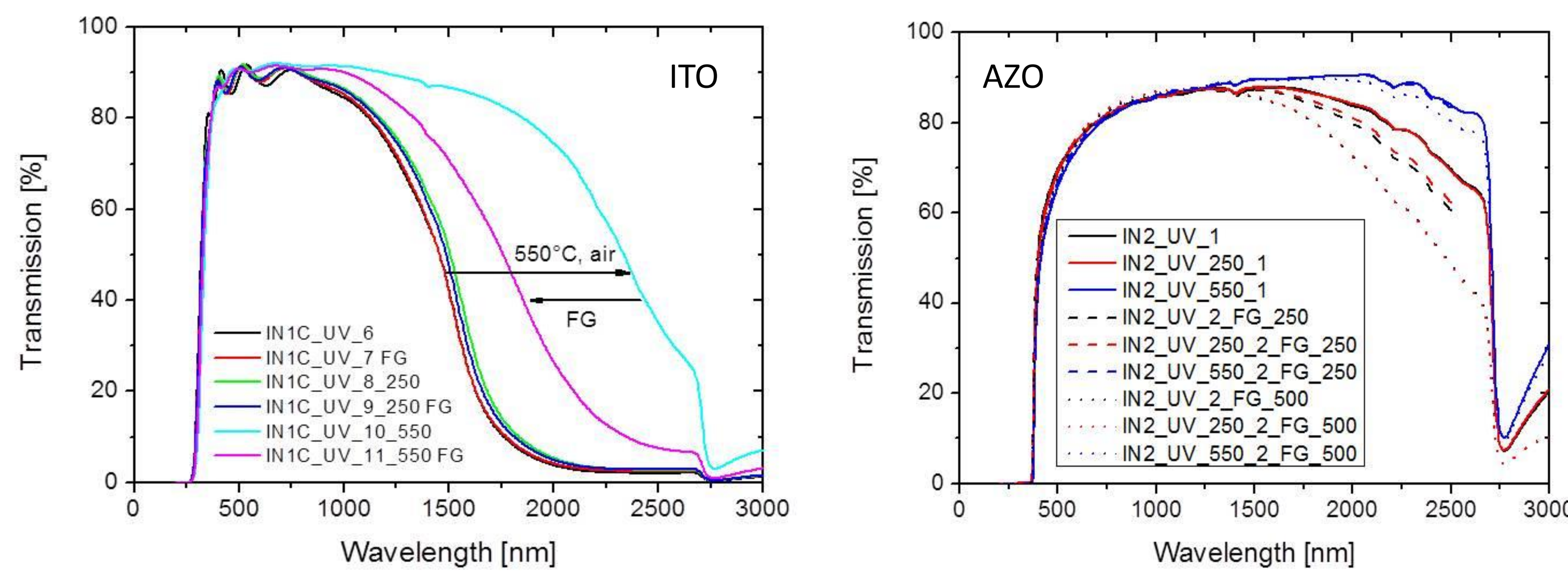

Fig. 5: Transmission spectra of ITO coatings (left) and AZO coatings (right) on borofloat glass substrates after UV treatment and various thermal treatments in air and forming gas (FG). The spectra of SZO coatings are similar to those of AZO.

OUTLOOK

Further studies are necessary to improve the conductivity of the In-free TCO coatings by decreasing the resistivity of the In-free TCO nanoparticles (AZO, SZO). Furthermore the dispersion of the nanoparticles has to be improved to obtain haze-free coatings.

Acknowledgements

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References

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[2] S. Heusing et al., in: Proc. of SPIE 6999 (2008) 69992I
[3] R. Nonninger et al., U.S. Patent No. 6533966
[4] TEM micrographs of AZO nanoparticles from Lurederra

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