SCREEN PRINTING OF TRANSPARENT CONDUCTIVE FEATURES BASED ON SILVER NANOWIRE NETWORKS

K. ELEN[1,2], S. NAGELS[3,4], H. PENXTEN[5], L. LUTSEN[1], W. DEFERME[3,4], A. HARDY[1,2], M. K. VAN BAEL[1,2]

[1] IMEC VZW, DIVISION IMOMEC, WETENSCHAPSPARK 1, B-3590 DIEPENBEEK, BELGIUM
[2] HASSELT UNIVERSITY, INSTITUTE FOR MATERIALS RESEARCH (IMO), INORGANIC AND PHYSICAL CHEMISTRY, AGORALAAN BUILDING D, B-3590 DIEPENBEEK, BELGIUM
[3] HASSELT UNIVERSITY, INSTITUTE FOR MATERIALS RESEARCH (IMO), FUNCTIONAL MATERIALS ENGINEERING, WETENSCHAPSPARK 1, B-3590 DIEPENBEEK, BELGIUM
[4] FLANDERS MAKE VZW, OUDE DIESTERSEBAAN 133, B-3920 LOMMEL, BELGIUM
[5] HASSELT UNIVERSITY, INSTITUTE FOR MATERIALS RESEARCH (IMO), ORGANIC AND BIO-POLYMER CHEMISTRY, AGORALAAN BUILDING D, B-3590 DIEPENBEEK, BELGIUM

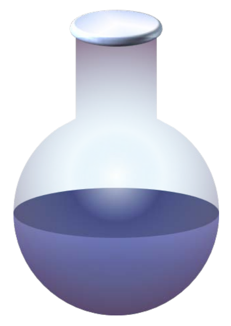
INTRODUCTION

Metal nanowire networks are a promising concept for replacing ITO in transparent electrodes for a range of optoelectronic devices. In these networks, the nanowires conduct charge carriers, while the open areas allow the transmission of light. Metal nanowires are both printable and achieve a performance equivalent to ITO upon thermal processing at moderate temperatures below 150°C which make them ideal for depositing transparent conductive features on plastic substrates.

Screen printing offers a number of advantages for upscaling, for instance low cost, few wastes and printing speeds that can exceed 20 m/min. Screen printing pastes are however complex formulations that require a specific rheological behavior, exhibiting both sheer thinning and thixotropy. To meet these requirements, various organic components are added during the formulation of the printing pastes. In this work we compare Ag NW pastes containing Clevios™ S V4 or cellulose as the organic binder and the effect that this has on the opto-electric properties of the screen printed features.

EXPERIMENTAL WORK

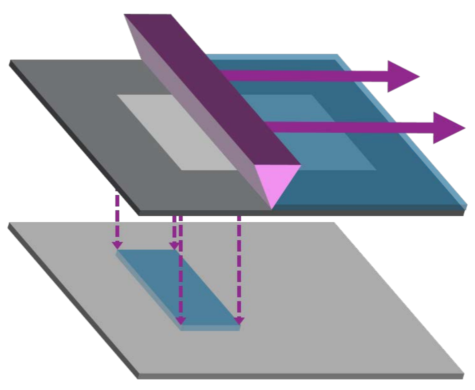
INK FORMULATION



Conductive material	Organic binder	Solvent
Ag NWs	Clevios™ S V4	Isopropanol
Ag NWs	Cellulose	Water Isopropanol

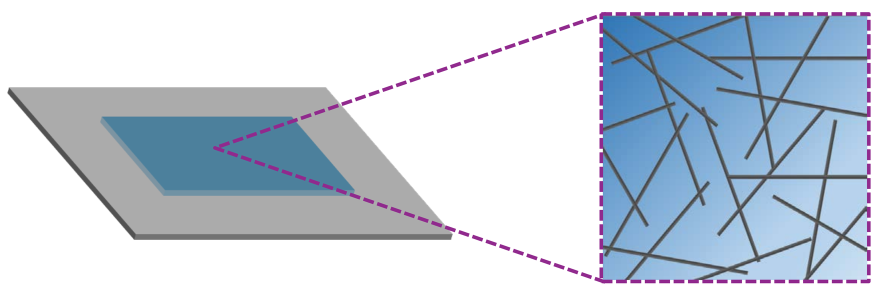
Two classes of printing pastes were formulated and evaluated: Ag NW based pastes containing Clevios™ S V4 (a PEDOT based formulation) on one hand, or cellulose as the organic binder on the other. Steady-state and peak-hold rheology measurements demonstrate that both organic binders provide highly viscous printing pastes that exhibit sheer thinning and thixotropy. The visco-elastic moduli were determined by stress sweep step measurements and demonstrate a transition from elastic to viscous behaviour in response to increasing stress.

SCREEN PRINTING



Substrates:
PET (Melinex™ 125)
Deposition
Screen printer: Isimat™ 1000P
Screen printing area: 25 x 25 mm
Mesh: Plain Weave 77-55
Drying
Oven @ 100-120 °C in air

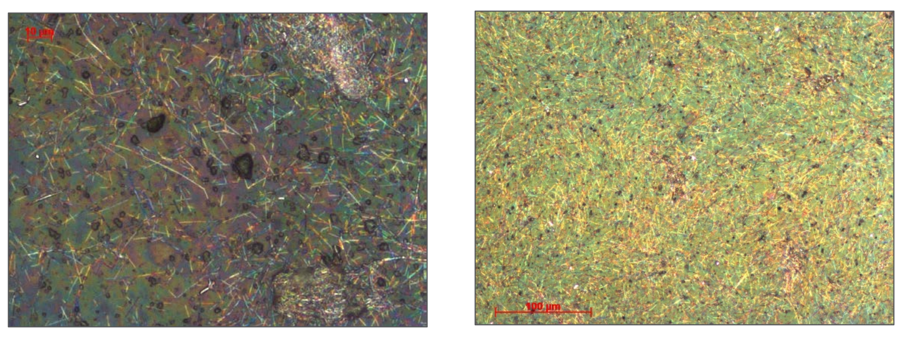
CHARACTERIZATION



Methods:
Microstructure: Optical microscopy
Transparency: UV-Vis Spectroscopy
Conductivity: Van der Pauw method

RESULTS & DISCUSSION

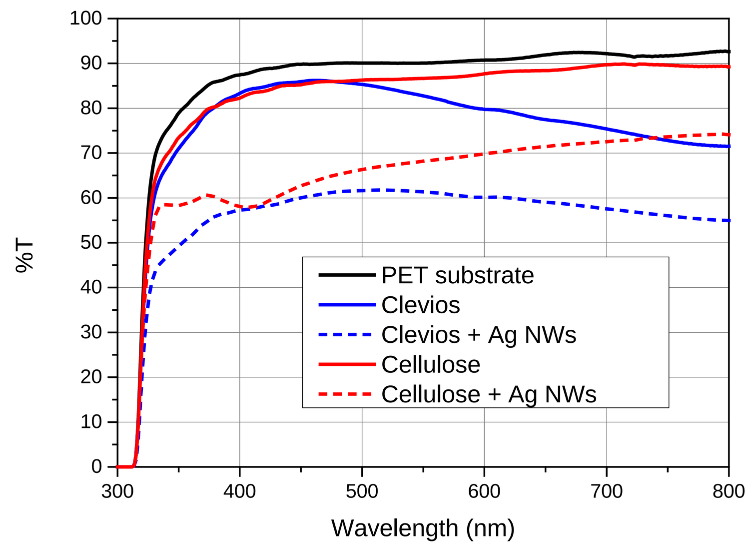
MICROSCOPY



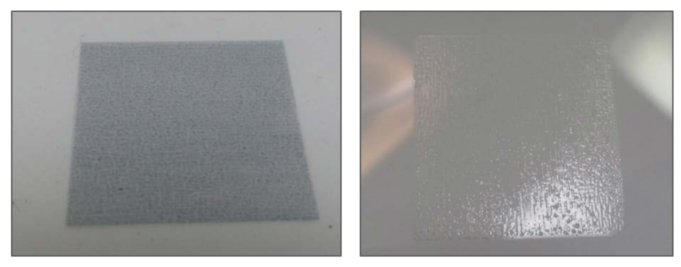
Clevios *Cellulose*

In both formulation a random distribution of NWs creates a network for the percolation of electrons

OPTO-ELECTRIC PROPERTIES

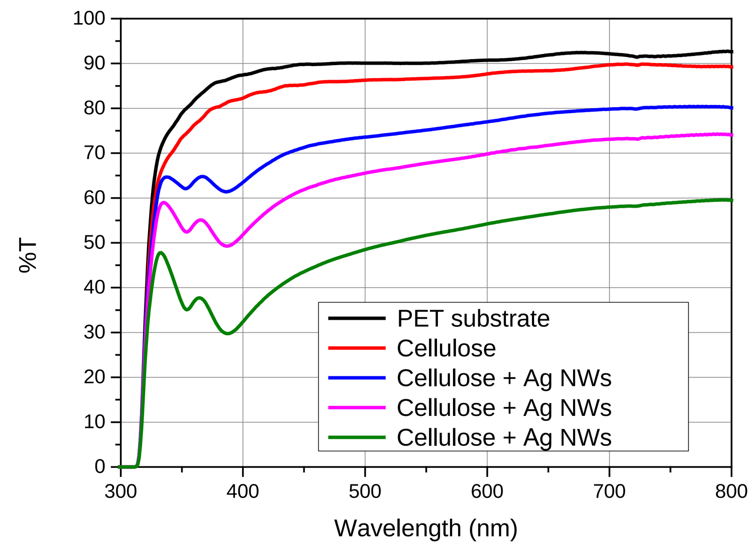


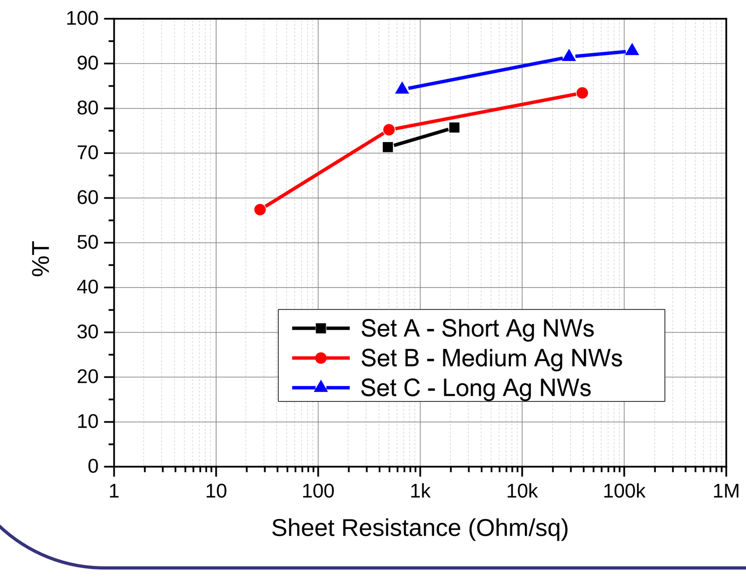
Formulations that contain Clevios exhibit a stronger absorption in the (infra-)red region compared to formulations that contain cellulose.



Clevios *Cellulose*

The effect of the NW concentration on the transparency of screen printed features, using pastes that contain a cellulose binder, demonstrates that an increase in NW concentration leads to a reduction in transparency.





Sheet resistance vs. transparency (at 550 nm) of screen printed features using formulations that contain a cellulose binder and increasing concentrations of Ag NWs. Long NWs exhibit a superior transparency for a similar sheet resistance.

CONCLUSIONS

Various formulations containing Ag NWs were prepared and their rheological behavior was assessed in view of screen printing. The most promising formulations were selected to print test features on PET substrates and the electrical and optical characteristics of these features were measured by a Van der Pauw method and UV-Vis spectroscopy respectively. By the addition of Ag NWs to a PEDOT-based formulation, the sheet resistance of the printed features can be decreased from ca. 200 Ohm/sq to values below 40 Ohm/sq, indicating that a nanowire network improves the conductivity. However these features appear blue due to the absorption of (infra-)red light by PEDOT. The optical properties can be significantly enhanced by replacing the PEDOT-based formulation by a cellulose-based formulation.

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