Fraunhofer IPA

P2.02

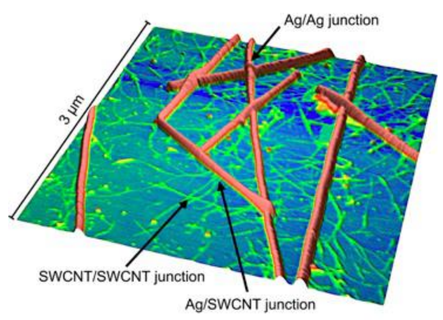
# Material- and Energy-efficient Production of Ultra-transparent Conductive Films Based on Rodlike Conductive Nanoparticles

T. Ackermann, S. Sahakalkan , L. Boonen, C. Glanz and I. Kolaric
Fraunhofer Institute for Manufacturing Engineering and Automation (IPA), Stuttgart, Germany

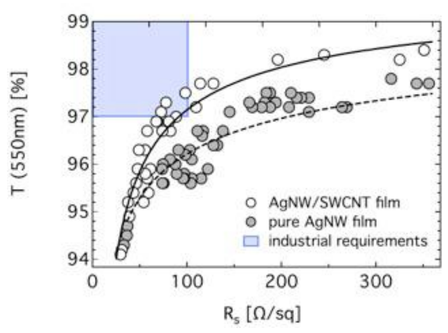
The market for transparent and conductive layers has grown remarkably during the past few years. The key drivers were consumer electronics and photovoltaics. Recent developments show a trend for products which are bendable or have complex 3D surfaces. Such applications need flexible and transparent electrodes. The state of the art materials cannot satisfy the flexibility requirement. Most promising candidates are fibrous conductive materials like nanotubes or nanowires and their hybrids. The main interest of Fraunhofer IPA is to develop processes for coating, patterning and printing of these nanomaterials.

## CNT – AgNW Hybrid Layers

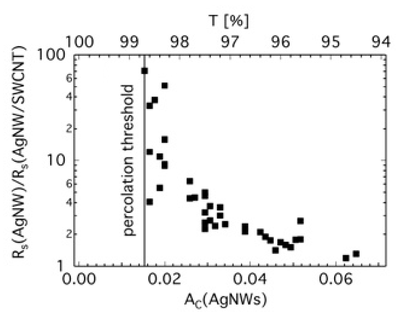

Ethanol based dispersion of silver nanowires and water based dispersion of carbon nanotubes.




Atomic force microscopy image of the hybrid layer. Produced in a two step coating process. [1]

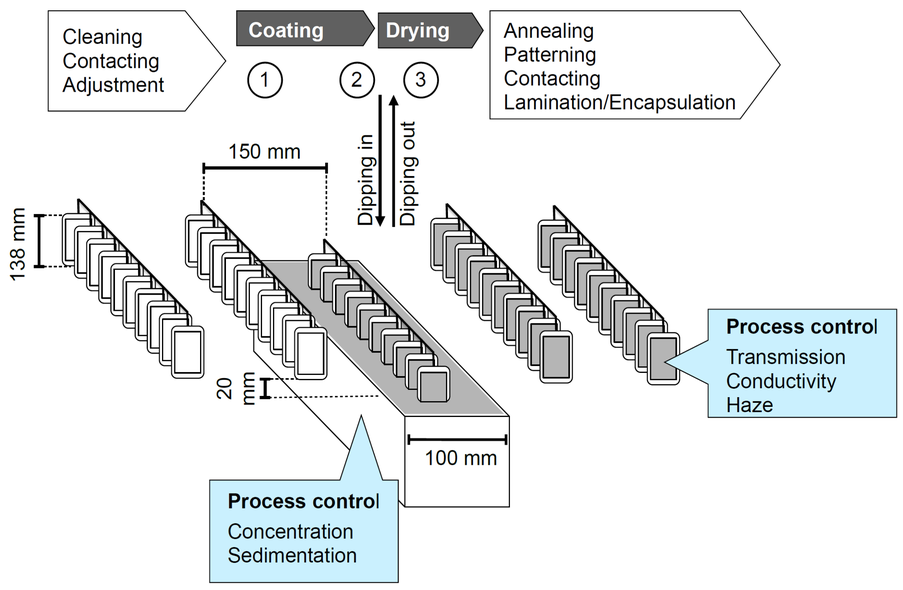



Transmission at 550nm vs. the sheet resistance. The effect of the addition of CNT is clearly visible. [1]

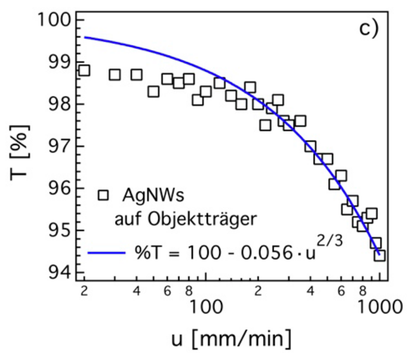



Relative change in sheet resistance of pure AgNW against Hybrid coating vs. the fractional area coverage $A_C$. [1]

## Processing

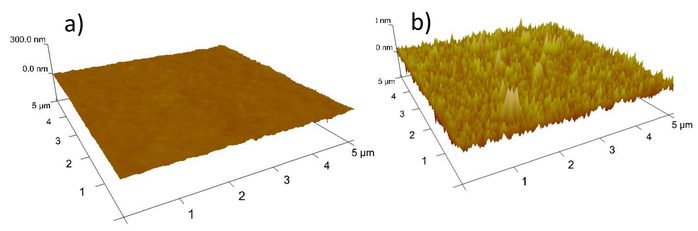



Conceptual setup of a production cell for AgNW-based transparent electrodes. [2]

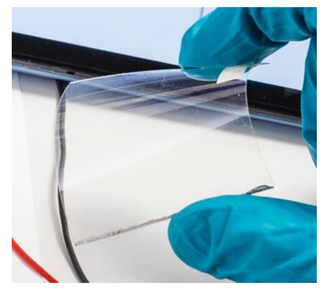



Transparency vs. withdrawal speed during the coating.

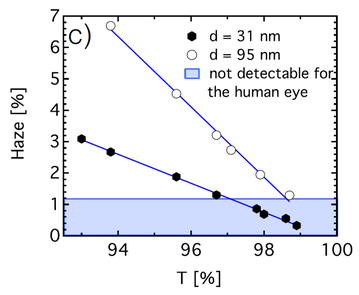
Conventional smart phone glasses coated with AgNWs. T = 97.5-97.7 % Rs ≈ 55-70 Ohm/sq. [2]



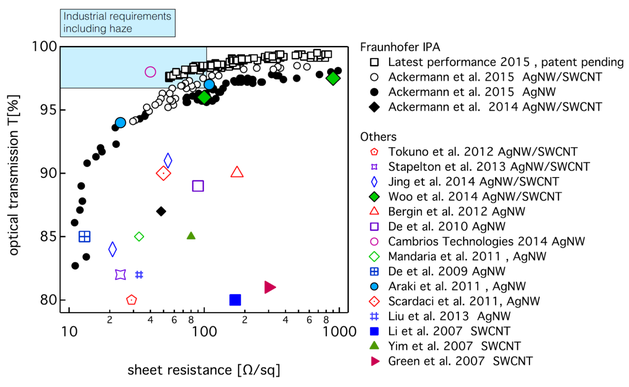

Atomic force microscopy images of substrate PET film before a) and after b) oxygen plasma treatment. Coated PET sample c). AgNW film on PET



## Performance

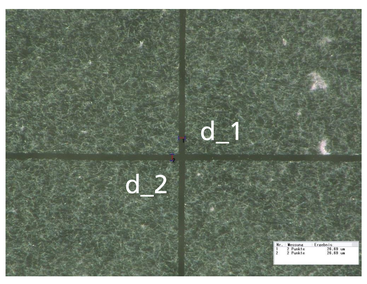



Optical transmittance vs. haze value. There is strong dependence of haze to the diameter of used silver nanowire.



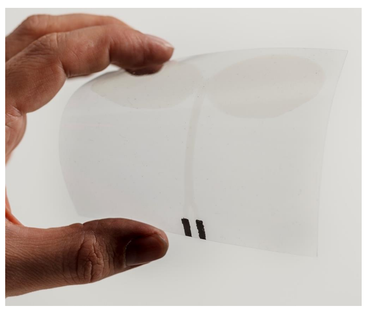

Comparison of the optical and electrical performance of AgNW and CNT Hybrid layers to values mentioned in the literature.

## Patterning : Scratch-Lithography




d_1 = d_2 ≈ **25 µm**

Microscopy image of the spacing between the patterned areas. Widths down to 25 µm are possible. [3]



**Transparent foil antenna** as demonstrator sample for patterning with scratch lithography. [3]

**Contact:** Carsten Glanz
Fraunhofer IPA, Nobelstraße 12, 70569 Stuttgart
Tel.: 0711 970 3736, Fax: 0711 970 3995
Email: carsten.glanz@ipa.fraunhofer.de

[1] Ackermann et al., *Phys. Stat. Sol. RRL* 9, pp. 141-144, **2015**
[2] Ackermann et al., *Proc. of SPIE* 9556, 955602, pp. 1-10, **2015**
[3] Sahakalkan et al., *WT Online* 105, pp. 195-198, **2015**