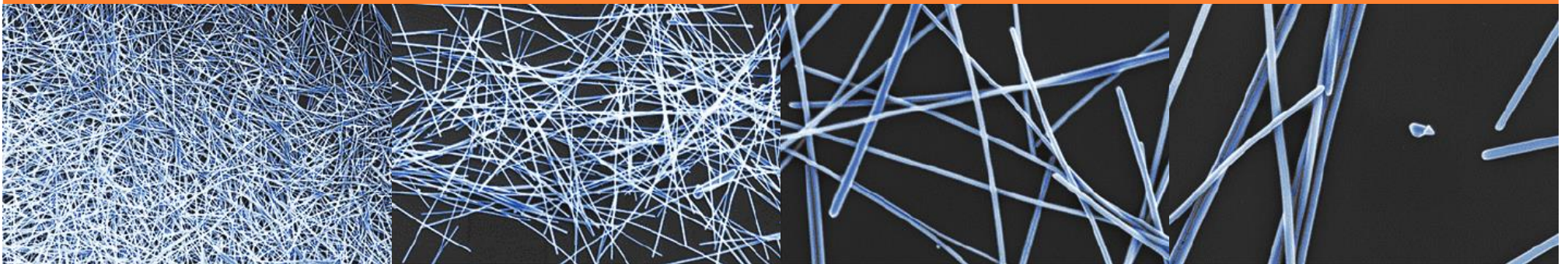


SILVER NANO WIRES

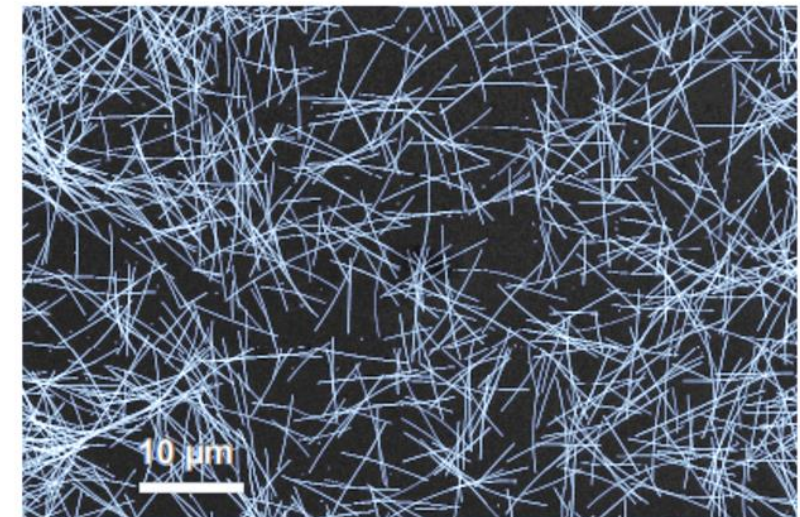
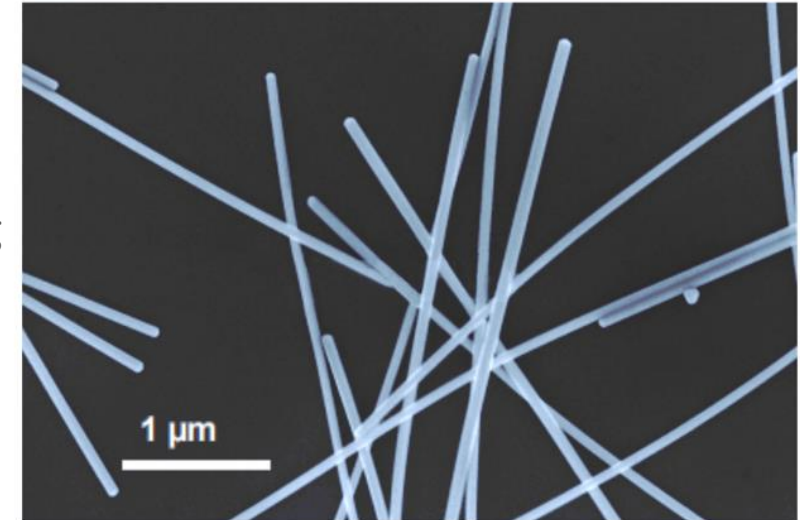


BACKGROUND

- The Silver Nano Wires were developed through a research project between PROTAVIC® INTERNATIONAL (PVI) and the French R&D institute CEA LITEN in Grenoble (Top Fundamental French Research Institute). The Silver Nano Wires manufacturing unit in PVI is operational since 07/2017.
- The production of Silver Nano Wires is a chemical process in a liquid environment with the same ingredients as per non-transparent conductive filler
- PVI is the only licensee of the CEA LITEN technology to exploit and market the Silver Nano Wires in all the application domains and all the regions

<http://www.cea-tech.fr/cea-tech/english/Pages/press-releases/PROTAVIC-INTERNATIONAL-silver-nanowires-CEA.aspx>

Clichés MEB :



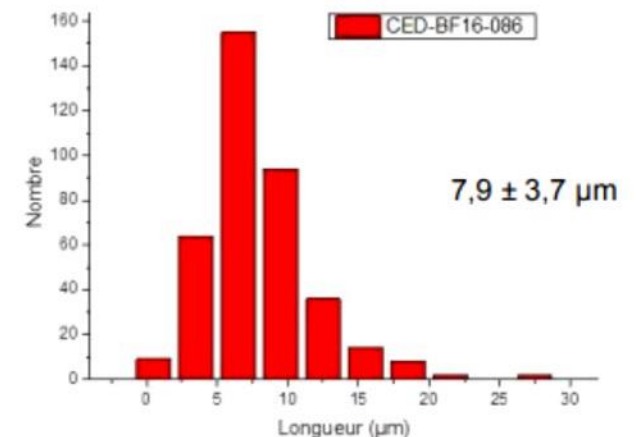
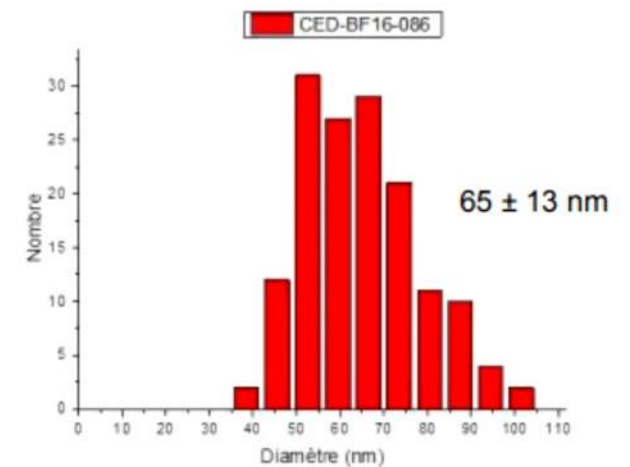
PROPERTIES OF SILVER (Ag) NANO WIRES WITHOUT FORMULATION

The Silver Nano Wires (SNW) are presented in the form of a slurry (suspension) in a solvent. The choice of the solvent is open, and PVI has studied different possibilities

The parameters of the slurries are as follows :

- Solvent type (organic versus aqueous, ...)
- Percentage of Silver Nano Wires dispersed in the solvent
- Geometry / shape of the Silver Wires : diameter, length, ...
- Degree of purity
- Stability in time of the slurry (no solid deposit)
- Easiness to re-disperse / re-homogenise the silver wires (The last 2 points are particularly important for a formulator to ensure easy formulation)

Analyse morphologique :



PROPERTIES OF FORMULATIONS BASED ON SILVER NANO WIRES

Formulation on the basis of Silver Nano Wires

PROTAVIC INTERNATIONAL has acquired know-how in the synthesis and the formulation of the Silver Nano Wires to achieve transparent, conductive and flexible coatings. The formulations are made of a solvent (organic or water-based) with a chemical binder and Silver Nano Wires.

Electrical conductivity

Silver has a very good electrical conductivity. A minimum concentration of Silver Nano Wires is required to achieve electrical conductive formulation.

The measured resistance is of the order 5-30 Ohm/square.

Transparency (see illustration)

The transparency depends on the application method, the quantity and the shape of the Silver Nano Wires dispersed and the nature of the binder.

Flexibility

This property depends on the formulation and the nature of the substrate.



COMMERCIALY AVAILABLE PRODUCTS FOR FORMULATORS



PROTAVIC® 28202 : slurry of **3%** by weight of Silver (Ag) Nano Wires **in isopropanol**, diameter 70 nm, length 10 μm

PROTAVIC® 28205 : slurry of **3%** by weight of Silver (Ag) Nano Wires **in isopropanol**, diameter 110 nm, length 6 μm

PROTAVIC® 28206 : slurry of **5%** by weight of Silver (Ag) Nano Wires **in water**, diameter 70 nm, length 10 μm

PROTAVIC® 28207 : slurry of **12%** by weight of Silver (Ag) Nano Wires **in isopropanol**, diameter 70 nm, length 10 μm

PROTAVIC® 28208 : slurry of **12%** by weight of Silver (Ag) Nano Wires **in water rich solvent**, diameter 70 nm, length 10 μm

CONDUCTIVE VARNISH : PROTAVIC® VCO 20261

Properties

VCO 20261 Properties	Typical value
Appearance and color	Pearly grey liquid
Viscosity at 25°C	< 100 mPa.s
Solid content	1,70 +/- 0,3%
Stability in original unopened packages *	1 year at T < + 25°C

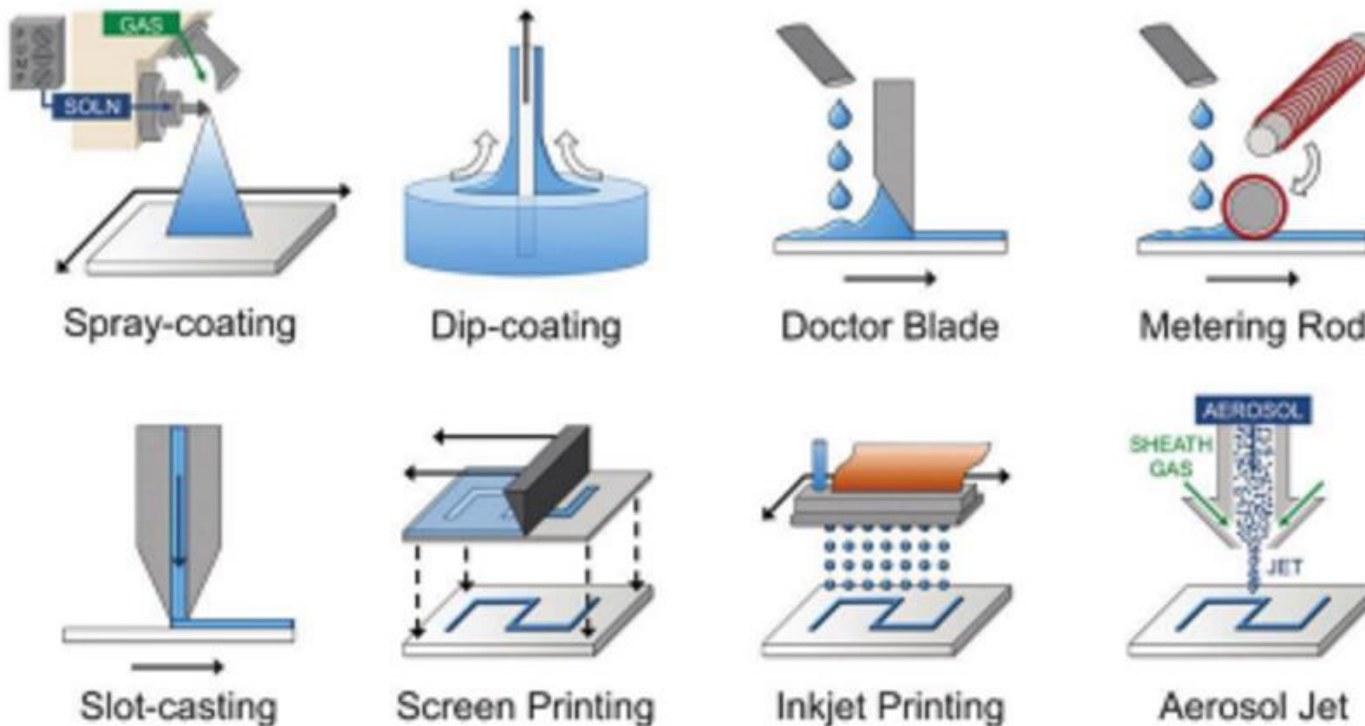


* Some reversible sedimentation of nanowires can occur over time. Always roll the container before use to homogenize the dispersion.

PROTAVIC[®] VCO 20261

Ready to use formulation

Thanks to its composition comprising a binder and silver nano-wires, VCO 20261 is a ready to use formulation that can be dispensed with various methods on many substrates.



Example of applicative methods. For the VCO 20261, the best results have been achieved using spray-application.

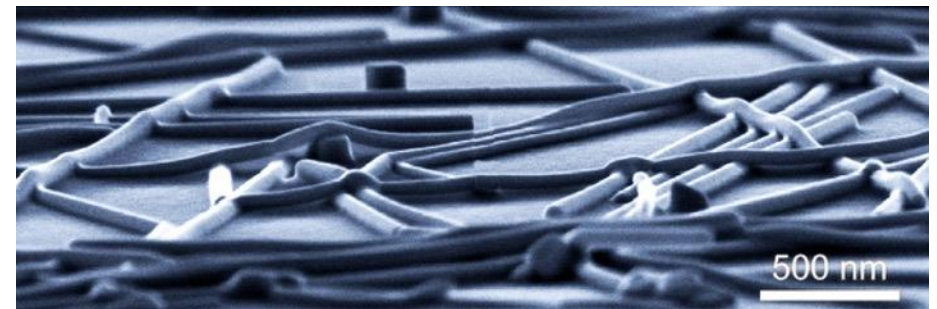
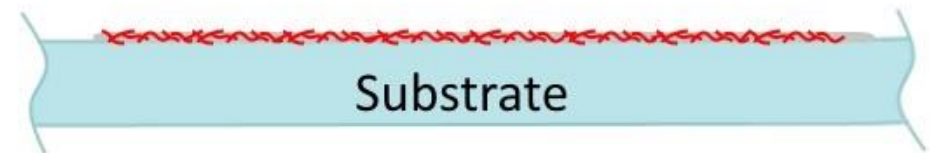
Dip-coating, doctor blade and metering rod were not or less efficient during CEI trials.

Other methods have not been yet tested.

Application

The aim is to obtain a thin film on the substrate surface

- ➔ The thickness of the application is very important for both surface resistivity and light transmittance
- ➔ The formulation must lead to the thinnest possible film
- ➔ Ideal < 1μ thick
- ➔ If necessary, several consecutive sprayings can be performed.



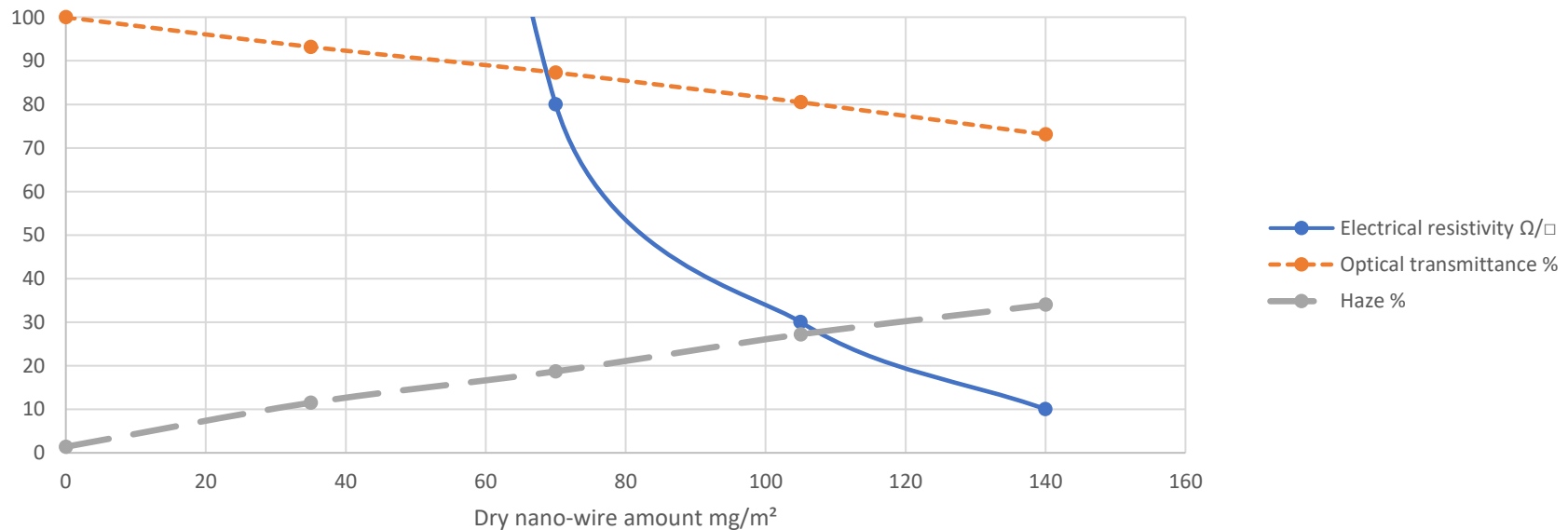
PROTAVIC® VCO 20261

Example of application

On polyester film – thickness 100µm. Pulverization of VCO 20261 – drying 30min at 150°C

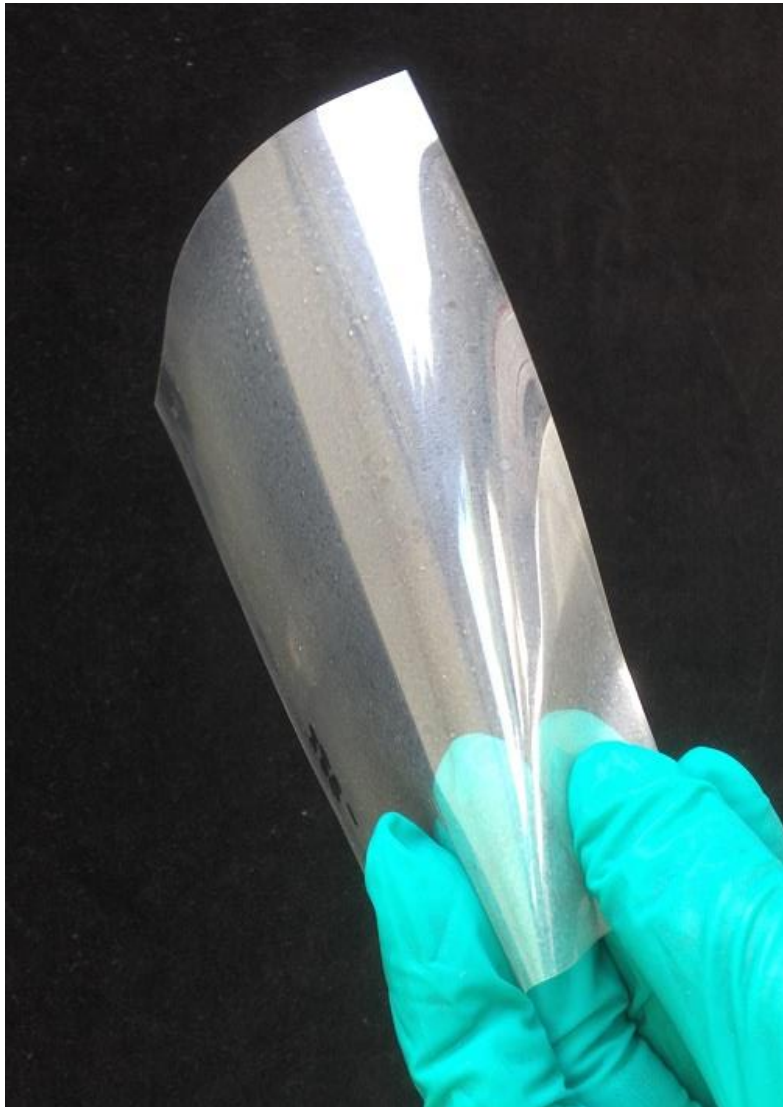
Dry nano-wire amount	Electrical resistivity	Optical transmittance	Optical haze
PET untreated	Not conductive	100%	1.4%
35mg/m ²	8 Million Ω/□	93.2%	11.5% (+ 10.1% / untreated)
70mg/m ²	80 Ω/□	87.3%	18.7% (+ 17.3% / untreated)
105mg/m ²	30 Ω/□	80.5%	27.2% (+ 25.8% / untreated)
140mg/m ²	10 Ω/□	73.1%	34.0% (+ 32.6% / untreated)

100 µm polyester film functionalized with VCO 20261

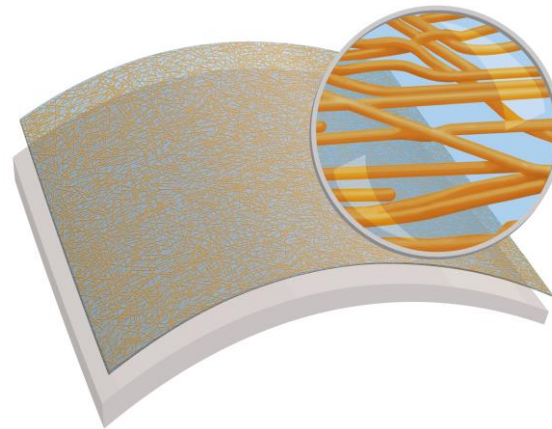


PROTAVIC[®] VCO 20261

Example of application

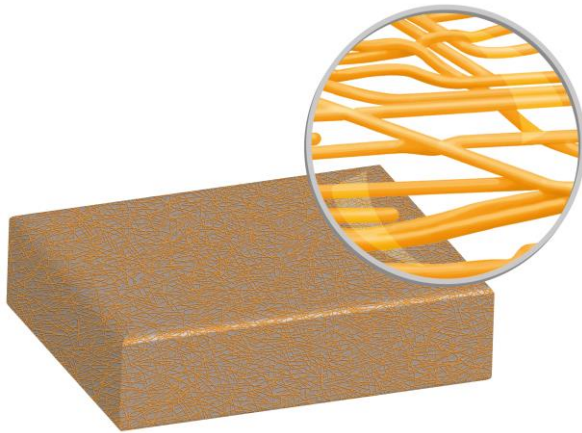


Almost transparent and flexible film

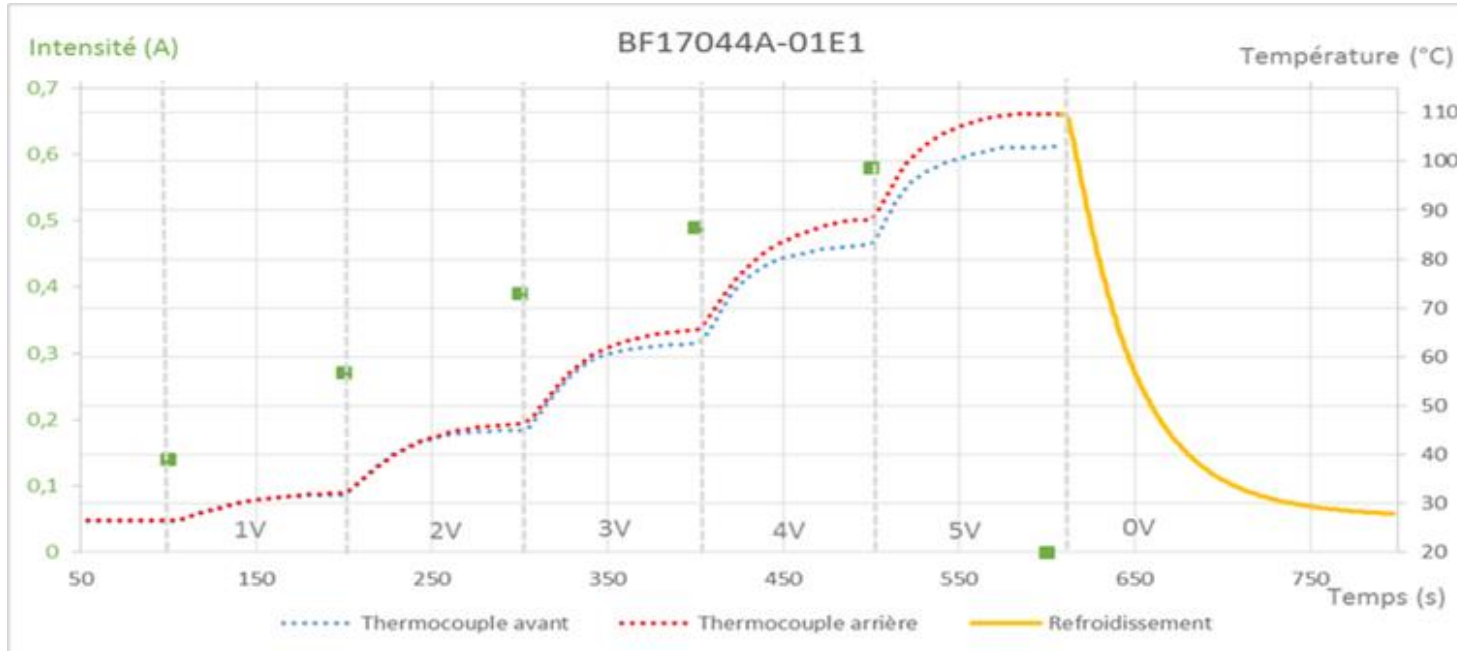


PROTAVIC® VCO 20261

Heating treated PET film



- ➔ Intensity in heating layer $I = U / R$
- ➔ Joule heating = $R \cdot I^2 = U^2 / R$
- ➔ Better heating properties for $R < 100 \Omega/\square$



PROTAVIC® VCO 20261



Conclusion

PROTAVIC® VCO 20261 may be suitable for the replacement of ITO (Indium-Tin Oxide) based products.

The high fluidity and self-leveling properties of **PROTAVIC® VCO 20261** makes it sprayable and allows the formation of almost transparent electrically conductive coatings on most substrates.

Applicative parameters are very important for achieving the final performances.

**THANK YOU FOR
YOUR ATTENTION**

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