Comparative Study on Carbon Nanotube Coating Methods

MIRWEC FILM

NIC NEWBY

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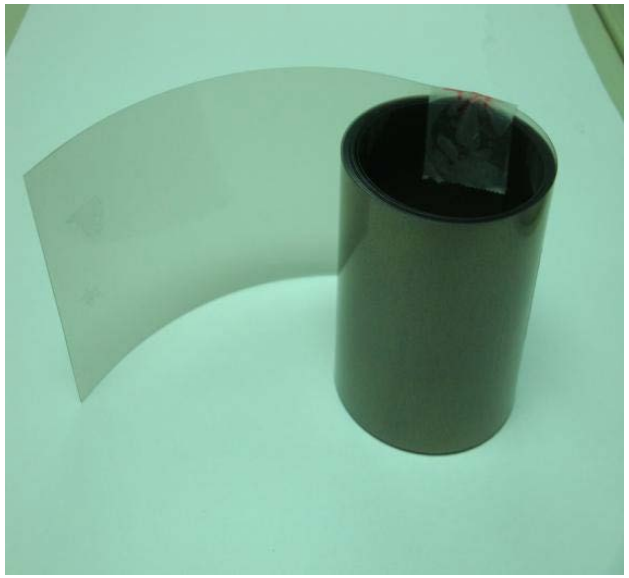
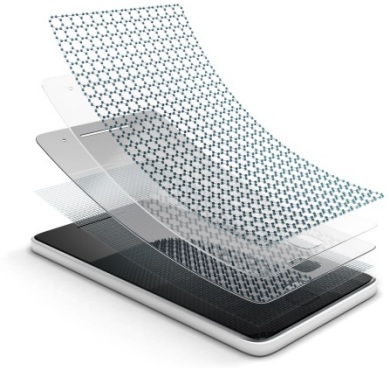
MIRWEC yasui SEIKI

Transparent Conductive Film

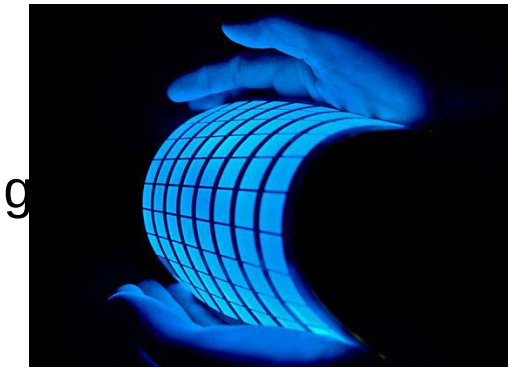


Touch Panels
& Screens



Smart Windows

LED & OLED Lighting



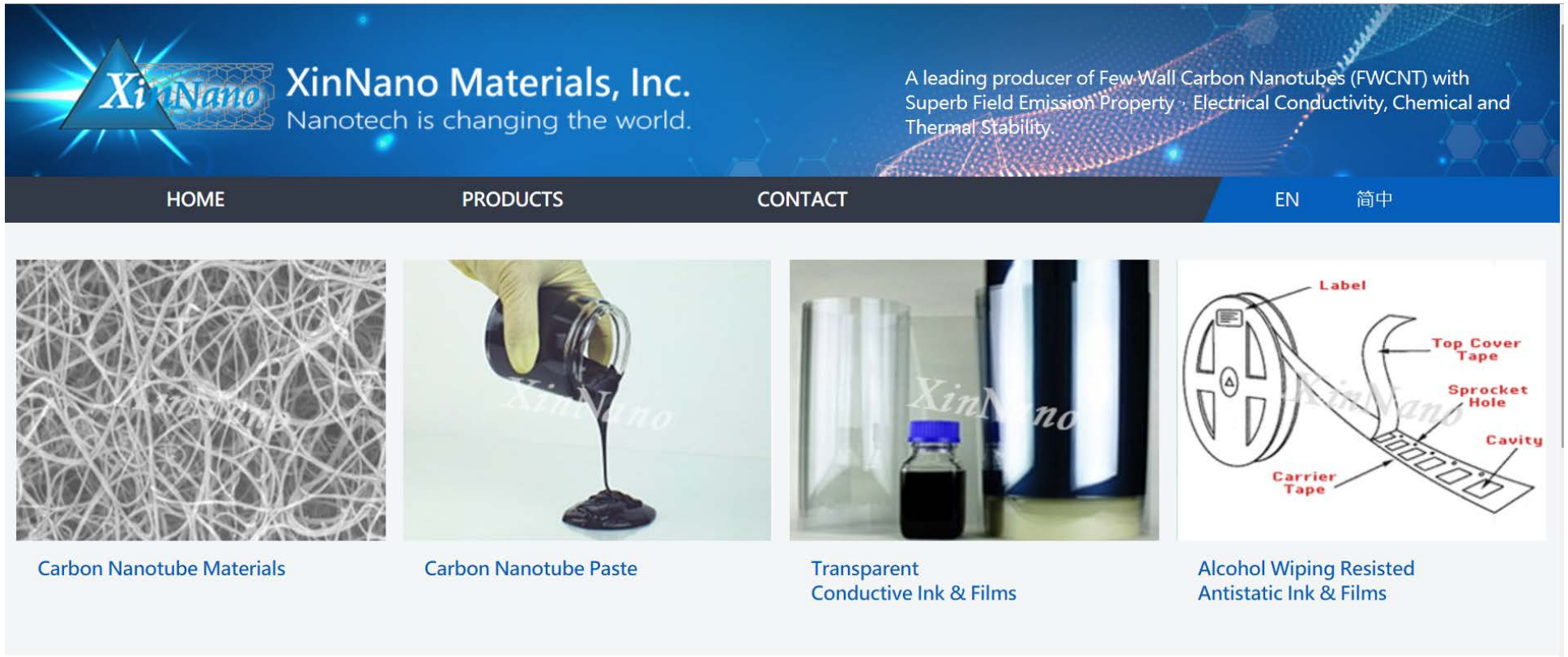
Transparent Conductive Film Material Analysis

	ITO	AgNW	CNT	Graphene	Conductive Polymer
Sheet Resistivity	100-500 Ω/sq	< 100 Ω/sq	100-500 Ω/sq	>100 Ω/sq	200-500 Ω/sq
Optical Properties	Transparent light yellow	Hazy	Dark	Dark	Transparent light blue
Flexibility	No Good	Good	Good	Good	Good
Weatherability	△	×（Migration）	○	○	○
Cost	△	△	△	△	○

KEY WORD : **ITO Alternatives**

- **Flexibility**
- **Cost**
- **Resource conservation**
- **Low resistivity**

Case study - XinNano Material, Inc.



Product: CNT-Polymer Conductive Ink

Applications:

- Touch Screens
- Flexible Solar Cells
- Smart Windows
- Flexible OLED lighting
- and more!

Initially, XinNano developed conductive film using slot die

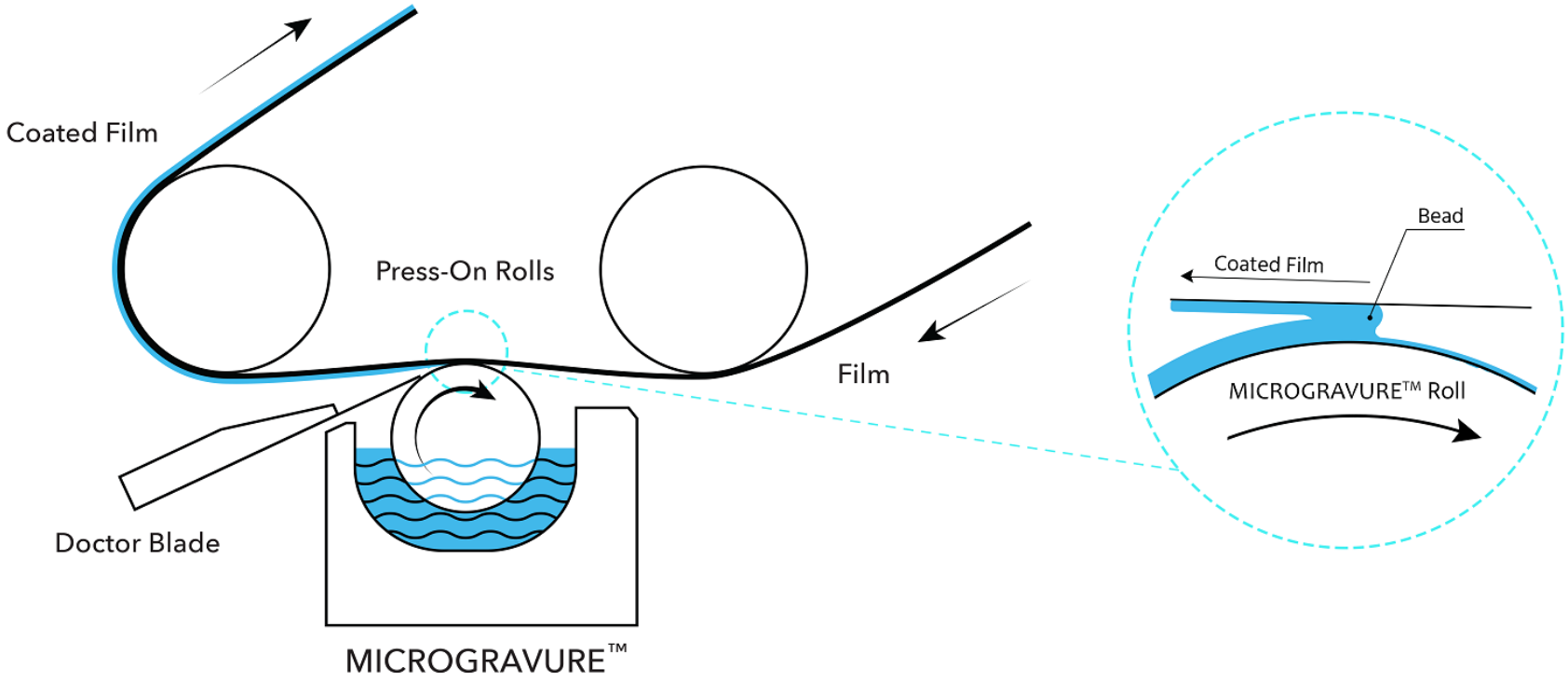
Two major issues

1) Sheet resistivity is non-uniform
   → Too low tolerance for transparent conductive film

2) “Striping” appears on the coated film
   → A critical defect for transparent conductive film

This led to a coating trial using MICROGRAVURE™

What is MICROGRAVURE™?



The coating surface coated by using MICROGRAVURE™ is very smooth and uniform

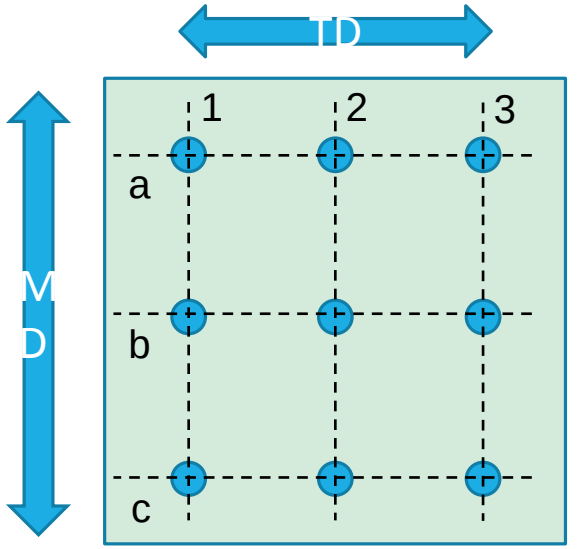
Sample Production (R2R coating)

- Substrate: PET based film
- Coating Method: MICROGRAVURE™
- Substrate Pretreatment: Corona Discharge
- Hot Air Drying: 160ºC for 3 min

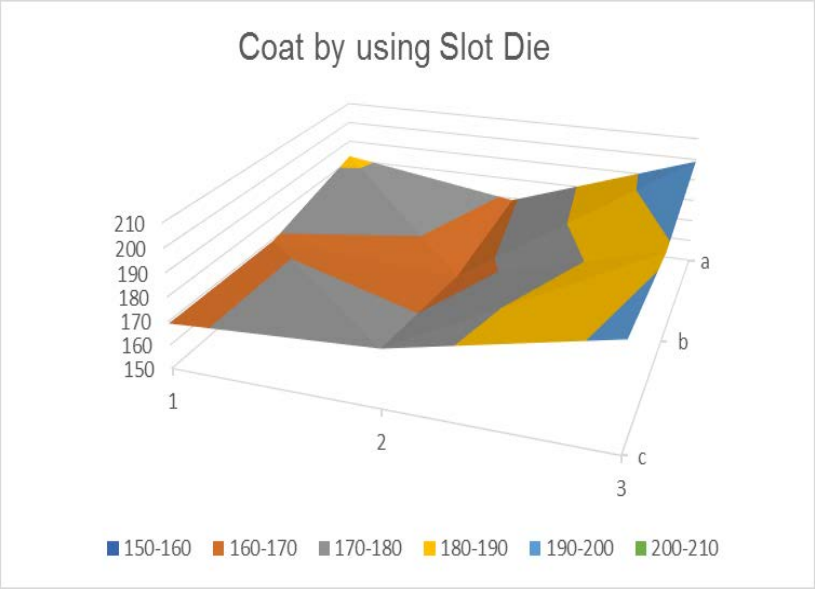
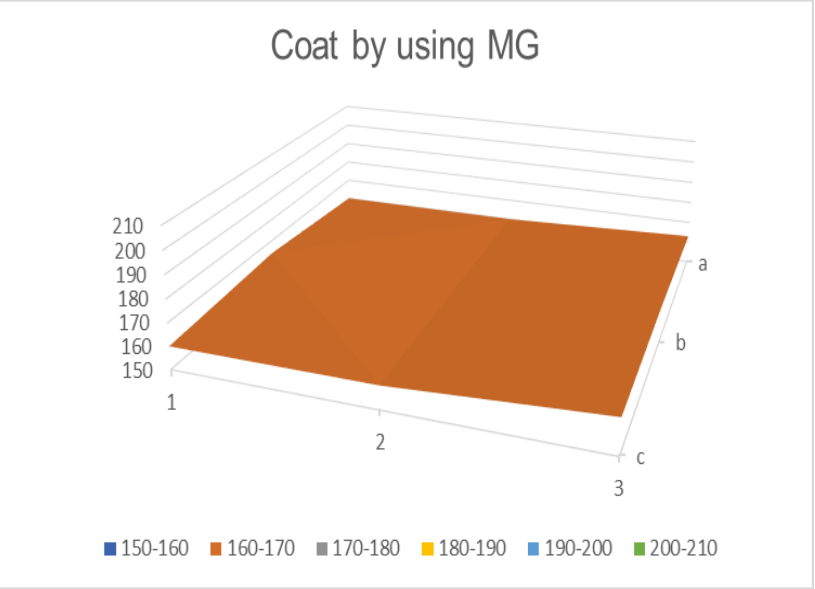
Sample Evaluation

1. Sheet Resistivity
- Resistivity meter: Loresta-AX (MITSUBISHI CHEMICAL ANALYTECH)
- Method: the 4 –pin probe method
- Measure 9 points within letter-size sample (as shown here)
- Analysis: Average, standard deviation, coefficient of variation

2. Sheet Appearance
- Visual Inspection: place white paper under the sample



Summary – Sheet Resistivity #1 (Comparative Coating Method)

Sheet Resistivity Contour Graph		
Resistivity(Ω/sq)	Ave:179.7 (Min:165, Max:199)	Ave:161.9 (Min:159, Max:165)
Standard deviation	11.50	2.25
Coefficient of variation	6.4%	1.4%

MICROGRAVURE™ method improved tolerance of resistivity by 1/5 !

Summary – Sheet Resistivity #2

Sample	Resistivity(Ω/sq)	Standard Deviation	Coefficient of Variation
100 Ω	98.9 (Max: 101, Min: 97.9)	0.73	0.73%
160 Ω	161.9(Max: 165, Min: 159)	3.02	1.4%
200 Ω	201.9 (Max: 208, Min: 195)	3.02	1.5%
320 Ω	321.4 (Max: 326, Min: 317)	2.09	0.9%
400 Ω	401.1 (Max: 410, Min: 392)	4.12	1.0%

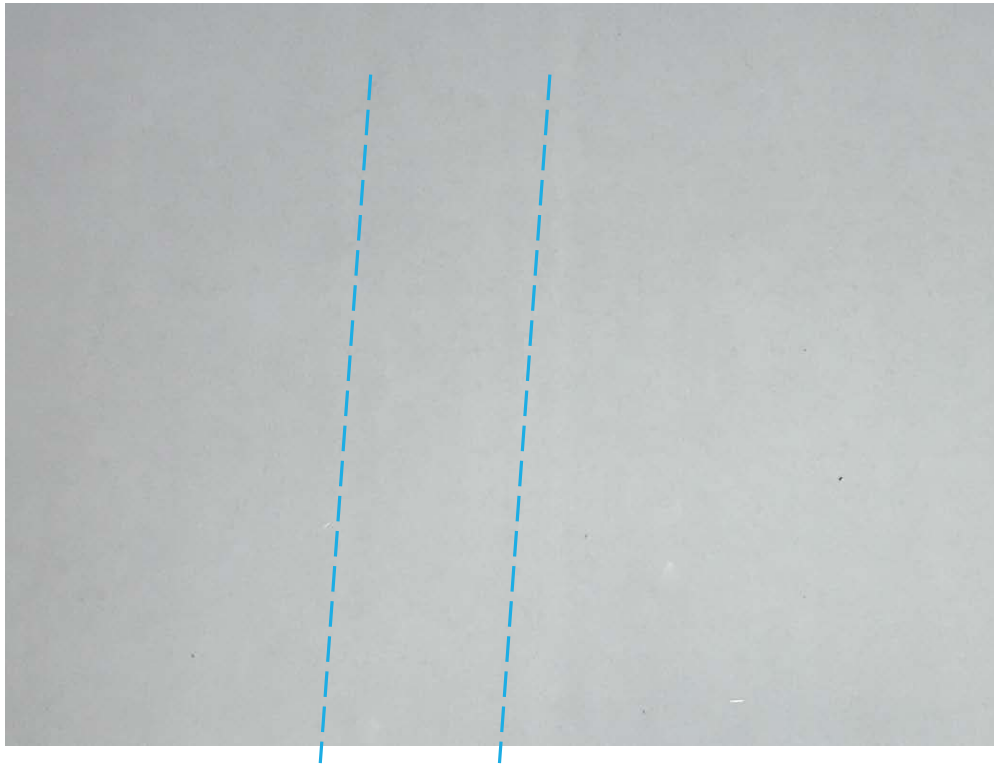
The tolerance of all samples coated by MG was good!
(All coefficients of variation are under 1.5%)

Appearance - “Striping”

In the MICROGRAVURE™ sample, thinner coating（Under 150 Ω/sq) is very good
However, “Striping” appeared on the thicker coating (100 Ω/sq) sample sheet.

We did “multi layer coating” with MICROGRAVURE™ (One of the many benefits of MG is that it is easy to do multilayer coating.)

⇒ **Results: No Striping**



Conclusion

1. Sheet Resistivity
   - The sheet resistivity is much more uniform with MICROGRAVURE™ compared to slot die
   - It is possible to coat large area
2. Striping
   - High resistivity(>150 Ω) = No striping
   - Low resistivity(100 Ω) = Multilayer coating by MICROGRAVURE™ resolved striping

MICROGRAVURE™ coating resulted in conductive film with uniform sheet resistivity and no striping

Acknowledgments

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