Metal Grids for OLED Transparent Conductors

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Mike Carmody
Chief Scientist
Intrinsiq Materials
Why Grids? Performance Drivers

• The best transparent conductors really aren’t conductive enough (sheet resistance > 5 Ω/sq)

• There are voltage and luminance drops as the current flows laterally

• Heat can build up locally

• As dimensions of the panels increase in size to greater than a few centimeters grids are thought to become necessary

Image from: J Park, J Lee, D Shin, S Park; J Disp Tech, 5(8) 2009
Grids bring their own set of problems

- \( T = 1 - \frac{w}{h} \) Increased Grid Width = Decreased Transparency
- We can increase the height of the metal, but that affects the next coated layer
- What metal should be used?
- What should the grid pattern be?
Printing Conductive Grids

• Expected to be significantly less expensive than sputtering and photolithography*

• Allows rapid change of pattern design (this might be especially useful for prototyping)

• Can printed grids meet the performance requirements
  – Low Sheet resistance < 1 Ω/sq  -- Thicknesses < 1 µm
  – Optical T > 90%  -- Line width < 150 µm

*H. Zhang, DOE SSL Workshop, Jan 30, 2013
Printing Considerations

• Nano Ag has been the metal of choice for printing inks

• Resistivity is still not good enough (5-10X bulk Ag)

• Does it have to be Ag? Au is expensive and there are worries about Cu and Al oxidation

• Inkjet printing may not be able to provide fine enough lines to meet fill factor requirements

• Experimentalists have used laser sintering or other deposition techniques to provide lines $\leq 10 \, \mu m$
Touch Screen Printing Market Opportunity
Bridge/Jumper Circuit

Pre-Patterned ITO

After Aerosol Jet Printing

Step #1: Insulator
100 um wide X 180um long X 1-2um thick

Step #2: Conductor
10um wide X 230um long X 0.3-1um thick

From Optomec, used by permission
Ag Lines by Selective Laser Sintering\textsuperscript{1}

- PEN substrate
- 10 \(\mu\)m lines
- \(~150\) nm thick
- 4.3 X bulk copper
- 9 to 22 \(\Omega/sq\)
- 80-92 \% T

S.H. Ko, ACS Nano, 2013 7(6) 5024-5031
Laser Sintering of Cu Nanoparticles

- Ambient conditions, no oxidation
- Spin coated on Glass
- Pattern height is 450 nm
- ~4.5 µm wide lines
- \( \rho = \sim 2 - 3X \) bulk Cu

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Can Printed Cu Withstand Oxidation?

- Spin coated and laser sintered three different Cu inks

- Compared to a similar Cu trace prepared by printing a seed layer and electroless plating Cu on top of it

- Kept in a chamber at 85°C and 85% RH

- Measured changes in resistivity over time
Cu Can Withstand Oxidation!

Average % Change in Resistance vs. Days at 85/85

- % Chg A
- % Chg B
- %Chg C
- % Chg Plated
Conclusions

• Printed metal grids offer the possibility of improved cost and improved performance

• Lines of widths necessary for high transmittance have been produced by a variety of techniques

• These lines need to be combined with OLED panels to determine interactions

• michaelcamody@intrinsiqmaterials.com