

71.4 SELF ASSEMBLED TRANSPARENT CONDUCTIVE COATINGS FOR FLAT PANEL DISPLAYS

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Abstract

A nano silver-metal based emulsion has been developed that, when coated on materials (flexible and rigid substrates, including both planar and three dimensional surfaces), self-assembles into a transparent conductive layer which has enhanced electrical and optical properties. This paper reviews the transparent conductive coating, including the emulsion itself and the self-assembly of the nano particles in the emulsion within the context of an EMI shielding application of the transparent conductive coating in the display industry.

1. Introduction

The objective of this work was to develop a highly transparent conductive coating based on inorganic nano materials that is applied via a simple, low-temperature deposition process which creates a flexible alternative to standard sputtered indium tin oxide (ITO) and copper mesh transparent conductive films for use in flat panel displays and other applications. Transparent conductive coatings (TCC) are a required, integral part of many electronics applications of today. For example, LCDs use an ITO conductive layer as an electrode, and plasma display panels can use a copper mesh transparent conductive film for electromagnetic shielding. This paper focuses

on the use of TCC with plasma displays as an overall demonstration of performance.

For electronic devices, CFR 47 Part 15 from the FCC stipulates restrictions for radio frequency (RF) emission of components in both commercial and residential settings². Because of the greater chance for close proximity of electronic equipment in a residential setting, the RF restrictions, commonly known as FCC 'B' regulations, are more limiting for the residential environment. For electronic components with a high degree of RF emissions such as plasma display panels, this necessitates the use of special components to attenuate the RF radiation created by the devices.

In order to attenuate the field, the transparent conductive layer is added to the plasma display stack, usually as part of the front filter (See Figure 1). This transparent conductive layer must exhibit as high degree of light transmittance as possible so as to minimize the optical attenuation effect of the TCC on picture quality, while achieving high conductivity in order to provide a means of 'dissipating' the RF emission. In addition, the transparent conductive layer must have as minimal impact as possible on the other qualities of the device, mainly having to do with picture quality and device reliability. In particular with plasma displays, optical phenomena such as the moiré effect need to be reduced or eliminated.

Today, the primary means of RF field attenuation for plasma displays has been through the use of very fine copper mesh on a polymer film. The copper mesh is manufactured via a multi-step photolithographic process that forms a fine grid pattern (see Figure 2). This patterned substrate is then placed in the plasma display stack to act as the RF emission shield. Main disadvantages of this approach are the costly and complicated production process and the optical moiré effect due to the systematic pattern.

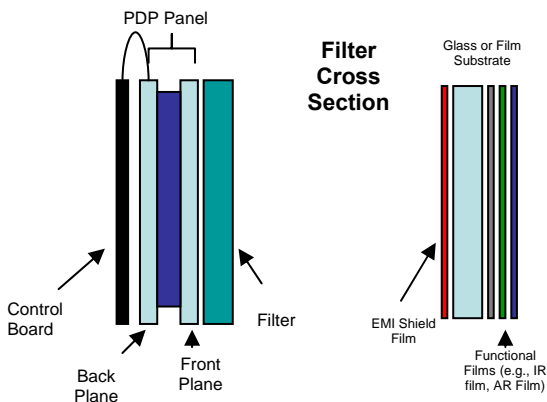


Figure 1: General plasma display panel configuration.¹

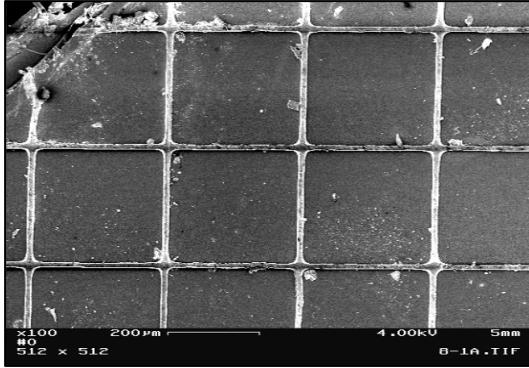


Figure 2: SEM picture of standard copper mesh film for use as EMI shield in plasma display panel

2. Principle Approach

In order to simplify the manufacturing process and potentially offer better physical and optical properties than the current mainstream copper mesh solution, a different approach for the transparent conductive coating has been invented and investigated. The main improvement targeted was the simplification of the multi-step, photolithographic manufacturing process which produces the copper mesh to a simple coating process on a roll-to-roll manufacturing line which produces the self-assembled transparent conductive coating and eliminates the moiré optical effect.

This simplified process is based on the special properties of nano materials and consists of a nano silver metal-based emulsion which is deposited onto a given substrate (either rigid, such as glass, or more flexible polymeric material, flat to three dimensional) at STP conditions. The nano silver particles within the emulsion have a D_{50} of 50 nm and a D_{100} of 70 nm and are completely dispersed and stabilized.

This emulsion can be deposited by a number of different methods, including coating, gravure, spraying, or other well known deposition and coating methods either in discrete batches or as part of a continuous roll-to-roll system. The coated film is then air dried, during which time the nano silver metal particles self assemble into a random pattern similar to that shown in Figs. 3 & 4. The self-assembly mechanism forms a network of conductive “lines” which form a continuous conductive phase and open “holes” (cells) through which light is transmitted. The silver nano particle network of lines is then sintered (done via a variety of methods, e.g., thermal sintering, or thermal sintering in combination with other methods) to obtain the necessary electrical properties. The sintering process is performed at low temperatures compatible with polymer and flexible substrates, taking advantage of the nano particle special properties.

3. Results and Discussion

With the plasma display example, the nano silver metal based transparent conductive coatings exceed functionality requirements and FCC B regulations. The EMI shielding effectiveness was tested using the KEC Method³ (see Figure 5 for example result). Values of >42 dB attenuation were seen across a wide spectrum of frequencies, up to 230MHz. This attenuation was achieved with visible light transmittance values of 80% and electrical resistance values of $1.85 \Omega/\square$.

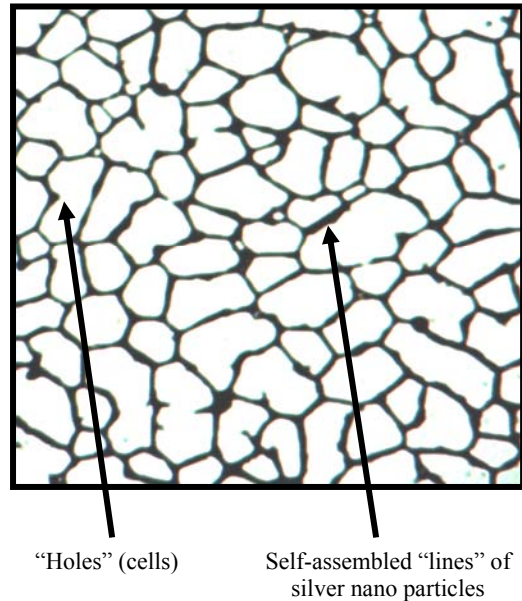


Figure 3: Random self-assembly transparent conductive coating

In addition to the main criteria of shielding effectiveness demonstrated, the optical properties exhibited were equal or greater than those exhibited by copper mesh.

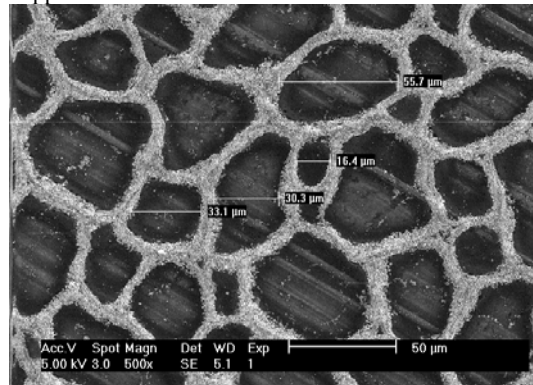


Figure 4: SEM picture of random self-assembly transparent conductive coating.

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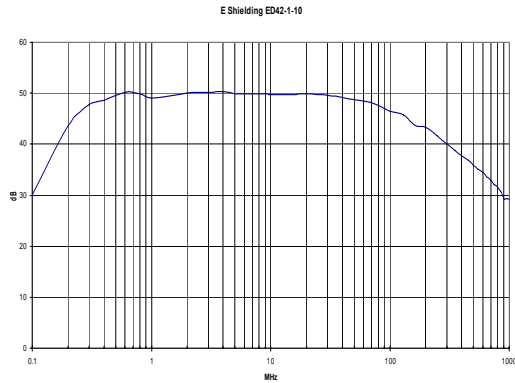


Figure 5: Shielding effectiveness for Cima NanoTech TCC (other properties, $T_{vis} = 80\%$, $R = 1.85$)

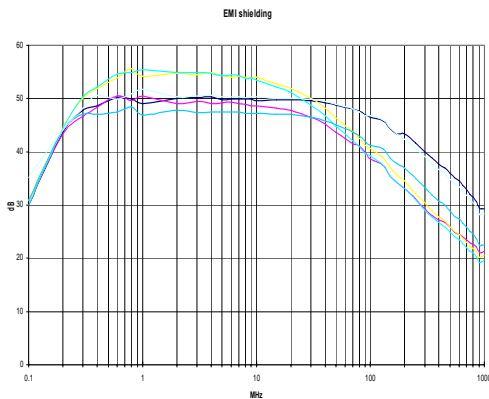


Figure 6: Different shielding effectiveness for Cima NanoTech TCC.

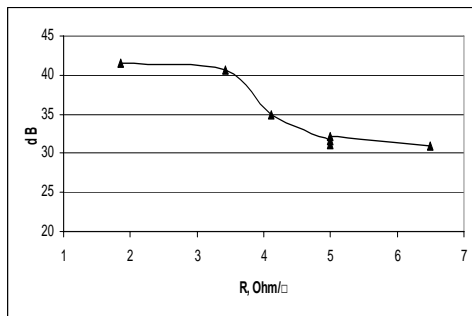


Figure 7: Different shielding effectiveness at 250 MHz for Cima NanoTech TCC versus pattern electrical resistance.

The random conductive pattern does not cause the moiré effect, a well known optical aberration in displays. We have demonstrated that the technology can be applied to a wide range of substrates, e.g. polymer films, glass, polycarbonate sheets and articles, metal, and others.

The system simplicity and its properties allow wide flexibility in applications and post treatments. With post treatment methods such as different sintering conditions, electroplating and others it is possible to reduce the electrical resistance of the pattern therefore changing the EMI shielding properties (see Fig. 6). Figure 7 shows the change in EMI shielding as a function of the pattern resistance at 250 MHz.

4. Impact and Conclusions

By having a simple emulsion system that can be applied via coating, spraying, or a variety of other means, the nano silver-based transparent conductive coating offers a simpler alternative to the current photo-lithographic etched solution (and also in some cases to the ITO sputtering process), thus offering a solution to potential production bottlenecks. As plasma display panel production is expected to increase from 7M units in 2005⁴ to 18.9M units in 2009⁵ and 25M units in 2010⁶ the ability to produce EMI shielding films at high speed on a roll-to-roll process addresses a potential major bottleneck in the PDP supply chain. Beyond plasma displays, the TCC creates an alternative way on a roll-to-roll process to achieve better conductivity performance, potentially provide better physical characteristics, achieve higher visible transmittance and alleviate supply chain bottlenecks in markets using conductive films.

5. Acknowledgements

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6. References

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