IEEE Industry Applications Society
Annual Meeting
Edmonton, Alberta

October 5-9, 2008

Electrostatic
Answers, LLC

Verifying Solution Component Concentration by Measuring Frequency Dependent Conduction of Electrically Charged Species

Kelly Robinson
Electrostatic Answers LLC
Rochester, NY USA
Kelly.Robinson@ElectrostaticAnswers.com

***Abstract*—A conductive layer in a film or a sheet is an effective method for preventing static problems during production operations and in customer applications. Additionally, conductive layers form active electrodes in MEMS devices and traces in printed electronic circuits that are now produced in continuous roll-to-roll manufacturing processes. The conductive layer is formed by coating a solution or ink onto the moving substrate and subsequently drying the liquid to form the solid layer. The coated solution contains many components including particles or large organic molecules that provide conductivity in the dried layer. The conductivity of the layer must be controlled to satisfy product requirements. Variation in the concentration of the conductive species in solution is common source of variability. Verification of the concentration is proposed using a conductivity sensor immersed in the solution and measuring electrical admittance as a function of frequency. For sufficient sensitivity, the conductive species must be the largest, electrically mobile species in the solution as is the case for the formulation of many conductive layers. The decrease in admittance with increasing frequency verifies the concentration. For satisfactory measurement sensitivity, the concentration of the mobile species must be sufficiently high so that conduction due to this species can be detected. And, the relaxation time τ_s, which is unique to a specific species must be large compared with the charge relaxation time τ_e of the solution so that the decrease in conduction due to the mobile species will be evident.**

Keywords-admittance; concentration; conductivity; ink; sensor; solution; static; verification

I. Introduction

Providing an electrically conducting coating in film or sheet media is an effective method for preventing electrostatic problems during production operations and in customer applications [1]. Conductive layers prevent problems such as contamination from dust attraction, sheet sticking during converting (sheeting operation), feeding from an input stack, jamming during transport in customer equipment, and electrostatic discharges or sparks that cause logic errors and reset control systems.

The electrical conductivity of the layer is a key design parameter to be selected when designing the product. Determining the range of acceptable conductivity involves making engineering trade-offs between competing requirements. For example, improved static protection usually requires higher conductivity. Achieving the lowest possible cost requires minimizing coated layer thickness and the solids content in the liquid formulation. The resulting product specification on electrical conductivity is that it be sufficiently high to achieve the needed performance and absolutely no higher.

Variability exists in manufacturing operations. The resistivity (inverse of conductivity) of a coated layer is typically measured by taking a sample of product from the winding stockroll after coating. The resistivity must be held within specification limits that typically differ by about a factor of 3X or 0.5 log(Ω/□). When the measured resistivity falls outside of the limits, the manufacturing process must be analyzed to determine the root cause for the variation so that the appropriate adjustment can be made to bring the layer resistivity back within the specification limits.

Variations in the concentration of components in the coated solution are a common source of variability in a coating process. Verifying that the solution to be coated has acceptable concentrations of key ingredients is valuable. However, identifying measurements on solutions that relate to the conductivity of the dried layer has proven elusive. The conduction mechanism in the dried layer is very different from the conduction mechanism in the liquid solution. The conductive layer is often formed using solid particles (carbon, tin, zinc antimonate) [2], organic conductors such as polyaniline [3] or polythiophene [4], or carbon nanotubes [5]. In the dried layer, conductivity is achieved by electronic conduction by particle to particle contact or through the continuous molecular coating. In contrast, current flow through the solution to be coated occurs by the motion of electrically mobile, charged species dispersed in the liquid.