Exploring the Effects of Photonic Curing on the RF/Microwave Performance of Printed Co-Planar Waveguides

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The field of printed electronics is a branch of additive manufacturing that enables rapid prototyping and low-cost fabrication of a wide range of devices, including antennas and other RF/microwave components. The performance of these devices depends on the conductivity of conductive inks, based on silver nanoparticles (AgNP) which typically have much lower values compared to their bulk counterparts. During the fabrication process, conductive inks are deposited on a substrate and then cured to increase the conductivity. This curing step typically requires at least 30 minutes and high temperatures (>250° C) to obtain good conducting lines. This long curing time limits the scalability of the manufacturing process, therefore, technologies that significantly decrease the curing time without sacrificing RF performance are advantageous. The RF performance and quality of the printed device depend on several factors, including the success of the curing process and resultant conductivity of the ink. One promising method, photonic curing, is a recent development in the field of printed electronics that enables the rapid curing of printed conductive inks on the order of milliseconds. This transient processing allows thin films to achieve high temperatures on a wide range of low-temperature substrates. In this work, a Pulseforge® 1300 (Novacentrix) was used to subject thin films of AgNP ink to intense pulses of broadband light (200–1500nm). The light is absorbed by the AgNP film, generating enough heat to cause the particles to sinter into a single component. The total radiant energy delivered to the film can be controlled by varying the applied voltage or the number and length of the light pulses. Control over the curing parameters must be exercised to maximize AgNP sintering and minimize excessive substrate heating and gasification, and gas generation within the film itself. Therefore, the careful application of light pulses can prevent undesired outcomes including substrate warping, film ablation, and cohesive failure of the film.

Herein, we explore how photonic curing affects the RF performance of printed electronics. CPWs were printed via the Optomec aerosol jet system on polyimide substrates to serve as test beds for microwave-frequency signals ranging from 2 to 18 GHz. CPW thickness was controlled by varying the number of deposited layers, which ranged from ~2 to 10 μm. Photonic curing parameters, such as voltage, pulse length, number of pulses, pulse frequency, and total radiant energy were varied. Sheet resistance was measured before and after curing. S-parameters (S_{11} and S_{21}) were obtained for each CPW using a network analyzer and two port—short, open, load, thru (SOLT)—calibration. Curing parameters and S-parameters were correlated and compared to CPWs cured using conventional heating. Scanning electron microscope (SEM) images of CPWs were obtained to observe film morphology and the extent of nanoparticle sintering. Finally, film morphology was compared to S-parameters to assess the impact of curing parameters on RF performance.