BAPVC Annual Project Report

Project Title: Materials and Processes for High-Resolution Printed Bus Bars

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Summary:

In this project, researchers are developing materials and processes for high-resolution bus bars through a combination of development of high-resolution gravure printing and development of advanced nanoparticle conductor inks. In the last year, substantial progress has been made on improving the resolution of gravure printing. Sub-5μm features have been realized, printed at printing speeds of ~1m/s. Additionally, novel copper/silver alloy nanoparticles have been realized that deliver good conductivity, low silver content, and significant resistance to oxidation; these are promising as a replacement for silver flake currently used in PV applications

Key Accomplishments:

In the area of high-resolution printing, significant progress has been made. Sub-5μm features have been realized using a custom gravure printing tool. Features sizes as small as 2μm have been realized with good line edge roughness and pattern fidelity, while maintaining high printing speeds of ~1m/s, as shown in figure 1. Good conductivity has been obtained using commercial nanoparticle inks. A detailed physical model of gravure printing has been developed, and this has been used to drive optimization and improvement in gravure printing. The process includes detailed fluid mechanical studies on the filling of gravure cells during inking, wiping of excess ink, transfer of ink, and the drying of the resulting pattern.

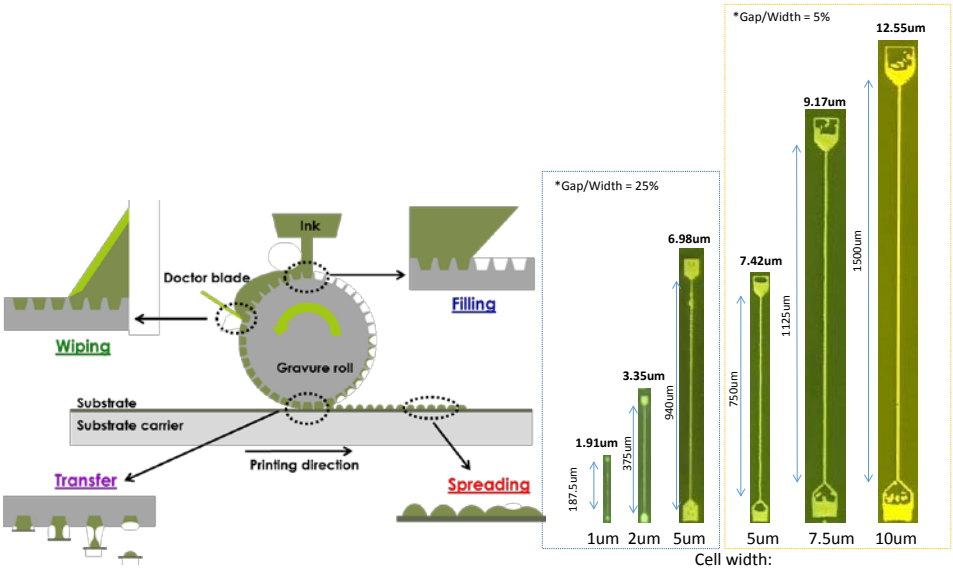

Figure 1: (left) schematic representation of overall gravure process, and (right) printed lines showing scalability below 5μm.

In the area of realization of low-cost conductor inks, an initial ink family has been developed that combines copper and silver to realize printed alloy thin films. Even at <20% silver content, the film shows excellent resistance to oxidation, and delivers good conductivity. The oxidative stability is apparent in figure 2 The low silver content is expected to be critical to delivering low cost for the ink. Cost modeling of the overall process is underway.

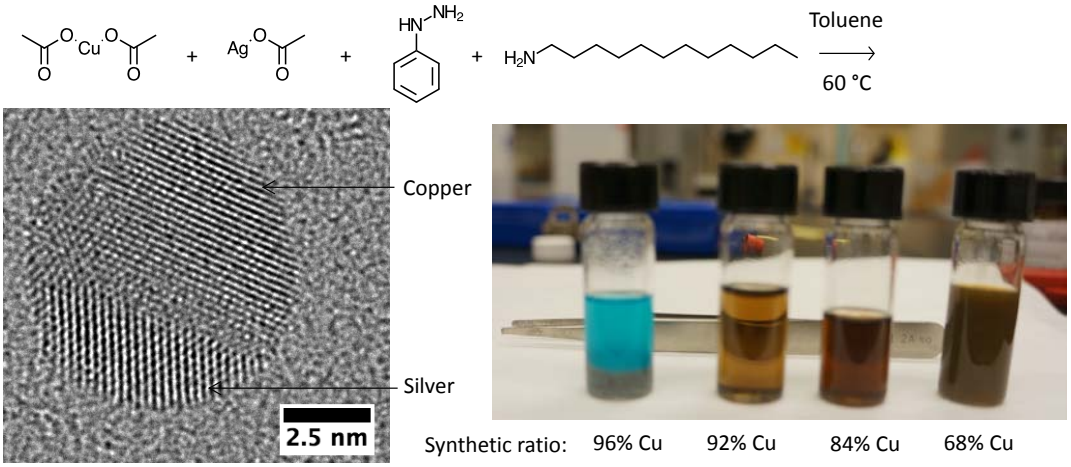

Figure 2: (top) synthetic process, (left) typical allow nanoparticle, and (right) illustrative oxidative resistance of inks as a function of silver content.

Future Work:

In the future, researchers will investigate impact of surface topology and rigid substrates on gravure printability. In the area of inks, the Cu/Ag inks will be optimized and used to demonstrate printed conductor patterns.