World Academy of Science, Engineering and Technology
International Journal of Chemical and Materials Engineering
Vol:14, No:09, 2020

Tuning the Surface Roughness of Patterned Nanocellulose Films: An Alternative to Plastic Based Substrates for Circuit Priniting in High-Performance Electronics

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Abstract : With the increase in global awareness of the environmental impacts of plastic-based products, there has been a massive drive to reduce our use of these products. Use of plastic-based substrates in electronic circuits has been a matter of concern recently. Plastics provide a very smooth and cheap surface for printing high-performance electronics due to their non-permeability to ink and easy mouldability. In this research, we explore the use of nano cellulose (NC) films in electronics as they provide an advantage of being 100% recyclable and eco-friendly. The main hindrance in the mass adoption of NC film as a substitute for plastic is its higher surface roughness which leads to ink penetration, and dispersion in the channels on the film. This research was conducted to tune the RMS roughness of NC films to a range where they can replace plastics in electronics(310-470nm). We studied the dependence of the surface roughness of the NC film on the following tunable aspects: 1) composition by weight of the NC suspension that is sprayed on a silicon wafer 2) the width and the depth of the channels on the silicon wafer used as a base. Various silicon wafers with channel depths ranging from 6 to 18 um and channel widths ranging from 5 to 500um were used as a base. Spray coating method for NC film production was used and two solutions namely, 1.5wt% NC and a 50-50 NC-CNC (cellulose nanocrystal) mixture in distilled water, were sprayed through a Wagner sprayer system model 117 at an angle of 90 degrees. The silicon wafer was kept on a conveyor moving at a velocity of 1.3+-0.1 cm/sec. Once the suspension was uniformly sprayed, the mould was left to dry in an oven at 50°C overnight. The images of the films were taken with the help of an optical profilometer, Olympus OLS 5000. These images were converted into a '.lext' format and analyzed using Gwyddion, a data and image analysis software. Lowest measured RMS roughness of 291nm was with a 50-50 CNC-NC mixture, sprayed on a silicon wafer with a channel width of 5 µm and a channel depth of 12 µm. Surface roughness values of 320+-17nm were achieved at lower (5 to 10 µm) channel widths on a silicon wafer. This research opened the possibility of the usage of 100% recyclable NC films with an additive (50% CNC) in high-performance electronics. Possibility of using additives like Carboxymethyl Cellulose (CMC) is also being explored due to the hypothesis that CMC would reduce friction amongst fibers, which in turn would lead to better conformations amongst the NC fibers. CMC addition would thus be able to help tune the surface roughness of the NC film to an even greater extent in future.

Keywords : nano cellulose films, electronic circuits, nanocrystals and surface roughness
Conference Title : ICCEA 2020 : International Conference on Chemical Engineering and Applications
Conference Location : Zurich, Switzerland
Conference Dates : September 16-17, 2020