Proceedings ECS
2021
Brussels, Belgium, September 7-9, 2021

P-52

INVESTIGATION OF INK-JET PRINTED LACQUER SYSTEMS FOR COATING APPLICATIONS

I. Preda [1], S. Filliger [1], N. Carrie [1] and G. Gugler [1]

[1]iPrint Institute, University of Applied Sciences and Arts of Western Switzerland, Fribourg, Switzerland

Email: ioana.preda@hefr.ch

Abstract

This work presents a material screening study conducted while researching an 100% UV lacquer for an ink-jet coating application. In the first part of the study, spin-coating was used for creating a uniform coating of 7 µm over a metallic substrate. The uniformity and the defect-free characteristics of the coating were confirmed by FIB microscopy and by electrical tests, which were found to be a reliable tool for ensuring the preparation of defect-free coatings over metallic substrates. In the second part of the study, the manufacturing process was switched to ink-jet. The best jetting and UV curing parameters were found to ensure good wetting between consecutive coating layers while having sufficient curing. Although thicker coatings of about 20 µm/layer were produced using ink-jet, the defect-free characteristics were conserved up to 50 consecutive layers, confirming that thicker yet uniform coatings could be obtained by ink-jet. The new testing method was helpful during the material screening. Furthermore, we have shown that lacquer systems can be easily obtained by ink-jet printing and could be very useful for electrical engineering applications.

Keywords*: 100% UV lacquer system, coating, dielectric breakdown strength, ink-jet, encapsulation.*

1. Introduction

Materials screening for coatings are very common and usually adhesion or humidity and temperature stability (85/85) tests are used to evaluate the quality and the compatibility of the coating with other materials such as metallic layers. When it comes to thicker, multilayer coatings or to multi-material systems, the previous tests can point towards the weaker point of the assembly but do not characterize the overall volume. As part of a material screening for a multilayer coating based on 100% UV lacquer for an ink-jet application, we have found that the quality of thicker layers could be sometimes hard to assess and that one possible solution comes from the use of dielectric breakdown tests.

2. Theory

Dielectric breakdown test consists of applying a high voltage over an insulating material sandwiched between two conductive layers. The obtained dielectric strength represents the maximum electric field that the insulator can withstand before undergoing irreversible degradation such as an electric short circuit between the electrodes (Figure 1). The maximum value of the voltage applied to the terminals is called the breakdown voltage and, given that the internal electric field is enhanced by defects, the higher the breakdown voltage, the lower the number of defects in the sample's volume.

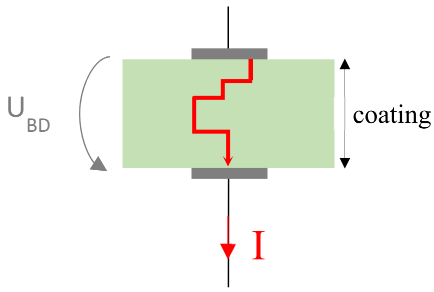

Figure 1. Schematics of a dielectric breakdown test

Similar tests are usually used in order to assess the number of pin-holes in polymers films. But, unlike those tests, which are simply representing a pass/fail test, the measurement of dielectric strength allows for a more thorough volume characterisation of the material. Although it is impossible to know where the defects are located, the “qualitative” output is extremely useful during a material screening or while improving a coating process. Furthermore, given that the materials are evaluated under a high electric stress, the “quantitative” output can also point out towards the suitability of the coating material for applications in the energy sector, where electrical stresses with the same order of magnitude could occur.

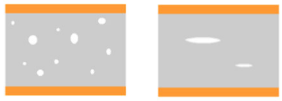

Figure 2. Possible defects found in the sample

Figure 3. Dielectric strength measuring setup

3. Experimental procedure and preliminary results

In the first part of this study, spin coating was used to create thin, uniform layers. For each investigated material, the coating speed was adjusted in order to obtain the desired thickness, knowing that the final uniform layers had to be 7 µm or less. Figure 4 presents the intermediate steps taken in order to determine the appropriate spin coating speed. The quality of the single layers was assessed by performing dielectric breakdown tests and part of the obtained results are presented in Figure 5.

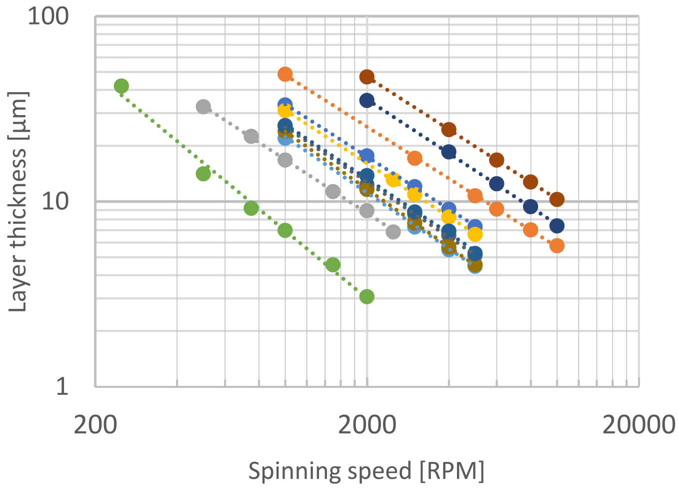

Figure 5. Layer thickness vs. spin-coating speed

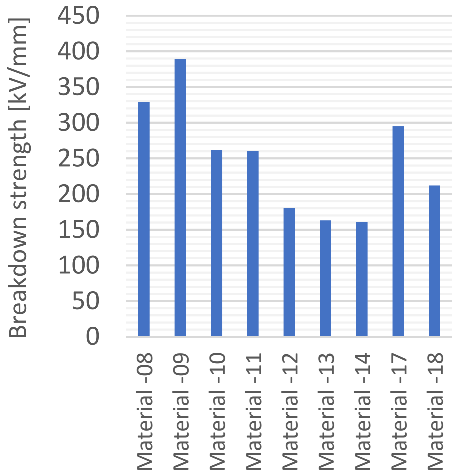

Figure 4. Dielectric breakdown strength for single-layer coatings

Once the best candidates were found – those with the higher dielectric strength being considered as being those having the lowest number of volume defects – spin coating was further used in order to create multi-layer coated samples. In between two insulating layers, a conductive layer was introduced in order to locally homogenise the electric field.

Additional dielectric tests were performed in order to confirm that the electrical properties are maintained and, before moving towards the ink-jet process, FIB Microscopy was used to further asses the homogeneity of the screen-printed coatings. Figure 6 shows one of the obtained images. Please note that the vertical line on the right is due to the alignment of the sample under the FIB beam.

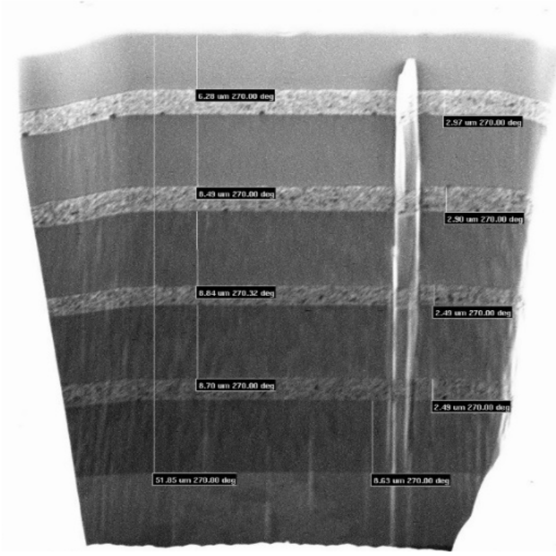

Figure 6. FIB microscopy presenting several <u>spin-coated</u> coating layers, "sandwiched" between <u>spin-coated</u> silver inter-layers

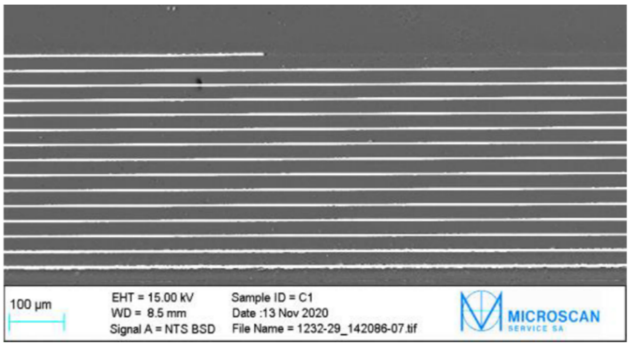

Figure 7. SEM microscopy presenting several <u>ink-jet printed</u> coating layers "sandwiched" between ink-jet printed silver inter-layers

4. Final results and discussion

Following our preliminary study using spin-coating, the goal objectives with respect to the coating layer's homogeneity were fixed, using both microscopy and electrical test results. We thus moved to the second part of the study which consisted of obtaining the same results by the use of the versatile ink-jet technology.

First of all, thanks to drop watching technology, we were able to find the best recipe for printing uniform insulating layers sandwiched between metalized electrodes. After optimizing the UV curing process, we were able reproduce as closely as possible the samples manufactured at the beginning of the study. Yet, one drawback was quickly discovered: it was impossible to obtain the same thickness for and individual layer printed by ink-jet as it was previously the case for spin-coating. Actually, in order to obtain homogeneous layers, without dewetting, layers three times as thick had to be printed. This change in thickness has also slightly affected the overall quality of the samples from an electrical point of view. Nevertheless, the structural uniformity of the sample was maintained, as shown by the SEM microscopy image shown in Figure 7.

The increase in the number of defects with respect to the thickness of the sample is a well-known phenomenon in electrical engineering and it was also confirmed by our results, as shown in Figure 8.

Hence, the ideal thickness for the ink-jet coated layer could be found as a compromise between a thin layer that is subject to dewetting and a thicker, uniform layer, having a minimum number of defects.

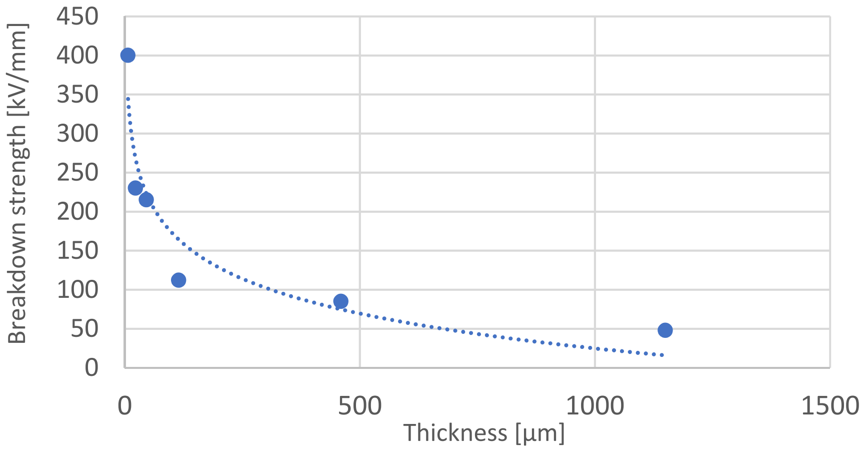

Figure 7. Breakdown strength values obtained for various thicknesses of the ink-jet printed layer

Furthermore, dielectric breakdown results have shown that the selected coating could be used as encapsulant for low and medium voltage applications, given that layers having a thickness of half a millimeter exhibit a breakdown strength of 100 kV/mm, thus opening the door for encapsulating power modules or for locally insulating energized nodes.

5. Conclusions

In conclusion, this work has allowed us to find the best 100% UV lacquer for an ink-jet coating application. The material study started with spin coating tests and moved to the final ink-jet technology. The use of dielectric breakdown tests was found to be a quick method to asses the quality of thicker ink-jet printed layers. Furthermore, we have shown that thicker, lacquer systems, can be easily obtained by multi-layer ink-jet printing.