Uniformity Evaluation Study Thick Electrode Using Noncontact Mass Estimation Method

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1. Introduction

To evaluate the placement accuracy of printed electrodes, measurement of electrical properties is of the utmost important,[1] but since this is limited to the evaluation of electrical properties between two points, the method of inspecting shape in terms of uniformity is mainly used to evaluate the overall print quality.[2] Since pattern-printed electrodes should have the same width, height, and line width, uniformity can be evaluated by quantifying the differences. In general, this uniformity is used as an index to measure the print quality of the printed electrode.

However, the shape test cannot detect a change in internal conductive material due to impurities, voids or particle heterogeneity in the electrodes,[3] and a risk of mishandling all other electrodes with different shapes exists.

To solve this problem, this study proposes a new method that defines the quality of printed electrodes using a mass estimation-based uniformity test. This method is proposed based on the principle of determining how uniformly the electrode material is applied by estimating the mass of the electrode material discharged in each printing pattern. Since information regarding the changes in electrode line width, height, and pattern spacing—which are used in existing homogeneity evaluation methods—is detected by the change in density according to location, the mass uniformity evaluation is expected to encompass the existing printing

2. Methods

To obtain the mass of the printed electrode, a non-contact mass estimation method is necessary because it is difficult to remove the electrode. The "contactless mass estimating technique," was developed in a previous study. The technique of mass estimation is one that enables estimation of mass by evaluation of grey values that vary according to the density of an object using transmitted radiation, and the working principle of mass detection changes in the target volume, when the density changes due to large particle deflection or materials having different densities, such as impurities, or voids. This mass estimation technique has been used for various other areas where mass measurements are required.

2.1. Homogeneity Evaluation Target

Although printing technology can generate a wide variety of materials for electrodes, the evaluation of the printability of various materials is beyond the subject of this study. Therefore, in this study, experiments were performed using gold and silver printed electrodes with excellent stability. Although a variety of materials can be used for printed boards, Teflon was selected and used. The gold and silver printed electrodes used in this experiment were fabricated by HANMITECH Co., Ltd., a thick-film electrode printing company.

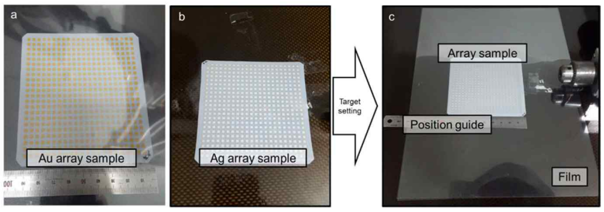

Figure 1. Homogeneity Experiment Samples a) Gold thick-film printed electrode b) Silver thick-film printed electrode c) Fixed samples using films.

Figure 1 shows a) a 22 × 22 array of gold thick-film printed electrodes having the shape of a 4 × 4 mm square, b) a silver thick-film printed electrode with the same shape, and c) the fixed electrodes using films for the experiment. A total of 484 printed electrodes each of gold and silver were placed independently for testing their uniformity using their respective mass deviations. Because the use of the Teflon substrate caused the electrode to be lifted, the film was used to fix it back in place. The current mass estimation techniques are limited to reading the relative mass deviations and require a mass conversion process by normalizing the mass to the average mass value measured with a balance. On a digital scale, weights of 50 randomly selected gold printed electrodes and 50 silver printed electrodes were measured, and it was found that the average weight of the gold electrodes was 1.979 mg and the average weight of the silver electrodes was 1.169 mg. Finally, the average of the X-ray attenuation signals was converted into mass using a method of normalizing to the actual mass average.

2.2. Mass estimation experiment using X-ray microscope

The tube voltage and output current of the microscopy device were determined to be 64 kV and 40 uA, respectively, to obtain transmission images of highly contrasted radioactive specimens using the X-ray microscope. In the transmission image measurement, the tube voltage was changed within ± 1 kV from the set value, and the output current was also changed within ± 1 uA.

Because the X-ray microscope used in the experiment was operated manually, much time was expended in obtaining X-ray images of all 968 printed electrodes. To improve this, experiments were conducted wherein images were collected in 2 × 2, 3 × 3, 4 × 4, and 5 × 5 arrays. As a result, it was found that a 3 × 3 array resulted in the optimal images being obtained, as shown in Figure 2. Therefore, the magnification was set to 5.92x to collect 9 images, and the mass estimation was then performed.

3. Results

Assuming that the average grey value of the pixels in the background is 0, as shown in multiplying the number of pixels in the printed electrode area by the difference of the average gray value of the pixels in the printed electrode area produces the amount of X ray attenuation that is proportional to the mass. Following that, this value is multiplied by the by the mass conversion correction factor to estimate the mass.

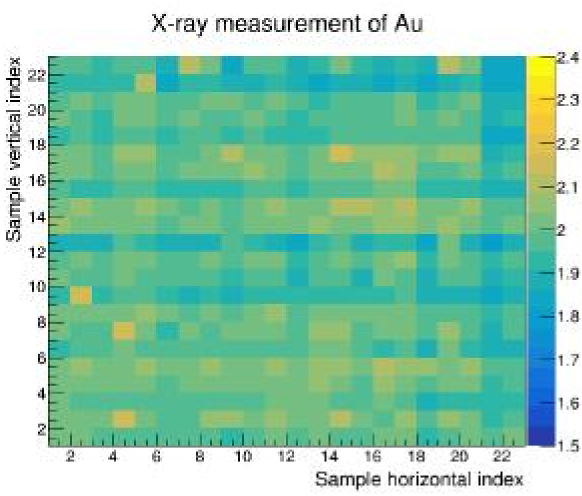

Figure 2. Printed mass plane analysis results of the gold printed electrodes.

Figure 2 shows the mass mapping result of each sample to a two-dimensional plane to check if any patterns or trends exist in the sample print job. An area with a very small mass reduction is observed along the top sides, which may be due to a drop in the ejection pressure on the edge during screen fitting, or an error caused by the microscopic horizontal error of the shooting table during X-ray microscopy.

mass conversion correction factor to estimate the mass.

4. Conclusion

As a result of evaluating the uniformity of printed electrodes using non-contact mass estimation technique, it was possible to evaluate the uniformity using the mass of printing material, unlike the line width and height inspections using the conventional shape inspection methods.

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