Morphological Analysis of Fabricated 5.0 μM Interdigitated Electrode (IDE)

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Abstract. The aim of this research is to study the morphological analysis of fabricated Interdigitated Electrode (IDE). This device electrode was physically characterized using 3D nano profiler, scanning electrode microscope (SEM), Energy-dispersive X-ray spectroscopy (EDX) and Atomic Force Microscope (AFM). Based on this analysis, IDE pattern was analyzed thoroughly based on the IDE pattern specifications with 5 μM finger gap and this research significantly will stand as a platform quantify the biomolecules in further analysis.

1. Introduction

Recently, miniature sensor devices have received a high demand from industries not only due to the sizes but also as beneficial promising tools and ready to be applied in many applications [1-3]. Within nanotechnology, micro- and nano-gap devices can be seen with optimum development for the specific purpose to detect and quantify the biomolecules on the sensors, such as Interdigitated Electrode (IDE) [3]. This device offers promising advantages in terms of low-ohm usage, rapid stability, rapid reaction kinetics and improved signal-to-noise ratio. Moreover, IDEs consist of a sequence of micro- or nano-bands electrodes in which these bands are joined together to create a group of interdigitating electrode fingers [5-7]. Meanwhile, both anode and cathode electrodes in IDE are assembled closely together thus creating highly efficient amount of ionic cycles between electrodes with more than 0.98 rate. Apart from that, this device is built without reference electrode, however, it provides a steady state current response as compared to other devices that contain three or four electrodes. Due to the smaller gap of the device, only a small amount of sample is needed due to its high surface-to-volume ratio and enabling label-free detection [8-9]. The uniqueness of IDEs is due to the structural design that can be developed based on our interest. Thus, in this research, the fabricated IDE was physically examined and validated with 3D nano profiler, scanning electrode microscope (SEM), Energy-dispersive X-ray spectroscopy (EDX) and Atomic Force Microscope (AFM) as referred based on pattern of 5.0 μM finger gap.

2. Materials and methods

2.1 Design of the interdigitate electrode

Using AutoCAD software as seen on Figure 1, the photomask for the IDE biosensor was developed and then printed on the surface of the chrome panel. The normal chrome mask was used in the method of photo masking. The complete fabrication was prepared by a private company based on the details and specifications given.
2.2 Instruments
The surface morphology of the IDE pattern was characterized by using a 3D nano profiler, scanning electrode microscope (SEM), Energy-dispersive X-ray spectroscopy (EDX) and Atomic Force Microscope (AFM). Briefly, the fabricated IDE was placed and observed at different magnification under different probes/instrument to capture and analyse the IDEs according to the design dimensions.

3. Results and Discussion
Aluminium (Al) was chosen as the main conductor element in fabricated IDE. In present sensor field, a lot of researchers used Al as a main component in deposited sensors surface or immobilization with biomolecules to enhance the signal measurement [10-14]. In comparison with other conducting materials like gold, platinum or copper, Al is a strong, conductive and a low-cost metal. Apart from the unique properties of Al such as good thermal stability and hardness, it is also known for its biocompatibility with biological elements such as antibody, DNA, enzyme, biomimetic and also phage [14-18]. Based on figure 2(a-b), the topography images of fabricated IDE were examined first by SEM. The rough edges and smooth surface of the IDEs can be shown to be well fabricated. Apart from that, the IDE finger design, with sharp edges and vertex, can be clearly observed and recorded with its 5 μm finger gap, same as the design in photomask layout.

Figure 1. IDE photomask layout design.

Figure 2. Close-Up image of the IDEs using SEM.
Figure 3. Topography image observed. (a) High Power Microscope (HPM) (b) 3D nano profiler

Based on figure 3(a) the topography of fabricated IDE was analysed using HPM. From these captured images, the images of finger gap that has no mishaps could be visually seen. Apart from that, images of the IDE were subsequently inspected via Hawk 3D Nano profiler. Figure 3a shows the aluminium was deposited uniformly. Figure 3b shows that the height of the aluminium electrode was 1216.2 nm. Apart from the electrode shape which showed acute similarity to the design on the mask, the uniformity of the deposited aluminium could also be observed clearly.

Figure 4. FETEM morphological (a) ash from paddy straw (b) Silica Nanoparticles.

To validate and ensure the originality of rice straw ash (before processed) and silica nanoparticles (after processed), both samples underwent EDX analysis with more advanced and sophisticated analysis. Based on the result for rice straw ash (figure 5a), the atomic compositions of the major availability consist of elements oxygen (24.88%), carbon (24.88%), calcium (7.58%), phosphorus (7.45%), magnesium (1.08%) and kalium (0.98%). Based on these atomic percentages, we can conclude that the highest amount of O is because of the thermal degradation during the burning of rice straw. Whereas for silica nanoparticles (figure 5b), the element of silica show the highest amount with 19.44% of atomic availability as compared to all other elements except for oxygen. Thus, it shows that the silica produced is successful and contains original particles.
Figure 5. EDX analysis (a) Rice straw ash (b) Silica nanoparticles.

The surface topography using tapping mode images were studied using AFM where the top view and lateral images were recorded. Based on figure 6a, we can observe the structured rice straw ash are compact in top view. Apart from that, for lateral images, the height was measured (red line) as 347 nm, whereas the sizing rice straw ash distance between each other is recorded to be 407 nm. Next, for silica nanoparticles, spherical forms were detected based on top view images. Based on lateral images, the range height of silica nanoparticles was recorded at 5–14 nm while the distance between each particle was 86–130 nm, which means the silica nanoparticles produced are dense and uniform.

Figure 6. AFM measurement analysis (a) Rice straw ash (b) Silica nanoparticles
4. Conclusions

From the conducted research, this method is a simple and effective way for preparing silica nanoparticles from the rice straw ash on a nanometer scale and with a dense particle size. The originality and morphology of silica nanoparticles were validated and confirmed that the produced silica nanoparticles consist silicon element without any other element or debris. As a result, this could lead to the production of low-cost silica nanoparticles for future applications such as fertilizers, treatments and synthesized nanomaterials.

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