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Application of Highly Flexible Conductive Nanocomposite Polymer Electrode Array to Tissue Electrical Impedance Scanning (EIS)

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Summary:
Our overall goal is to overcome the limitations of current EIS systems such as low spatial resolution, poor electrode design, and skin contact issues[1] using novel flexible conductive nanocomposite polymer (C-NCP) microelectrode arrays. In this paper, we present improved electrode designs with decreased skin contact and greater mechanical stability using a two-level embedded process. Anomaly detection test is performed using tissue phantom.

Flexible C-NCP Electrode Array:

We have previously presented the development of a flexible Ag/AgCl electrode array via soft-lithography based fabrication, and employed it for impedance measurements[2]. We now improve the electrode design to provide multi-layer electrodes with decreased skin contact size, with a larger portion embedded under a non-conductive surface. Fig. 1 shows the double-level electrode fabrication process. We prepared and poured the mixture of silver nanoparticles (90-210nm size, NanoAmor) and silicone based elastomer (Dow Corning 734) on the PMMA master, and scraped off the excess. A nonconductive PDMS layer was then poured and cured on it to serve as a substrate. Next, PMMA "pipes" were fit on the top layer of the electrode to prevent them from being covered by PDMS, and PDMS was poured on the electrode array again so that the bottom layer of the electrodes can be covered by the second level of PDMS. Lastly, the electrodes were chloridized to make Ag/AgCl electrodes.

The fabricated electrodes possess an average conductivity of 571.43S/m +/- 14.3% at 65wt-%. Fig. 2 shows the photographs of a single electrode before and after the second PDMS layer.

Anomaly Detection Tests:

In order to demonstrate the usability of the electrode arrays for EIS systems, an anomaly detection experiment was performed to detect anomalies surrounded by baseline phantom tissue. An agar tissue phantom was developed and two types of anomalies having different electrical conductivity were inserted into the tissue phantom. The electrode array was pressurized against the phantom using weights and the impedance between electrodes was measured for each pair of electrodes.

The results are presented using Cole-Cole plot, which provides a convenient method for comparing impedance[2]. Fig. 3 presents an illustration of the anomaly detection test and the results. Average impedance is presented with deviation bars. For both anomalies, the anomaly-inserted region's impedance was clearly different from the base impedance of the phantom. The impedance difference between the piece of wood anomaly and baseline was a maximum of 41.95% for resistance and 59.2% for reactance, and the impedance difference between the C-NCP anomaly and baseline was a maximum of 15% for resistance, and 28.1% for reactance.

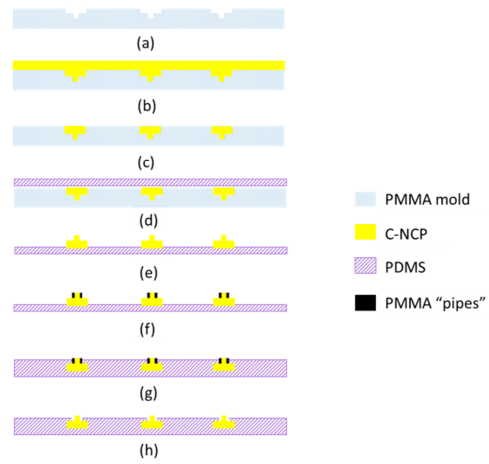

Fig. 1. Fabrication process for making two-level flexible electrode arrays.

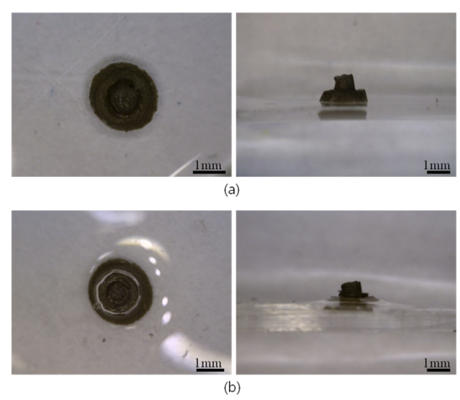

Fig. 2. Photograph of single two-layer polymer electrode: a) before second level PDMS; b) after second level PDMS.

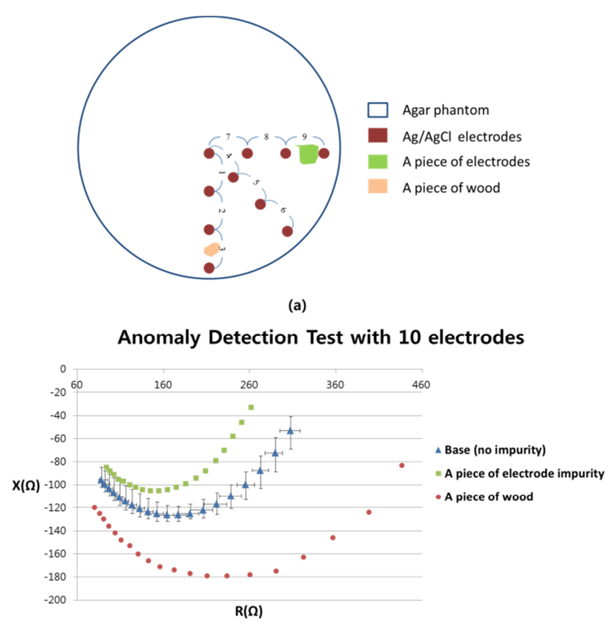

Fig. 3. Anomaly detection test with 10 electrodes: a) illustration of top-view of the tissue phantom; b) measured impedance maps.

References:
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