Fabrication of Functional Micro- and Nanoneedle electrodes using Template of Carbon Nanotube Nanoneedle and Electrodeposition

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With the development of nanotechnology, demands of information about microscale system have increased.[1][2] Micro- and Nanoneedle electrode provides opportunities for electrochemical and biological studies of micro-environments such as AFM-SECM[3][4][5] and single cell analysis[6][7][8]. Although a lot of fabrication methods of nanoneedles were reported, those methods have a limitation of material because most nanoneedles were fabricated using carbon nanotube[7][9][10] and silicon[6][11]. Yet the fabrication of nanoneedle using various materials is very difficult.

In this research, we report a fabrication method for functional micro- and nanoneedle using template of carbon nanotube (CNT) nanoneedle and electrodeposition. Because various materials such as metal, metal oxide and polymer can be coated to the desired location, electrodepoeition are very useful for the fabrication of functional nanoneedle.
First, CNT nanoneedles were fabricated at tungsten tip and AFM tip using dielectrophoresis (DEP) and surface tension.[8][12] As shown in figure 1a, two tungsten tips are placed a few micrometers apart, and an AC electric field is applied between them. When the suspension droplet is placed between the electrodes, CNTs are attracted toward the region between the tips of the electrodes due to the DEP force. The suspension was the partially removed and the remaining suspension formed a water meniscus between tungsten tips. The collected CNTs were compressed by the surface tension and attached to the tungsten tip. As a result, CNT bundle nanowire was fabricated between tungsten tips. For the fabrication of CNT nanoneedle, center of the CNT bundle nanowire, weak point, was cut using high electric current. As shown in figure 2, diameter of the CNT nanoneedle was *ca.* 100nm, which could be controlled by changing the concentration of suspension, amplitude of AC voltage and collection time. Length of the CNT nanoneedle was determined by spacing between the tungsten tips.
For the fabrication of functional micro- and nanoneedle, desired material was coated on the CNT nanoneedle by electrodeposition (figure 1b). CNT nanoneedle was submerged electrodeposition solution up to desired position using micro stage and microscope. Au, Ni, ZnO and Ppy were successfully coated on the CNT nanoneedle (figure 3). Thickness and morphology of coating material could be controlled by electrodeposition conditions such as electric potential, solution concentration and deposition time.

In summary, functional micro- and nanoneedle were successfully fabricated using template of CNT nanoneedle and electrodeposition. Because this fabrication method is very simple and able to use various materials, it can be applied to fabrication of micro- and nanoneedle having the desired properties.

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References

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Figures

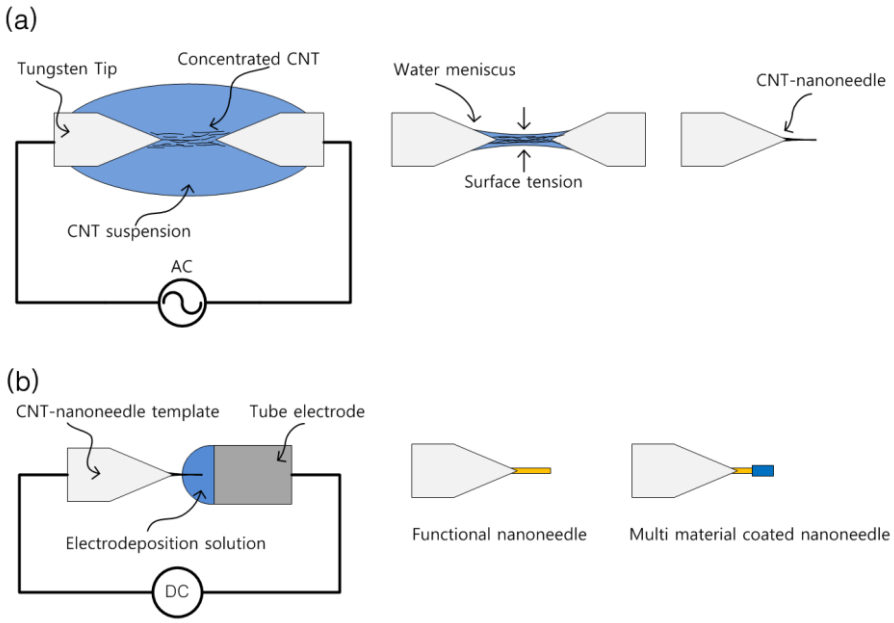

Figure 1. Fabrication process of functional nanoneedle. (a) fabrication process of CNT nanoneedle template , (b) electrodeposition process.

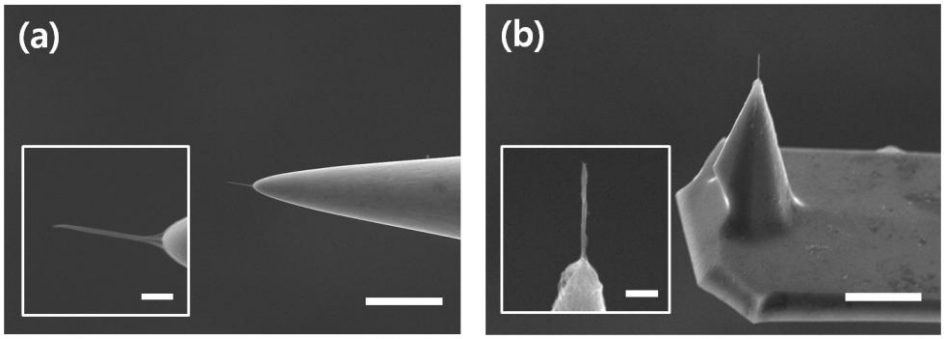

Figure 2. SEM image of (a) nanoneedle at tungsten tip and (b) AFM tip (Scale bar : 10 μm). Insert show magnification view (Scale bar : 1 μm)

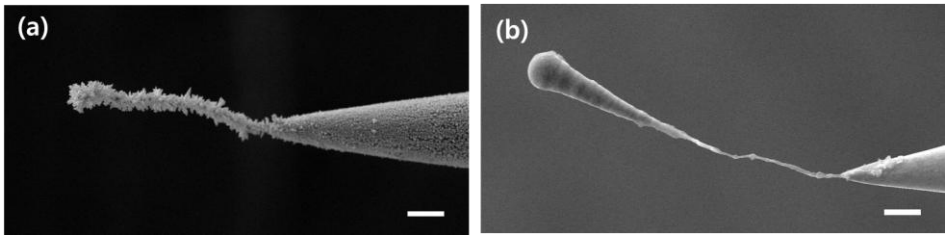

Figure 3. SEM image of functional nanoneedle coated by (a) Au and (b) Ni (Scale bar : 10 μm).