Nanogripper using Carbon Nanotube

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ABSTRACT

Nanogripper was made from two nanotips and the nanotip is composed of tungsten tip and carbon nanotube. The tungsten tip was made by the electrochemical etching with KOH solution. The initial and final diameter of tungsten tip were 500 micrometer and several micrometer respectively. The carbon nanotube is multi-wall carbon nanotube grown on the Al_2O_3 by chemical vapor deposition. The average diameter of carbon nanotube is 130 nanometer. The procedure to make nano-tip is monitored by optical microscope of two thousand magnifications. The length of carbon nanotube in nanotip was controlled by the electrochemical etching to satisfy in special application. The nanogripper was made by the fixing stage that has three degree of freedom.

Keywords: nanogripper, nanotip, electrochemical etching, carbon nanotube

1 INTRODUCTION

Sumio Iijima firstly discovered carbon nanotube at 1991[1]. Many research results about the properties of carbon nanotube have been reported in many fields. And, Hongjie Dai proposed the first report about nanotip in 1996[2]. In that report, carbon nanotube was attached on the conventional AFM tip with acrylic adhesives. The lateral resolution of nanotip was compared with the conventional silicon tip. In 1999, Philip Kim proposed the nanogripper firstly[3] and he made nanogripper using glass electrode under optical microscope. In 2001, Seiji Akita reported the nanogripper that was made from conventional AFM tip under scanning electron microscope[4]. The proposed nanogrippers in previous researches are made from one substrate and attached two carbon nanotube. But, in this paper, we proposed a new method to make nanogripper using nanotip and it is possible to make various types of nanogripper.

2 MANUFACTUREING NANOTIP

2.1 Tungsten Tip

The proposed nanogripper was made from nanotips and nanotip was composed with tungsten tip and carbon nanotube. In this section, the method to make tungsten tip is described.

The electrochemical etching method is used to make tungsten tip. The initial and final diameter of tungsten tip are 500 micrometer and several micrometer respectively. In Figure 1, the system to make tungsten tip and manufactured tungsten tip are shown.

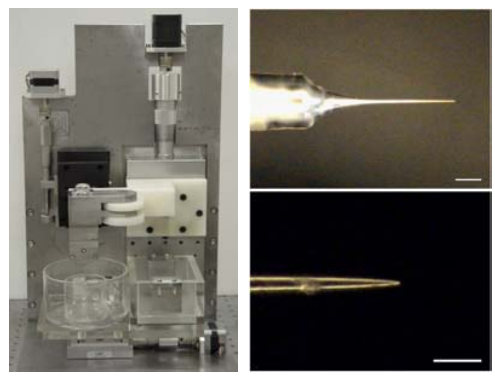

Figure 1 : Electrochemical etching system and manufactured tungsten tip (scale bar : 200 ㎛(upper), 10 ㎛ (lower))

As shown in Figure 1, the diameter of the end region of tungsten tip is several micrometer. The used electrolyte is 5 mole of potassium hydroxide and the immersion depth of tungsten tip is controlled by the step motor and several optical stages.

2.2 Preparation of Carbon Nanotube

In this paper, we used multi-wall carbon nanotube(MWCNT) which was grown on the Al_2O_3 with chemical vapor deposition(CVD). The average diameter of carbon nanotube is 130 nanometer and the range of length is from 5 to 50 micrometer.

It is essential to purify the MWCNT to use in the process to make nanotip. We obtained some of purified MWCNT from 600W sonicator in the isopropyl alcohol(IPA) for 2 hours. The purified MWCNT in IPA is poured on the slide glass and the IPA is evaporated. Then, some of purified carbon nanotube can be obtained. In Figure 2, the original MWCNT, which was used in this paper captured by SEM in commercial company, and the

purified MWCNT on the slide glass captured by optical microscope are shown.

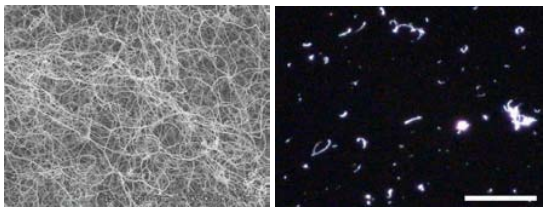

Figure 2 : The original MWCNT entangled and purified MWCNT on the slide glass

2.3 Manufacturing Nanotip

We used two tungsten tips and carbon tape to make nanotip. The method to make nanotip is shown in Figure 3.

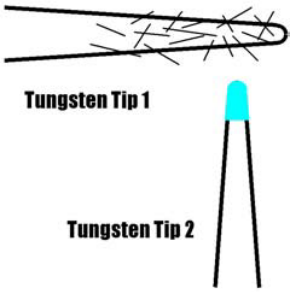

Figure 3 : How to make nanotip

As shown in Figure 3, the carbon nanotube was attached on 1st tungsten tip with scratching on the slide glass covered with purified carbon nanotube. In 2nd tungsten tip, some of carbon tape is painted in the end region under optical microscope. The process to make nanotip is shown in Figure 4 and the all process was monitored by the optical microscope.

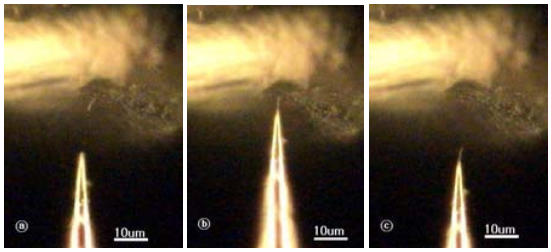

Figure 4 : The attachment process captured by optical microsocpe

As shown in Figure 4, the attachment process is composed of 3 steps. The first step is to find out the appropriate carbon nanotube in 1st tungsten tip. The second step is to approach the 2nd tungsten tip to the found carbon nanotube using optical and piezo stages and dwells several seconds for firm attachment. The final step is the separation of the 2nd tungsten tip from the 1st tungsten tip. Then the carbon nanotube is dragged out to the 2nd tungsten tip due to the acrylic adhesive force by carbon tape.

2.4 Length control of Nanotip

Because the nanotip made by this process has arbitrary length and improper end shape for nanogripper, the length of carbon nanotube must be controlled for its special application. The schematic diagram of cutting procedure of carbon nanotube is shown in Figure 5.

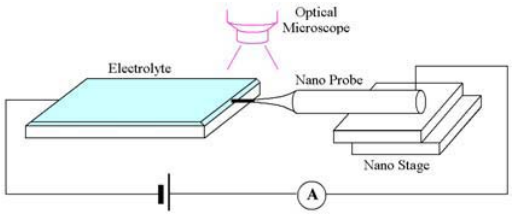

Figure 5 : Schematic diagram of cutting system

The cutting mechanism is to use the electrochemical etching process using KOH solution and DC power supply, and the all procedures are monitored by optical microscope. The nanotip is approached to the electrolyte by nano-stage such as pizo actuator under optical microscope. Since the immersed depth of carbon nanotube in the electrolyte can be controlled by nano-stage, the length can be controlled with nano scale. The start and end of the process was checked with the value of current. The overall procedure is displayed in Figure 6 that was captured by optical microscope.

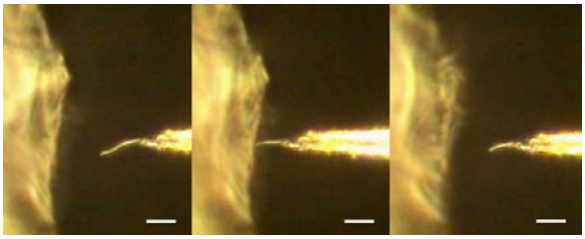

Figure 6 : The process to cut carbon nanotube in nanotip (scale bar : 5 ㎛)

In Figure 6, the left is the electrolyte and the right is nanotip. When the nanotip contacts to the electrolyte with DC power supply, the electrochemical etching and polishing process will be produced with the current flow through closed electrical loop.

The detail views of nanotip are shown in Figure 7 which were captured by SEM. As shown in Figure 7, the cut length of nanotip is about 2 micrometer.

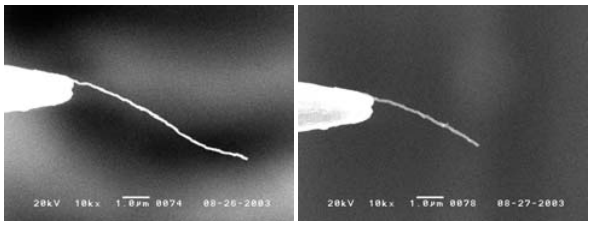

Figure 7 : The SEM images of nanotip prior(left) and post(right) cutting process

Since the process is monitored by optical microscope, it is possible to cut repeatedly. In Figure 8, the example of repeated cutting and the results of the cutting are shown.

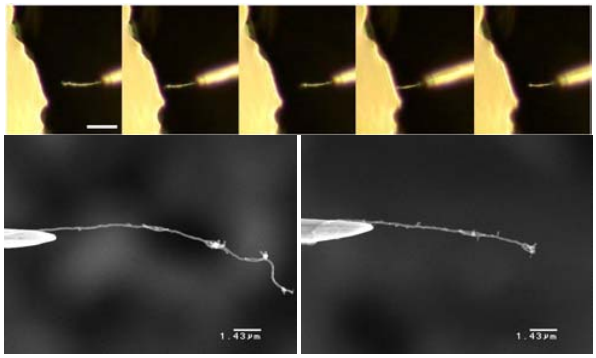

Figure 8 : The repeated cutting(upper, scale bar:5 ㎛) and the results of cutting captured at prior and post process

Through the cutting process, we can obtain the increase of the contact force between tungsten tip and carbon nanotube.

3 MANUFACTURING NANOGRIPPER

Because we made nanogripper using two nanotips, the fixing stage, which is used to approach two nanotips each other, is required. Using this method, we have some advantages as followings.

- It is possible various type of nanogripper.
- It is possible large grip motion using fixing stage.
- It is possible to use conducting substrate.
- It is not necessary to deposit additional electrode.

In Figure 9, the nanogripper is shown that was made from the fixing stage and two nanotips.

As shown in Figure 9, we made nanogripper using fixing stage. The fixing stage has three degree of freedom and is operated by the bolt with ball and spring. After manufacturing the nanogripper, the fixing stage is become the body of nanogripper. So, the fixing stage must be small and not expensive.

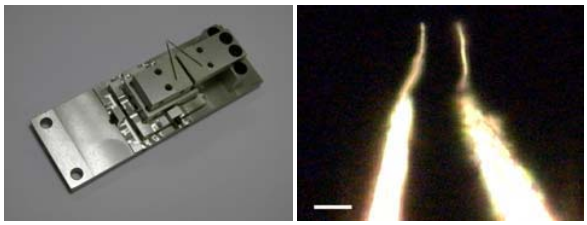

Figure 9 : Manufactured nanogripper (scale bar in right image : 5 ㎛)

The movement of nanogripper and gripping of nano particle are doing now. From the simulation of nanogripper, we found that the desired nanogripper size is 7 ㎛ of length, 1 ㎛ of initial gap between the end of nanogripper and 50 ㎚ of diameter of carbon nanotube.

4 CONCLUSION

In this paper, we proposed a new method to make nanogripper using two nanotips. The tungsten tip was made by electrochemical etching and the purification of carbon nanotube was done by sonication. The nanotip was made by two tungsten tips and mechanical attachment with carbon tape. The length of carbon nanotube in nanotip was controlled by the electrochemical etching and the carbon nanotube was dissolved in electrolyte. Although the type of nanogripper in previous research is confined with one type, it is possible to make various type of nanogripper with proposed method such as a tripod.

5 ACKNOWLEDGEMENT

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