Development of the Nano Aligner for CNT-tip fabrication

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ABSTRACT

AFM tip has been used for surface profiling with a fine resolution, but there is a barrier to improve its performance because of the low aspect ratio. Many researchers have solved this problem with attaching carbon nanotube (CNT) to Si-tip. In this paper, we proposed the aligner system that composed of dual type stage system, and these stages could attach a carbon nanotube to tungsten-tip in vacuum condition. We used tungsten tip instead of Si-tip because of its conductivity. The aligner system proposed in this paper has 10 degree-of-freedom that 3 in the first stage and 7 in the second stage. With picomotors and piezotube, the first stage has the resolution about several tens of ㎚ and the second stage has a resolution about 1 ㎚. With this aligner system, we could make nanotip and with 2 nanotips, we can make nano tweezer.

Keywords: aligner system, dual type stage system, carbon nanotube, picomotor, piezotube

1 INTRODUCTION

Because of its high aspect ratio, CNT-tip can be useful for measurement of surface profile like high-dense semi-conductor which has narrow, deep valley structure [1]. CNT also can be used for nano tweezer composed of two CNT-tip, that can grip and operate nano meter sized materials [2].

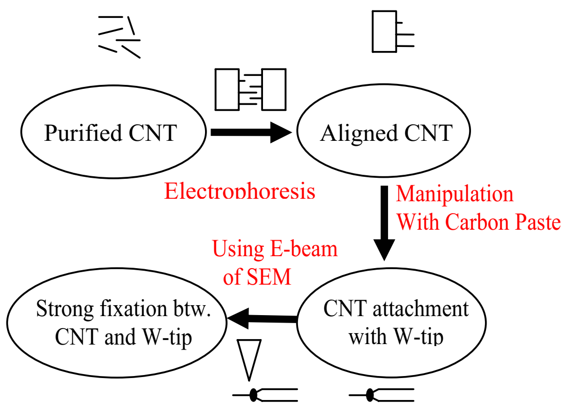

Figure 1 : Schematic diagram to make CNT-tip

As shown in Figure 1, fabrication process of CNT-tip needs SEM because we deal CNT with several tens of ㎚ diameter, and precise manipulation system for aligning CNT and W-tip.

The aligner system must have efficient degree-of-freedom to place carbon nanotube and tungsten-tip to the operating area in SEM.

2 REQUIREMENTS FOR THE NANO ALIGNER AND ACTUATORS

2.1 Requirements for the Nano Aligner

For manipulation of attachment of W-tip and CNT, following conditions are needed.

1) Aligner system has dual-type two-stage for placement W-tip and CNT separately.
2) Stage1 and stage2 can be moved along X, Y axis for placing to the SEM gun spot region.
3) Both stages should be moved along Z axis for focusing.
4) After attachment process, we should check the axial-attachment condition with the rotating movement.
5) Since the diameter of CNT is several tens of ㎚, nanometer-order resolution is needed in stage system for fine motion.
6) Since SEM chamber has limited space size of height and diameter, the size of aligner system should be as small as possible.

For satisfaction of these requirements Zyvex company made dual-type stage which the stage1 has linear motion along X, Y axis with picomotors, stage2 can move linearly along Z axis and rotate with X axis. And with a piezotube, they experimented the attachment of CNT on the STM probe, also measured the mechanical and electrical properties of CNT [3]. KRISS in Korea made CNT-tip with an AFM and CNTs, using two stages which can move linearly along X, Y, Z axis [4].

But there are some problems for experiment with the Zyvex`s proposed system. Cause both 2 stages can`t move along X, Y, Z axis, we must use the stage in SEM chamber and that is uncomfortable, also need a good skill. And, it is impossible for fast experiment with variable tips, because attachment regions are different with where the tips are used.

As mentioned in 5), a fine motion actuator like piezotube is needed. Piezotube has a resolution of about 1 ㎚ and this makes the improvement of resolution in whole system.

2.2 Principle of Picomotor`s movement

For the purpose of giving linear movement along X, Y, Z axis to the stage, linear picomotors are adopted which can go back and forth with screw motion. And rotating picomotor is used for rotating motion.

Linear picomotor has a screw and if the screw rotate in CW direction then picomotor`s ahead ball go forward, in CCW direction then picomotor`s ahead ball go backward. The PZT exists in picomotor and the screw moves with the slow force by high static friction, and does not move with the fast force by low dynamic friction [5].

Namely, if picomotors are in the condition of long rising time and short falling time, the screw rotates with CW direction; but the other case of short rising time and long falling time, the screw rotates with CCW direction. The principles of movement for rotating picomotor and general motors are similar.

2.3 Principle of Piezotube`s movement

But the resolution of linear picomotor is about 30 ㎚, we obtained more precise motion using 4-quadrant piezotube which made more fine motion possible. We used simple cylindrical shaped piezotube, and this is similar to a hollow bamboo. Electrodes are coated on inner and outer surface of piezotube, and outer plane is divided to 4 parts. We experimented with 4 divided type, calling 4-quadrant piezotube, and outer electrodes are called +X, +Y, -X, -Y domain. +X is placed opposed to –X, and +Y, -Y are also. If we commit high voltaged opposite alternating current to the +X and –X electrodes, then a piezotube swing along X-axis. Meanwhile giving same voltage to 4-outter electrodes and ground to inner electrode makes it move along axial direction.

Scanning range of piezotube depends on its length, inner diameter, wall thickness, strain coefficient of piezotube, and operating voltage. The piezotube can scan from several tens of Å to about 100 ㎛ in lateral direction, and below Å to about 10 ㎛ in axial direction. The equation of range in axial direction is shown in Eq. (1) [6].

$$\Delta L \approx d_{31} \cdot L \cdot \frac{U}{d} \qquad (1)$$

where, △L: scan range in Z [m]
d_{31}: strain coefficient [m/V]
L : length of the PZT ceramic tube [m]
U : operating voltage [V]
d : wall thickness [m]

We used the piezotube which has specification like Table 1.

	PT 130.14
Length (mm)	30
Outside dia. (mm)	6.5
Inside dia. (mm)	5.35
Max. operating voltage (V)	500
Strain coefficient (m/V)	2.1×10^{-10}

Table 1 : Specification of the piezotube

Using the specification in Table 1 and Eq. (1), we can obtain that the range of axial motion is 2.3 ㎛. And it is considered that the clamping length is is 5 ㎜.

In similar way, it can contract in same displacement, so the final range of axial direction is ± 2.3 ㎛. In addition to axial direction, the range of lateral direction can get from following equation.

$$\Delta X \approx \frac{2\sqrt{2} \cdot d_{31} \cdot L^2 \cdot U}{\pi \cdot ID \cdot d} \qquad (2)$$

where,
ΔX : scan range in X and Y [m]

Using the Eq. (2), the range of deflection in X and Y can be calculated to 9.6 ㎛. And the final range of lateral direction is ± 9.6 ㎛.

3 DESIGN OF NANO ALIGNER

3.1 System Structure

From above condition, we made up with the aligner like Figure 2, stage1 can move along X, Y, Z axis and aligned CNTs are adopted here. The stage2 also moves along X, Y, Z axis, and it has a rotating picomotor. At the end of the axle, 3 DOF piezotube with sleeve is put on. With the other sleeve, W-tip is inserted at the other platform of piezotube. So overall aligner system has 10 DOF with 3 DOF in stage1 and 7 DOF in stage2.

3.2 Principle of Operation

The used stage body is Sigma-Koki TSDS-255 SL which is composed of X, Y Stage and bracket type Z stage. X, Y, Z stage has dimension of 25×25×60 ㎜, that is quite small enough to place in SEM chamber. Picomotors are attached to the stage removed microhead. The operating range of the X, Y, Z axis is ±5 ㎜. The rotating picomotor is put to the Z-bracket of stage2 with holder.

The total size of the aligner system is about 170×135×65 ㎣, and it can be put in the SEM chamber.

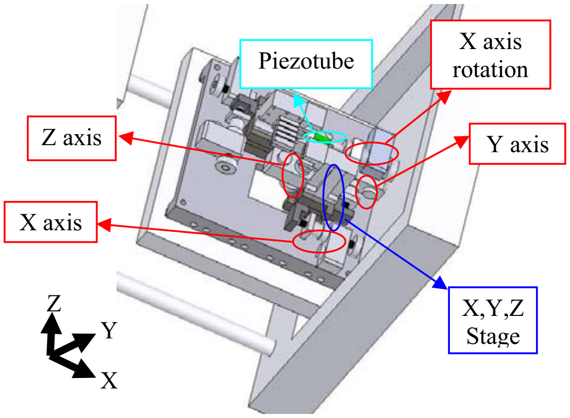

Figure 2 : The nano aligner in SEM

3.3 System Composition

The schematic diagram of the system is shown Figure 3. Stage1 is composed of 3 linear picomotors, and stage2 is composed of 3 linear picomotors, a rotating picomotor and a piezotube. 5 input channels are needed to operate piezotube, and we used 2 piezotube drivers (PI, E-463.00) which has 3 output channels. And for picomotors, we used 9 channel picomotor driver (New Focus, Model 8769) to operate 7 picomotors.

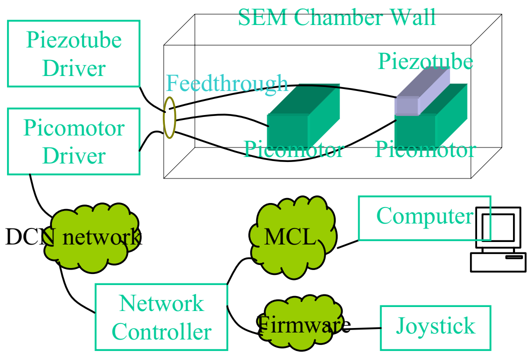

Figure 3 : Schematic Diagram of the System

4 FABRICATION OF THE NANO ALIGNER

We make some of holders, mountings and stages to make the nano aligner. These components have the unique shape to satisfy the requirements of the nano aligner. As mentioned previously, some of sleeves are used to connect piezotube and insulated from the high input voltages on piezotube.

The whole shape of system is shown in Figure 4.

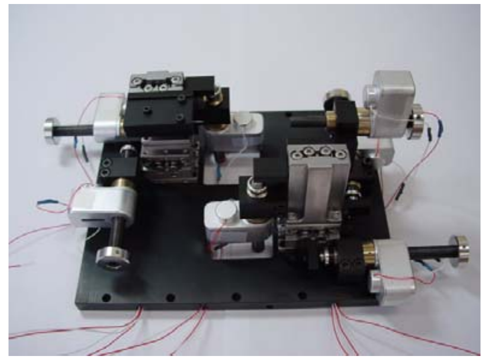

Figure 4 : The Nano Aligner

For the purpose of operating the nano aligner in SEM chamber, the electrical feedthrough is fabricated using the hole in chamber wall. The vacuum condition is maintained using the elliptical O-ring in the feedthrough.

The connectors are the Amphenol`s product and it has 12 pins in one connector. Since 19 pins are needed to operate the nano aligner, two connectors are used. The input signals are 5 for piezotube and 14 for picomotors. In Figure 5, the manufactured feedthrough is shown.

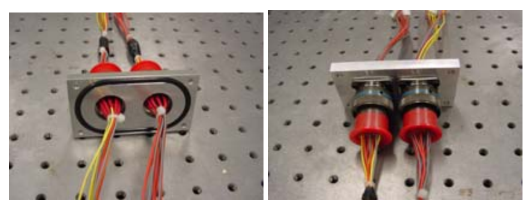

Figure 5 : Electrical feedthrough (left : inside view, right: outside view)

Among the total system, the movement of picomotors can be controlled to the desired displacement at the uniform speed or stayed at the wished speed by a supplied DCN (Distributed Control Network) with the picomotor driver. The motion program of picomotor is done by Labview and Visual C++. And, the motion of piezotube can be controlled by the voltage input of piezotube driver (PI, E-463.00).

5 CONCLUSION

In this paper, we designed and fabricated the nano aligner system which has 10 DOF and small size. The system has the picomotors which has a resolution of several tens of ㎚ and a piezotube which has a resolution of about 1 ㎚.

This system could make CNT-tip that is composed of carbon nanotube and W-tip with a precise manipulation in SEM vacuum chamber. With two CNT-tips, the system can make a nano tweezer.

6 ACKNOWLEDGEMENT

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