

4.1.3 Comparison experiment

Here the order of negative and positive bias applied is changed to identify electron and ion moving direction. It has varied positive bias voltage and applying period time after the negative bias to get the surface alteration gradually. The Fig 4.13 (a) ~ (d) shows images of applied positive bias voltage change before fixed negative bias.

Initially, the tube-like still can be obtained and the curvature has changed its direction. Forward experiment mentioned in 4.1.2 has stated that the curvature formed a up-direction thus the pore shaped. The inverse order of positive bias applying indeed changes the curvature, and corresponds to a suspension related to electron bombarding direction.

In Fig.4.13 (b) ~ (d) the later negative bias applied thickens the bottom of a-carbon film. Finally the rod disappears and still the curvature left. Fig.4.14 is an additional comparison between negative to positive bias and positive to negative bias products. It apparently indicates the difference between them.

Otherwise, applying the positive bias directly on the carbon nanotubes gained the porous petaloid sheets grown from the stem body as well. The Fig.4.15 shows the improvement of nanotube by applying the positive bias. Not only the aligned nanotube changed totally but the branch one can rehash from top to toe.

Thus, it is possible to renew every tube's shape from a lavender-like fine petal to rose-like wide petal just by changing the voltage or period time of positive bias. Fig.4.16 shows a CNF collection in several types. Fig.4.17 is HRTEM images about carbon nanoflakes on carbon nanotubes. It is apparently seen that the tube's stem has several petals surrounded. Some tubes even have a branch structure as the enlarged image shows.

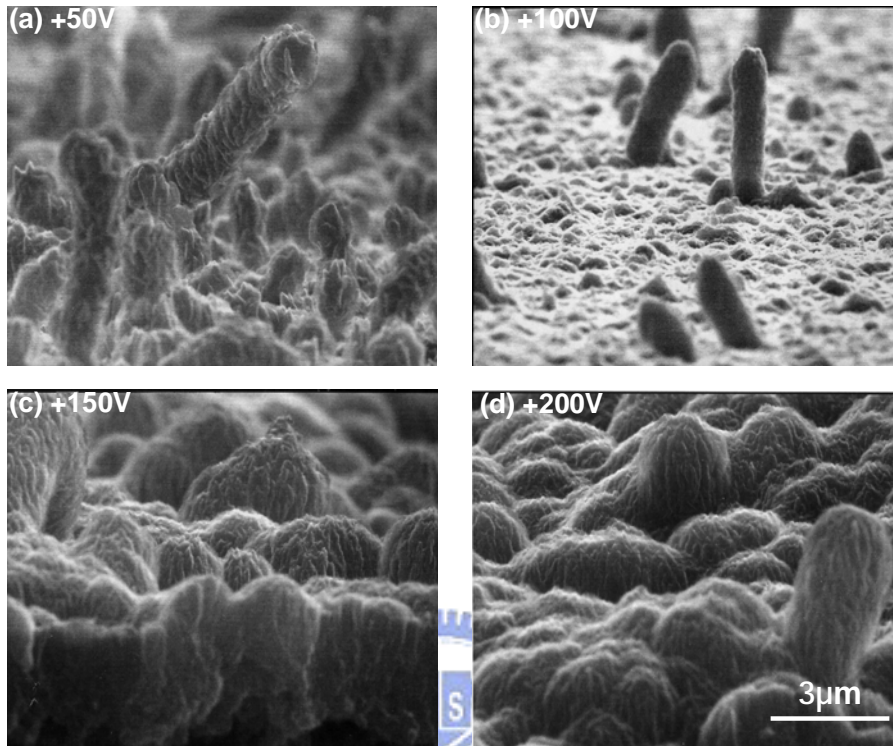


Fig.4.13 SEM images of changed +50~200V, each for 10mins before fixed -100V for 10 mins: (a) +50V (b) +100V (c) +150V (d) +200V

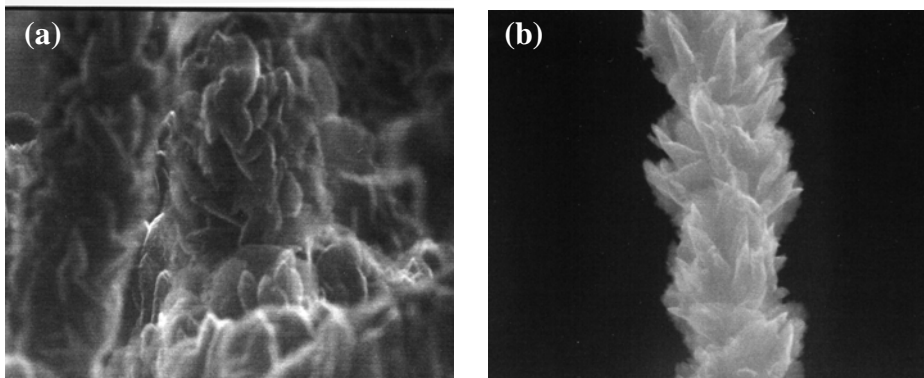


Fig.4.14 SEM images of compared two orders of positive bias applying: (a)+100V,-100V (b)-100V, +100V, each for 10 mins

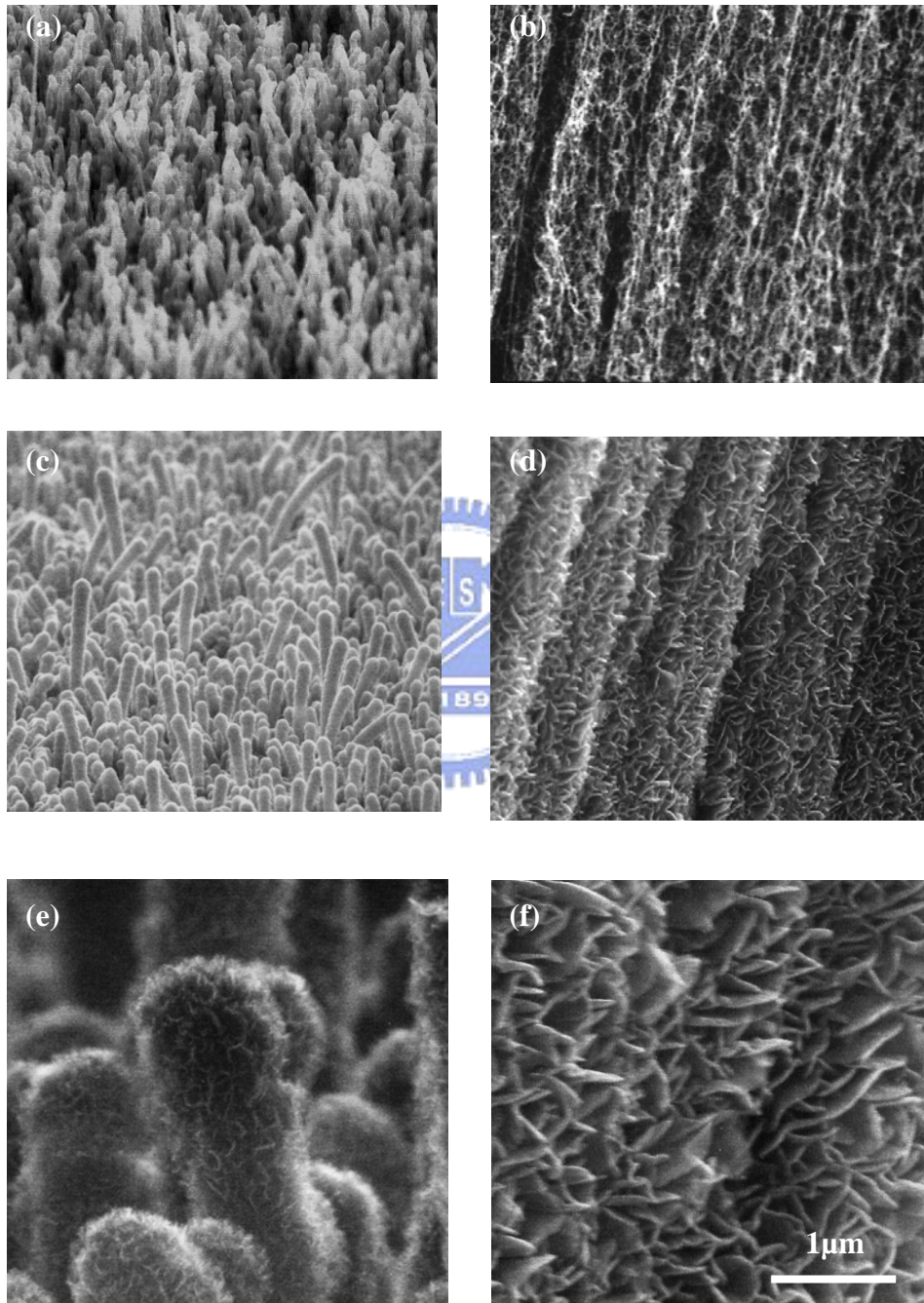


Fig.4.15 SEM images of improvement of CNT to CNF :(a)-(b) two types of CNT, (c)-(d) CNF grown on CNT separately of (a)-(b), (e)-(f) enlarged image of (c)-(d)

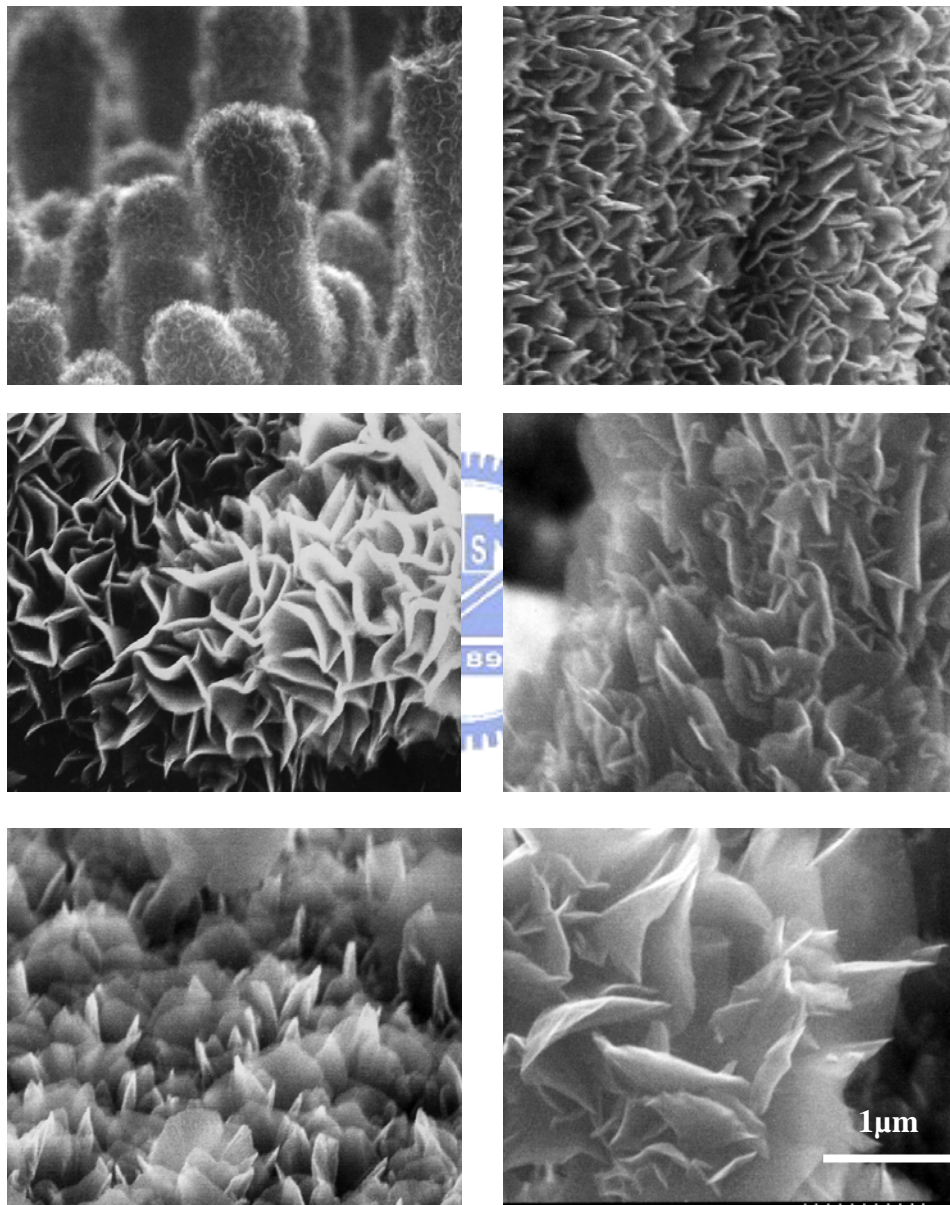


Fig.4.16 SEM images of carbon nanoflakes' collection

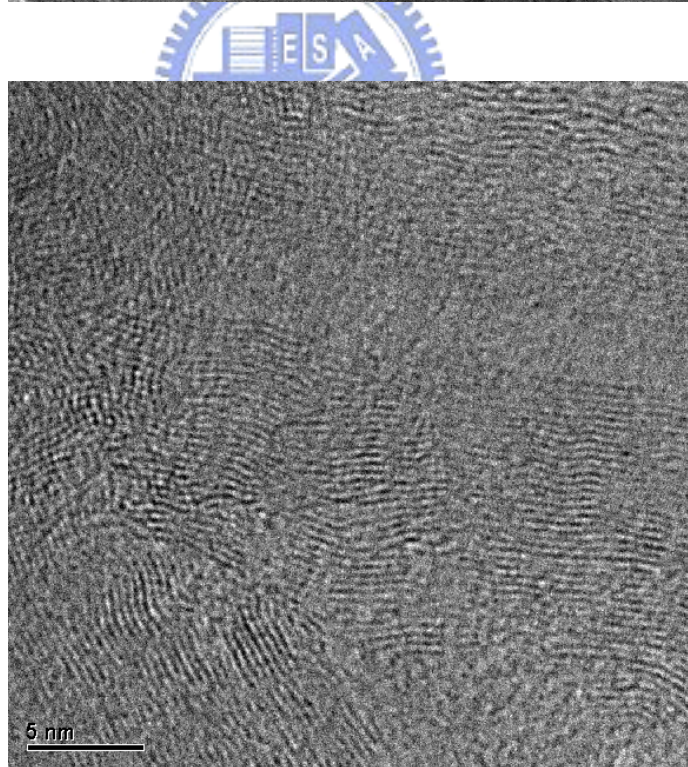
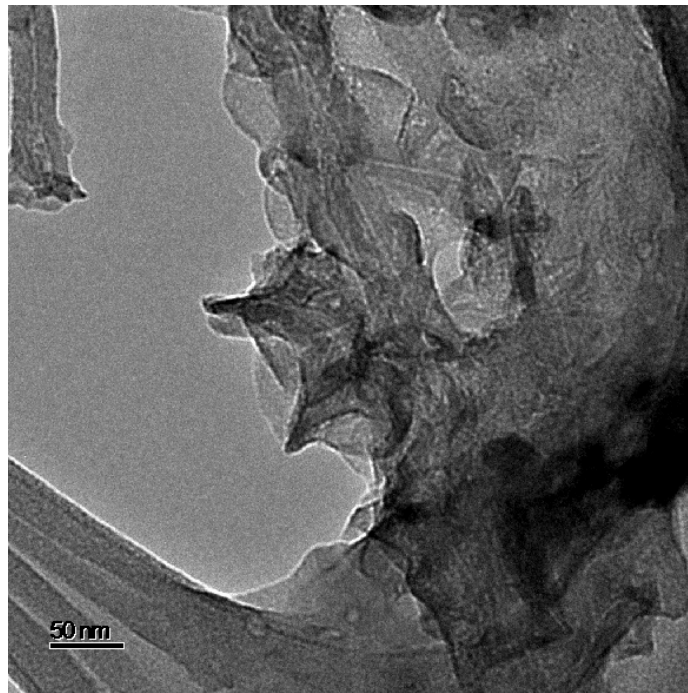


Fig.4.17 HRTEM of CNF grown on CNT: (a) CNT stem with petals
(b) Stem has branch shown graphitic layers

4.1.4. Growth model suspension of CNF

At first stage, the tubes grow follow VLS mechanism and have catalyst on top of them. As the negative bias continually applying, the tubes enhance their length and become aligned. When the negative bias time extends, surface defects begin to form. Now switching the positive bias makes depositing direction differ and the petals grow from the defect sites. Along the extended time, the petals become more stronger and shaped pores. Fig 4.18 is a schematic program of carbon nanoflake's growing.

Growth model hypothesis

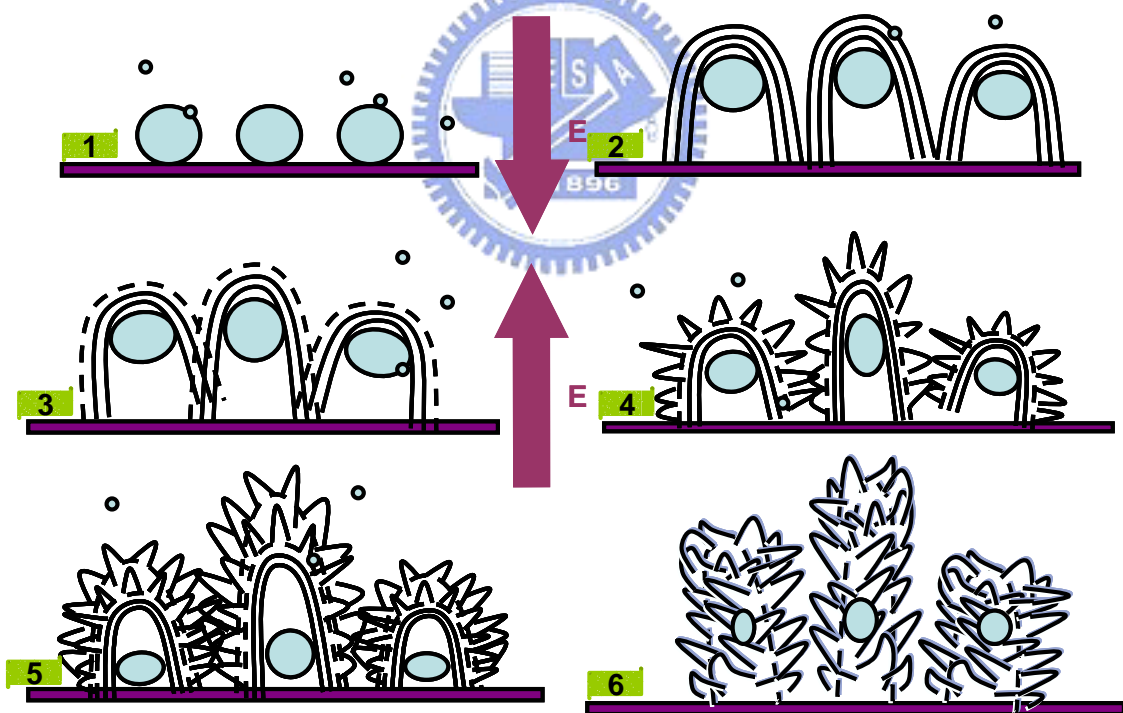


Fig.4.18 Growth model hypothesis of carbon nanoflake [Depict by I- Hsuan Lee]