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In-situ Observation of Ultra-fine Surface Modification by Micro-capillary Atmospheric Pressure Plasma Jet Using Long Focus Lens ICCD Camera
長焦点レンズ付きICCDカメラを用いたマイクロキャピラリー
大気圧プラズマジェットによる微細表面修飾のその場観察

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Nowadays the development of novel bio-chip devices is playing an important role for the detection and inactivation of different biological process. In the last decades carbon nanotubes (CNTs) received an important attention from the scientific community due to their remarkable mechanical and chemical properties. In our studies we showed that the functionalization of CNTs can be achieved by employing micro-capillary plasma jet and that the introduced functionalities on the CNTs can serve as reactive sites for further connection with different biomolecules of interest. Time-resolved images by fast ICCD camera of the micro capillary plasma jet were acquired to better understand the plasma jet processing method.

1. Introduction

As part of the cold plasma sources, the non-equilibrium atmospheric pressure plasma jets (APPJs) show great potential for developing innovative application able to interact with biological samples, like mammalian cells, and to offer valuable information. The big advantage of the APPJ is the fact that it can create the necessary reactive moieties that can enrich the carbon nanotubes materials (CNTs) with new functionalities and thus can be later use as sensing platform for new types of biochip devices.

The use of CNTs is due to the fact that they pose unique properties like good electrical conductivity, high aspect ratio, mechanical strength, chemical stability and so on. Functionalization of CNTs with amino groups and/or carboxyl groups is achieved by plasma processing. Functionalities can further be used as reactive sites for the immobilization of various biomolecules,

In this study we focus on the analysis of the capillary plasma jet by fast ICCD imaging.

2. Experimental details

The schematic drawing of the experimental setup is shown in Fig. 1. The APPJ consists of two electrodes: a grounded electrode that is fixed on the upstream side of gas flow, and one electrode where the high voltage is applied for igniting the plasma in the downstream side. The high voltage electrode is located at about 30 mm from the capillary tip. Usually functionalization of the CNTs can be achieved by employing a gas mixtures of He and NH_3 or He and O_2 depending on what kind of modification is needed. However, for this study only He gas is used as working gas and a pulsed voltage of ±7.0 kV with a frequency of 5 kHz and 50% duty ratio is used to generate the plasma. The ICCD camera and the pulsed generator are synchronized together and thus time resolved ICCD images can be acquired.

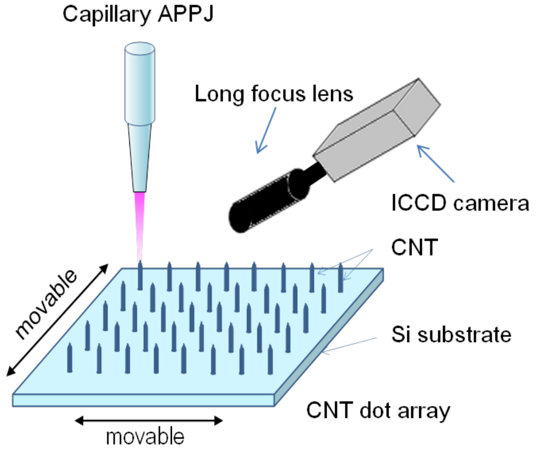

Fig.1 The schematic of the experimental set up

Dot-arrayed CNTs (1 µm in diameter) with 10 µm dot spacing are prepared on Si substrate by CVD method as it can be seen from FE-SEM image in Fig. 2. We also used dot-arrayed CNTs (5 µm in diameter) with 50 µm dot spacing on Si substrate during our study.

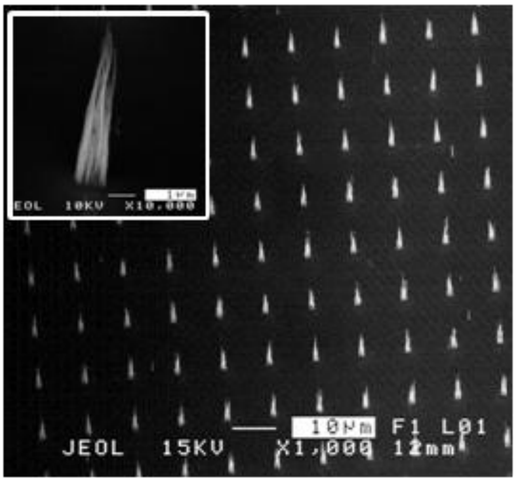

Fig.2 Typical FE-SEM image of vertically aligned dot-arrayed CNTs on the Si substrate

3. Results and discussion

Using synthesized CNTs, the ultra-fine surface modification with functional group has been carried out in this study. Functionalization of the CNTs can be easily observed by fluorescent microscopy. By using fluorescent dyes (Alexa Fluor 488 for amine groups and AABD-SH for carboxyl groups) the successful patterning functionalization can be seen in Fig. 3 and Fig. 4.

The analysis of the plasma jet by ICCD measurements will provide some valuable insights about the selective functionalization of the CNTs.

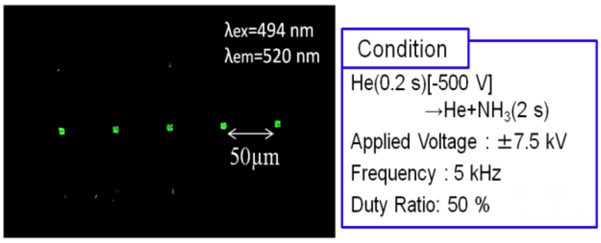

Fig.3 Patterning using amino group modification

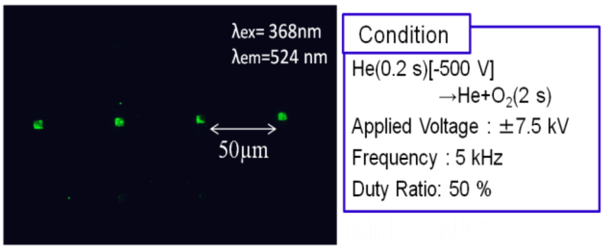

Fig.4 Patterning using carboxyl group modification

Dynamics of the capillary plasma jet was recorded both with the CNTs on Si substrate and also in the absence of the CNTs sample to be able to better understand the phenomena and the behavior of the plasma. We also analyzed different types of capillaries with different inner diameters: 0.75mm and 20 µm.

ICCD imaging of the plasma produced with the 0.75mm inner diameter capillary is presented in Fig.5 for different delays times for the ICCD camera and thus the plasma dynamics can be observed in time.

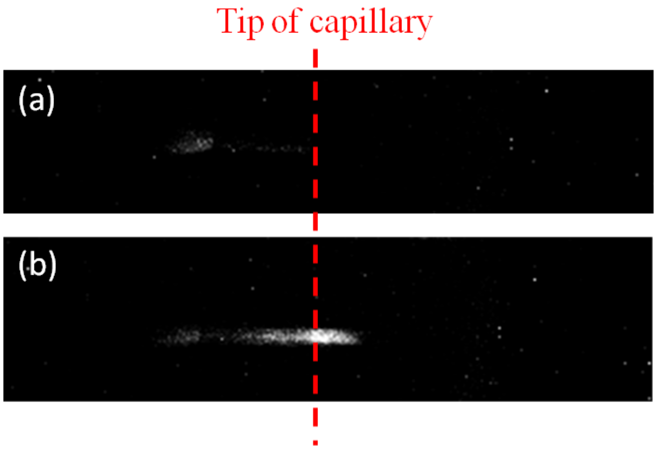

Fig.5 Dynamic behavior of plasma bullet from APPJ measure by ICCD camera around the capillary for delay values of (a) 16 µs, (b) 19 µs

4. Conclusion

We carried out in-situ observation of ultra-fine surface modification of micro-capillary APPJ using long focus lens ICCD to better understand the chemistry and behavior of the plasma. This time plasma dynamics was recorded without positioning our samples in place for treatment but we expect that the plasma behavior will be the same also in that case. Further details will be presented on conference site.

Acknowledgements

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Reference

[1] T. Matsuda, J. Sato, T. Ishikawa, A. Ogino, M. Nagatsu: Diam. Relat. Mater. **18** (2009) 548.

[2] T. Matsuda, et al.: Diam. Relat. Mater. 17 (2008) 772.