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Plasma biomedical application and its prospect
医療・バイオ分野へのプラズマ応用とその展望

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In this talk, the recent research progresses on medical and biological applications of plasma science and technology and their prospects will be presented. The main topics are; first fabrication of the nano-structured materials by plasma processing and development of the virus detection system using surface functionalized magnetic nanoparticles, secondary functionalization of the surfaces locally by an ultrafine atmospheric pressure plasma jet(APPJ) for developing biochip sensor, and finally development of the surface functionalization of ZnO nanoparticles for bioimaging.

1. Introduction

Plasma processing has been proven its numerous advantages in the surface functionalization of the polymer, metallic materials, nano-structured materials such as carbon nanotubes and various kinds of nanoparticles, for aiming at application to biomedical and environmental fields. An important subject of plasma processing for nanostructured materials is to unveil the functionalization mechanism so that a better control of the functional group could be achieved.

In this study, we will present our recent results on the fabrication of nano-structured materials, such as carbon nanotube, graphite-encapsulated metal nanoparticles, or metal oxide nanopartucles, and the surface functionalization by plasma chemical modification, and immobilization of the biomolecules onto the surface of nano-structured materials for bio-medical application.

2. Experimental

2.1 Graphite-encapsulated magnetic nanoparticles (MNPs) for virus detection

Graphite-encapsulated iron particles were prepared by a DC arc discharge, which was generated by applying a dc current of 150–200 A between anode and cathode. Figure 1 shows a size distribution of MNPs and a typical high-resolution TEM image. The particles mainly have an average diameter of 20 nm in the range 10–50 nm.[1)]

Figure 2 shows an illustration of virus condensation procedure using surface functionalized MNPs. After surface modification of MNPs with amino groups, the antibody of influenza virus was immobilized onto the surface of MNPs.

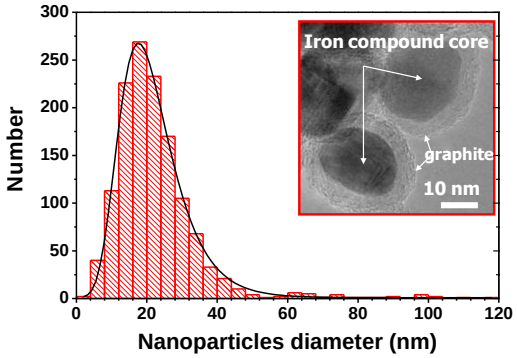

Fig. 1. TEM image and size distribution of MNPs.[1)]

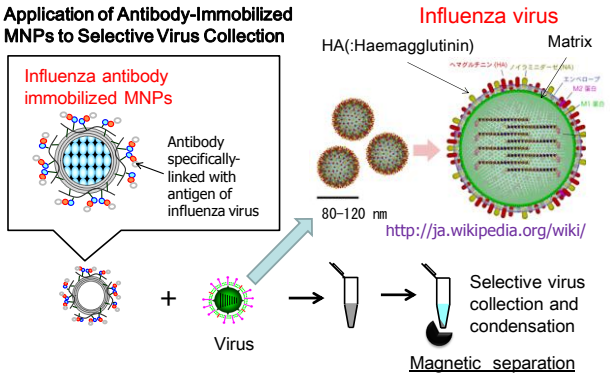

Fig. 2 Illustration of virus condensation procedure using surface functionalized MNPs.

With a specific antibody for influenza virus, we successfully demonstrated an enhancement of collection rate of influenza virus. Figure 3 shows the illustration of influenza virus capture procedure. So far, we have improved the influenza virus concentration by a factor of 10.9 using antibody-immobilized magnetic nanoparticles, as shown in Fig. 3. It indicates the feasibility of selective influenza virus collection.[2)]

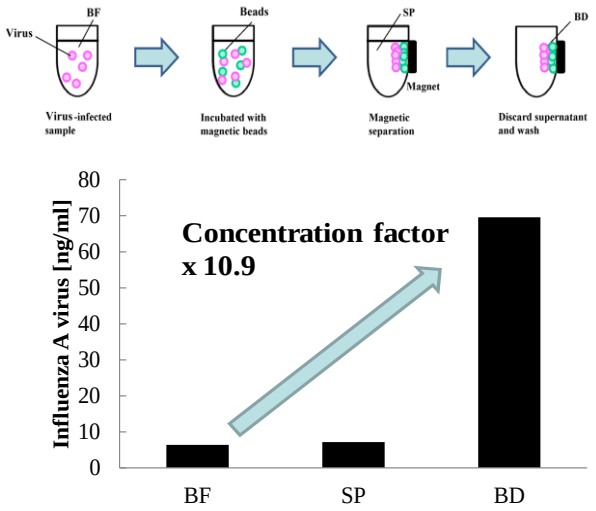

Fig. 3 Illustration of influenza virus capture procedure.

2.2 Surface functionalizion of CNT by ultrafine APPJ

For the surface functionalizaition of CNTs dot array, an APPJ with a micro-capillary was used to functionalize amino groups. Plasma discharge was produced in the glass tube under the high voltage square-wave pulses of ±7.5 kV at a frequency of 5 kHz and 50 % duty ratio. Figure 4 shows the illustration of maskless surface functionalization of CNT dot-array substrate by using the ultrafine APPJ. Bottom images indicate the magnified images of fluorescence microscope for untreated (left), amino group (middle) and carboxyl group (right) added CNT substrates. It is clearly shown the spatial resolved surface patterning with the ultrafine APPJs.

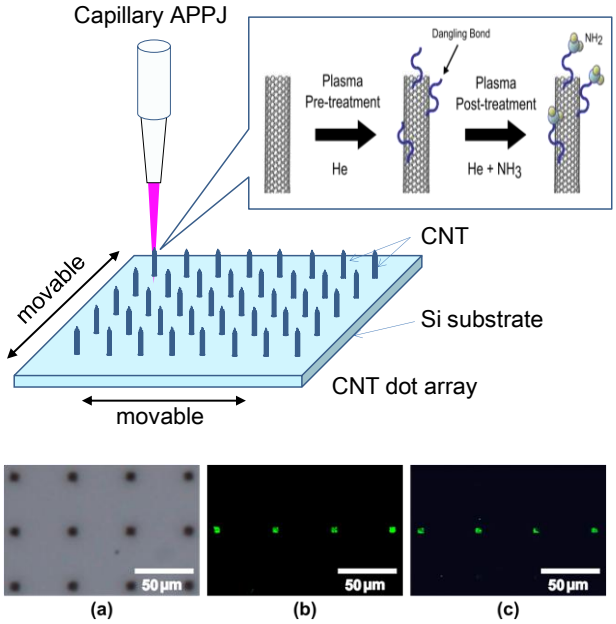

Fig. 4 Illustration of surface processing with ultrafine APPJ and fluorescence images.

2.3 Surface functionalization of ZnO nanoparticles.

ZnO nanoparticles were fabricated by YAG laser ablation method. Surface modification of the ZnO nanoparticles was realized by employing microwave-excited surface wave plasma (SWP), where it was produced by launching a 2.45 GHz microwaves through quartz windows via slot antennas and exciting different mixtures of ammonia and argon gases.

With an Ar/NH_3 microwave excited surface wave plasma, the ZnO paricles were functionalized with amino groups and analyzed by chemical derivatization with Dextran with fluorescent isothiocyanate(FTIC) or fluorescent dyes. Connection of amine functionalizaties with sugar chains, in our case FTIC-dextran, can be monitored by fluorescence microscopy. When exciting with 494 nm wavelength, it is possible to measure the fluorescence at 518 nm. In Fig. 5, it can be seen that the unprocessed ZnO nanoparticles has no ability to connect the labeled dextran and thus no fluorescence can be observed.[3] Despite that, the plasma-treated ZnO nanoparticles has the ability to connect with the biomolecules as it can be seen from the right picture in Fig. 5.

These results offers us the good premises that the functionalized ZnO nanoparticles can be further used to connect with biomolecules and thus opening new opportunities for development of novel bioimaging techniques.

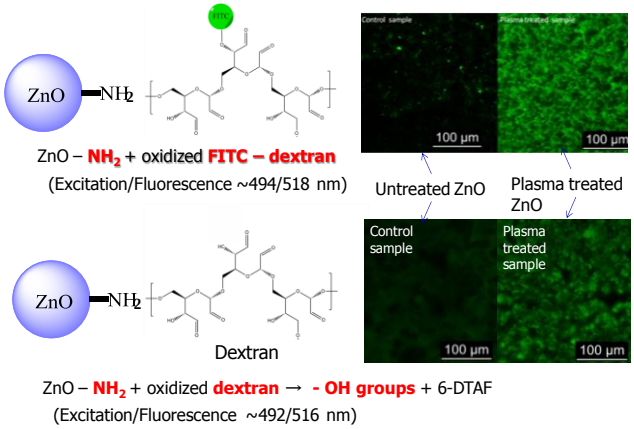

Fig. 5 Fluorescent images of NH_3 plasma aminated ZnO nanoparticles.[3]

Acknowledgements

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References

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