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Nitrogen plasma for h-BN deposition
h-BN成膜の為の窒素プラズマ

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Atomic layer physics have received a lot of attention in recent year, and application of two-dimensional material such as graphene is expected. On the other hand, insulator substrate materials having three-dimensional structure such as silicon oxide have an influence on the physical property of them due to the atomic interaction. h-BN is two-dimensional material and is expected to reduce the influence of the atomic interaction. Generally, h-BN is prepared synthetically under high-pressure condition or by the plasma assisted CVD device using harmful materials. The author is planning the h-BN deposition using no harmful materials but using the technic of the plasma generation from solid sate. Nitrogen plasma experiment have been started for the previous step of h-BN deposition. Nitrogen plasma is generated by the microwave in the multipole-cusp magnetic field.

1. Background

Recently, two-dimensional atomic layer material has received a lot of attention. Graphene is a flat monolayer of carbon atoms and has two-dimensional honeycomb lattice. Graphene has excellent electrical properties and is expected as a material for future electronics. On the other hand, insulator substrate material of electronics such as silicon oxide usually has three-dimensional lattice structure. The surface of the insulator substrate is not flat at the atomic level, and the atomic interaction between the insulator and the graphene has an influence on the electrical properties of the atomic layer electrical device. h-BN also has two-dimensional honeycomb lattice as like graphene and the surface is flat. The influence of the atomic interaction between the insulator substrate and graphene can be reduced.

The author has been proposed a new device using cusp field plasma device as a nitriding device and arch plasma device to generate boron plasma. In this paper, the newly developed nitriding device is presented. The first result of the nitriding of titanium foil is also presented.

2. Multipole cusp magnetic field device

Multipole cusp magnetic field has been used as a plasma source in neutral beam injector [1-3]. Multipole cusp magnetic field is generated near the surface of the plasma chamber by the array of the permanent magnets. The magnetic field strength at the large center area of the plasma chamber is almost uniform and weak. The plasma electron density at the center area has a flat profile [2-4]. Microwave can generate high-energy electrons by electron cyclotron resonance (ECR) near the plasma chamber, and the deep electron potential is generated [2]. Electrons trapped along the cusp magnetic field (magnetron orbit) excite the gas [4].

Newly developed multipole cusp magnetic field device is shown in Fig. 1. The size of the plasma chamber is 400 mm of length and 73 mm of inner diameter. There are 3 viewports at the middle of the plasma chamber, and the magnetic field is separated into two sections. The multipole cusp magnetic field is generated by the 16 permanent magnet modules for each sections. The magnet module consists of two series connected rectangular Nd-magnets (width of 8 mm, depth of 8 mm, and length of 150 mm) and Cu spacers. The set of the magnets is sandwiched in the middle of the Cu spacers by Cu-tape. The Cu spacers play roles in fixing the position of the magnets and of the heatsink. The magnet modules are surrounding the outer side of the plasma chamber. The position of the magnets is rotatable.

The plasma is generated by several kinds of radio frequency (RF) sources. The author uses two frequencies, 200 MHz and 2.45 GHz. The sleeve antenna for 1 kW of 2.45 GHz is installed at the end of the plasma chamber. Three turns coil is installed for 200 W of 200 MHz ICP at the end of the plasma chamber. The coil is made by Cu and coated by alumina ceramic. Two sets of thin rectangular aluminum bar are installed along the plasma chamber for 100~200 W of 200 MHz CCP. These Al-bars are installed from the view port and are facing each other. Figure 2 shows the picture of the nitrogen plasma generated by these RF-sources from right hand side in Fig.2. There are two kinds of bright arches near the chamber in Fig.2 (indicated by black broken line). The arch closest to the wall is generated by 2.45 GHz and the other arch is generated by the 200 MHz. Plasma electron is heated at the each ECR surface and a part of the electron is trapped along the magnetron orbits. The both of the ECR surface and the magnetron orbit is depend on the magnetic field correlated to the frequency. The electron trapped along the magnetron orbit excites the gas and the plasma is generated. Figure 3 shows a typical emission line spectrum of the nitrogen plasma. The nitrogen gas pressure is controlled to 2.0 mTorr at this experiment.

3. Nitriding of Titanium foil

Test experiment of nitriding of Titanium foil has been done. In this experiments, the experimental setup was still under constructed, so the plasma was not stable yet. The 30 mm square of target Ti-foil was mounted on the heater unit at 100 mm down stream from the plasma chamber. It is considered that the plasma density is less than in the plasma chamber. 10 V of the bias voltage is applied to the Ti-foil target, and the drain current is about 10 mA when the microwave power transform is well. Figure 4 shows the Raman spectrum of the nitrided Ti-foil. The typical Raman spectrum of Ti-N is observed around 600 cm^{-1}.

4. Conclusion

Nitrogen plasma experiment have been started for the previous step of h-BN deposition. Nitrogen plasma is generated by the microwave in the multipole-cusp magnetic field.

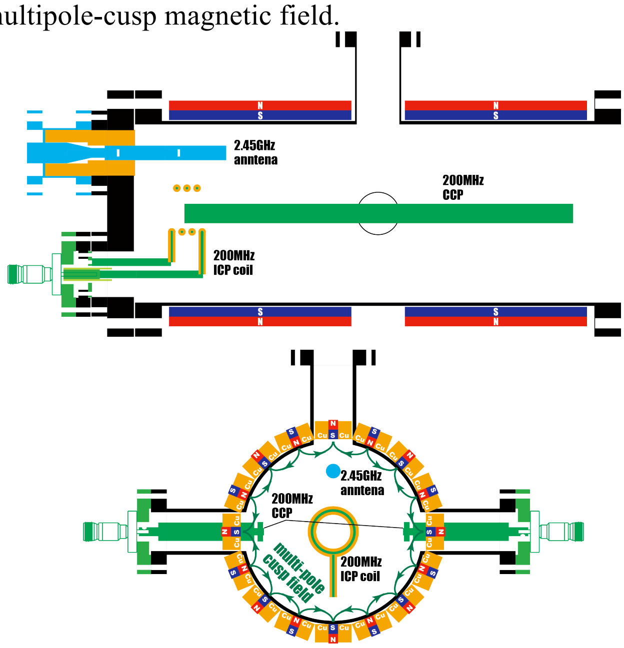

Fig.1.Experimental setup.

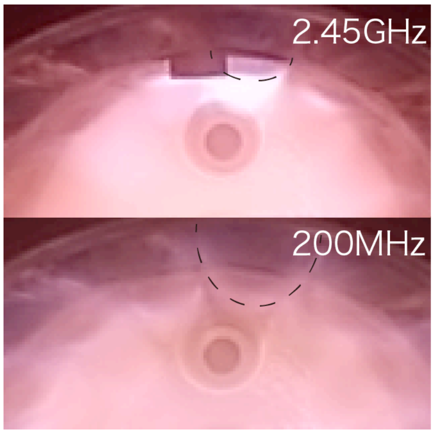

Fig.2. Nitrogen plasma.

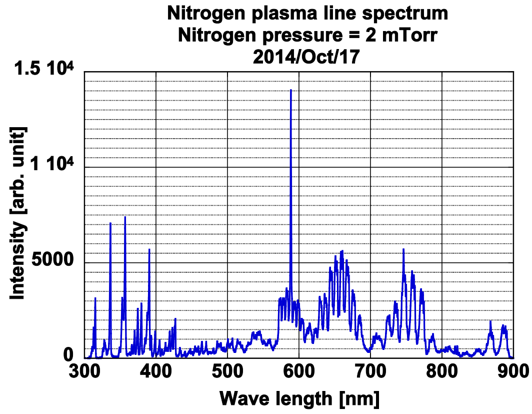

Fig.3. A typical emission line spectrum of nitrogen plasma

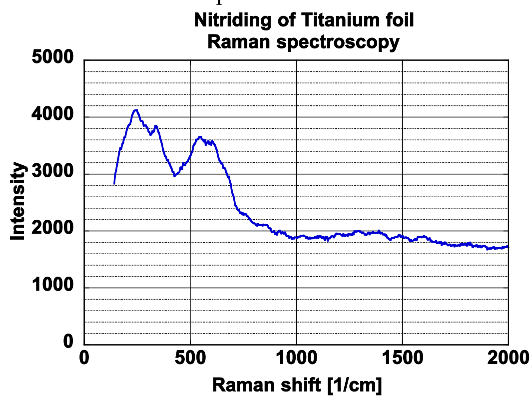

Fig.4. A typical Raman spectrum of Nitriding of Titanium foil.

References

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