[Study on manufacturing of patterned graphene by electron beam irradiation method]

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1. Abstract

In this research, we succeeded in graphene production using original produced method called electron beam irradiation method. Since this method can easily perform fine patterning, it is expected to be applied to LSI wiring.

2. Introduction

Semiconductor integrated circuits tend to be miniaturized as cost reduction and performance improvement are expected by miniaturization. However an increase in wiring resistance and wiring delay can not be ignored as miniaturization progresses. One approach to solving this problem is to replace the new material graphene with the current material copper. Graphene has a characteristic called ballistic conduction that conducts electricity without scattering electrons. Also, graphene has excellent resistance to electromigration. As a result, graphene is expected to be applied to future LSI wiring and device reliability improvement.

3. Experiment and Result

Fig.1 shows the outline of the electron beam irradiation method. In addition, Fig.2 shows the process and procedure for production. We will now explain the outline of the process in Fig.2. First, fullerene, which is a raw material for graphene production, is applied on a Si substrate. Next, electron beam is irradiated to change the structure of fullerene. Thereafter, the portion of the fullerene which has not changed structure is removed by using chloroform. Finally, a Ni film as a catalyst is vapor-deposited and annealed at 1300 ° C to produce graphene.

Next, we evaluate graphene produced using Raman spectroscopy and Transmission electron microscope. Fig.3 shows results by Raman spectroscopy. In this study, we conducted an experiment by changing the parameters of the Ni film thickness. Comparing the Raman spectra in Fig.3, we are able to observe the G band near 1580 cm^{-1} and the 2D band near 2700 cm^{-1} peculiar to graphene. However, since the 2D band is not a sharp peak but a gentle peak, we can see that the graphene produced this time is multilayer instead of single layer. In addition, since it is possible to observe the D band near 1350 cm^{-1} indicating the structural defect, we can see that there are defects in the graphene produced. Fig.4 shows the results of the Transmission electron microscope. First, we consider the lattice spacing d of the selected area diffraction image obtained from the Transmission electron microscope. Since the lattice spacing of the Ni film thickness of 6 nm and 20 nm was less than 2% from the lattice spacing of graphite, we can see that the one produced this time forms a graphite structure. Next, we consider that the full width at half maximum of the spectrum obtained by performing Fourier transformation on the selected area diffraction image. The half width of the Ni film thickness of 6 nm is larger than the half width of the Ni film thickness of 20 nm. From this result, it was found that there were many defects with a thin Ni film thickness.

4. Conclusion and Future effort

In this research, graphene was produced by using the electron beam irradiation method and evaluated by Raman spectroscopy and Transmission electron microscope. As a result, we were able to confirm that graphene was produced. By developing this research we can solve the problem of miniaturization in LSI wiring, and we think that further high integration and fabrication of high speed device will be possible. However, since many defects were observed in the graphene fabricated this time, it is a future effort to further improve the quality by optimizing various parameters in the manufacturing process.

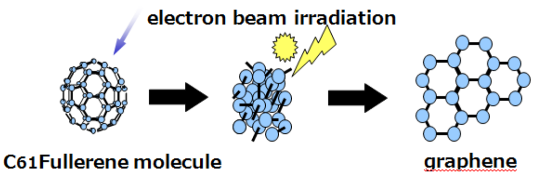

Fig.1: The outline of the electron beam irradiation method

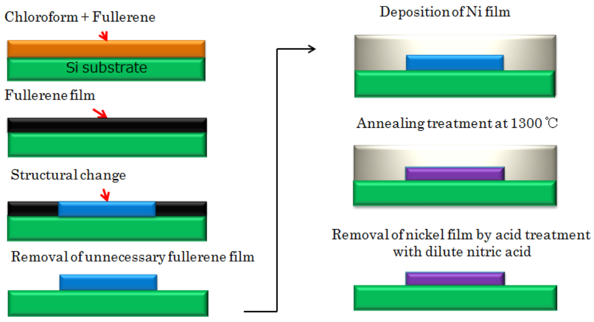

Fig.2: The process and procedure for graphene production

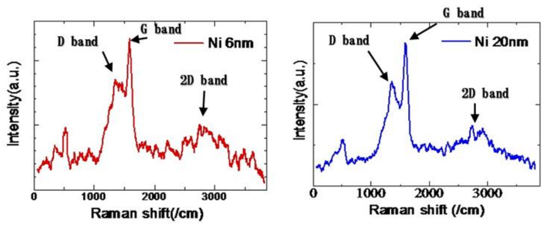

Fig.3: The Raman spectrum image of Ni catalyst 6 nm (left figure) and 20 nm (right figure)

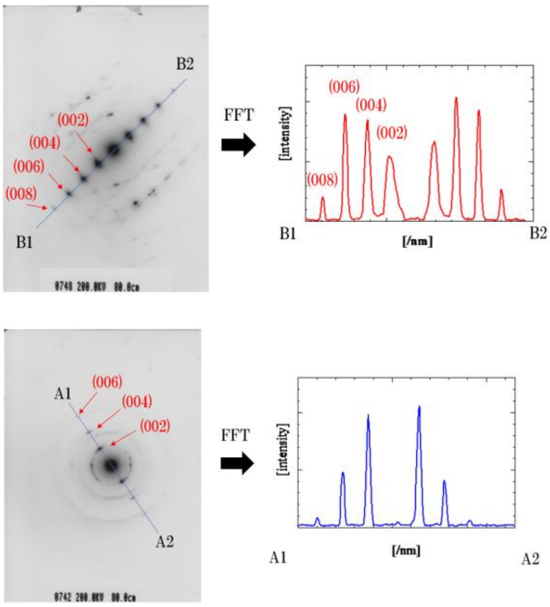

Fig.4: The selected area diffraction image of Ni catalyst 6 nm (upper figure) and 20 nm (lower figure) and its full width at half maximum