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# Graphene Synthesis by Laser-Annealing Technique Using Co Catalyst

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**Abstract**

**We have demonstrated a transfer-free and position-controlled synthesis of graphene on dielectric surfaces using Co layer by laser-annealing technique. Cobalt acted as catalyst and the quality of graphene was improved under the optimized thickness of amorphous carbon layer. Graphene-FETs using Co catalyst were fabricated in simple step by laser scanning across the substrate and the calculated mobility was increased 4-fold larger than the previous works using Ni catalyst. Utilizing Co catalyst in laser-annealing techniques provides improved quality of graphene and properties of graphene FETs.**

## 1. Introduction

Graphene has an ideal two-dimensional structure permits various attracting properties such as high carrier mobility [1]. Graphene-synthesis method by thermal-CVD has been investigated [2]. However, it includes a transfer process and needs highly reactive carbon gases. Thus, transfer-free graphene-growth techniques have been desired [3]. In the previous study, graphene was synthesized from an amorphous carbon (a-C) by laser-annealing technique [4]. The a-C layer was sandwiched between a Ni layer and a $SiO_2$/Si substrate. The solid-state carbon was dissolved and was diffused into the Ni layer by laser-irradiation, and then graphene was synthesized on the dielectric surface when the Ni retracted. Moreover, this technique was applied to fabrication of graphene-FETs by scanning the laser beam across the substrate (Fig. 1).

In this abstract, we reported direct graphene synthesis by the laser annealing technique using Co catalyst instead of Ni. Co has been well known as catalyst for synthesis of graphene in CVD process as well as Ni. After laser-irradiation, graphene was clearly synthesized using Co catalyst. The characteristics were measured by Raman spectroscopy and electrical measurements, resulting in improvements of quality and mobility of the graphene.

## 2. Experimental Procedure

A thin a-C as solid-state carbon source layer and Co as catalytic layer sequentially were deposited on a Si substrate with a thermally grown 300-nm-thick $SiO_2$ substrate using an electron beam evaporator without ambient conditions. Prepared samples had different thickness of a-C (from 1 nm to 10 nm) and catalytic metal thickness was fixed at 30 nm. Then, graphene growth was carried out by laser irradiation in a vacuum chamber. A continuous wave Ar-ion laser with a wavelength of 514.5 nm provided thermal energy to localized area on the surface for several minutes. For supporting the laser annealing, the heater was set up to the backside of the substrate and the temperature was maintained at 200 °C. The area annealed by laser-irradiation was investigated by optical microscopy, Raman spectroscopy and electrical measurement.

## 3. Results & Discussion

Figure 2 shows an optical image of a sample with a Co layer after laser-irradiation where the dark circular hole corresponds to laser-irradiated area.

Figures 3(a), 3(b) and 3(c) show Raman spectra of laser-irradiate area using Co catalyst with a-C thickness of 3, 4, and 10 nm, respectively. At less than 3 nm of a-C, no peaks were obtained. However, G and G' bands were clearly observed at more than 4 nm of a-C. The results indicate that graphene was directly synthesized on $SiO_2$ surfaces at more than 4 nm of a-C layer when Co was utilized as catalyst metal. Moreover, the Raman spectra reveal the sample with 4 nm of a-C have larger $I_G/I_D$ ratio and sharper FWHM of G bands than that with 10 nm of a-C. Thus, the thickness of a-C is an important parameter for synthesizing graphene.

Previously, Ni was used as a catalyst metal for direct graphene synthesis using laser-annealing technique. Figure 4 shows a typical Raman spectrum of laser-irradiated area for a sample using Ni catalyst with 1 nm of a-C layer. The result indicates that more than 1 nm of a-C is needed for synthesis of graphene and that minimum thickness of the a-C layer for synthesis of graphene is thinner than that using Co catalyst. As compared with the Raman spectrum of the sample using Co catalyst with 4 nm of a-C layer, the sample with Ni has a smaller $I_G/I_D$ ratio and a broader FWHM of the G band. Thus, when Co is utilized as catalyst for graphene synthesis by laser-annealing technique, the quality of directly synthesized graphene was improved.

Finally, graphene FETs were fabricated by laser scanning across the substrate. An inset in Fig. 5 shows an optical image after laser-scanning across the substrate, revealing that the patterned Co layer was separated into two areas. The two areas were applied to source and drain electrodes. Thus, this technique fabricated graphene and FET device simultaneously. Figure 5 shows a transfer characteristic of the graphene FETs using Co catalyst. For comparison, a property using Ni catalyst was also plotted in Fig. 5. The measurements revealed that the transconductance of the

device using Co is much larger than that using Ni. The calculated electric-field-effect mobility for the device with the Co layer was 4-fold higher than that of Ni. The results are attributed to higher quality of graphene for the sample with Co catalyst.

## 4. Conclusions

We have carried out graphene synthesis using Co catalyst by laser-annealing techniques and have investigated qualities of the graphene by Raman spectroscopy. Graphene-FETs were simply fabricated by laser scanning across the substrate. The transfer characteristics revealed that mobility using Co catalyst was 4-fold larger than that using Ni. Thus, the laser-annealing techniques are simple and useful for fabricating graphene devices when selecting proper catalyst.

## References


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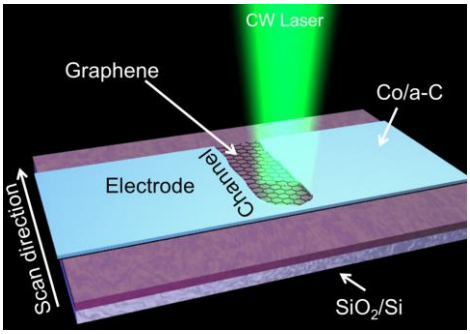


Fig.1. Schematic of fabrication process of graphene-channel FET by laser-scanning across a substrate.

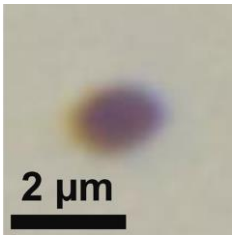


Fig.2. Optical image at laser-irradiated area.

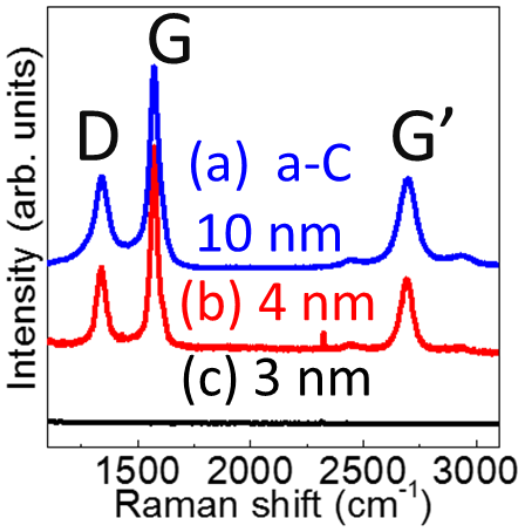


Fig.3. Raman spectra for samples using Co catalyst with different thickness of a-C; (a) 10, (b) 4 nm and (c) 3 nm of a-C.

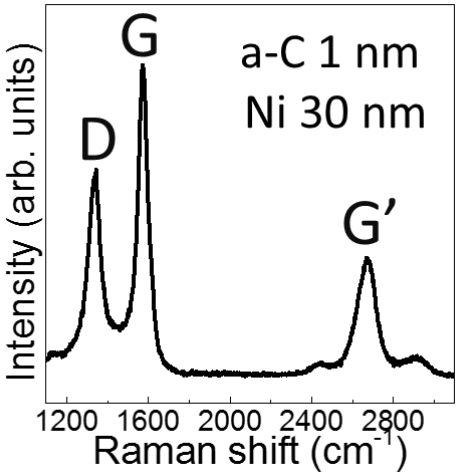


Fig.4. Raman spectrum for a sample using Ni catalyst with 1 nm of a-C layer.

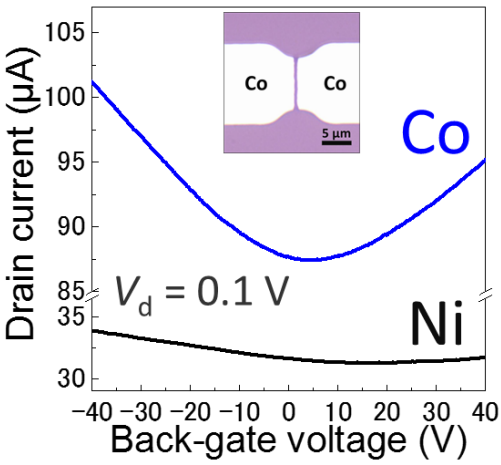


Fig.5. Transfer characteristics of $I_D$ versus $V_{Bg}$ using Co and Ni catalyst. An inset shows an optical image of a channel for the device.