High quality multi-layer graphene grown by low-temperature plasma CVD for future nano-carbon LSI interconnects

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Graphene has various superior properties over Cu such as high current tolerance, ballistic transport and high thermal conductivity, and therefore, is one of the most promising material for interconnect like carbon nantube (CNT). According to theoretical study[1], graphene shows lower resistivity compared with Cu in the form of ultrafine, less than 10 nm in width, interconnect. High-quality graphene growth at low temperature and on a large-area substrate is indispensable for realizing application for interconnect. In general, a plasma-based chemical vapor deposition (CVD) technique has the advantage of low-temperature thin film growth because it can supply a plasma-decomposed radicals and ions on a substrate. We have reported extremely high-density CNT growth at the growth temperature as low as 450 °C[2], which indicates that a plasma-based CVD is suitable for growing carbonaceous materials at low temperature. Since graphene is one of carbon allotropes, high-quality graphene growth at low temperature is expected by using a plasma-based CVD. In this study, we investigated the dependence of crystalline quality of graphene on major parameters of plasma, plasma power density and distance between a substrate and plasma, in low-temperature graphene growth by a plasma-based CVD.

Co was used as a catalytic thin layer in order to obtain multi-layer graphene. The thickness of which was 30 nm. Plasma power density was widely controlled to the range of 0.01-25 W/cm^2. Growth temperature was ranged 500-600°C. We employed a two-step growth method. Firstly, plasma pretreatment was carried out for reduction of Co film and subsequent step was graphene growth. Plasma pretreatment was performed at lower temperature, 25-350 °C, than that for growth temperature. Crystalline quality of graphene was evaluated by Raman spectroscopy and transmission electron microscope.

Figure 1 shows a typical Raman spectrum. The G/D ratio, ratio of G peak at ~1580 cm^{-1} to D peak at ~1360 cm^{-1}, which is used as an index of crystalline quality of graphene was calculated to be about 12. This was considerably high taking account of growth temperature of 580 °C. TEM image of graphene was shown in Fig. 2. Layers of graphene were clearly seen. It was observed that higher plasma power density leads to higher G/D ratio. Concerning plasma pretreatment, gas species have more influence on G/D ratio compared with plasma power density.

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References

[1] A. Naeemi et al. IEEE EDL **28** (2007) 428.
[2] Y. Yamazaki *et al*. Appl. Phys. Express **3** (2010) 055002.

Figures

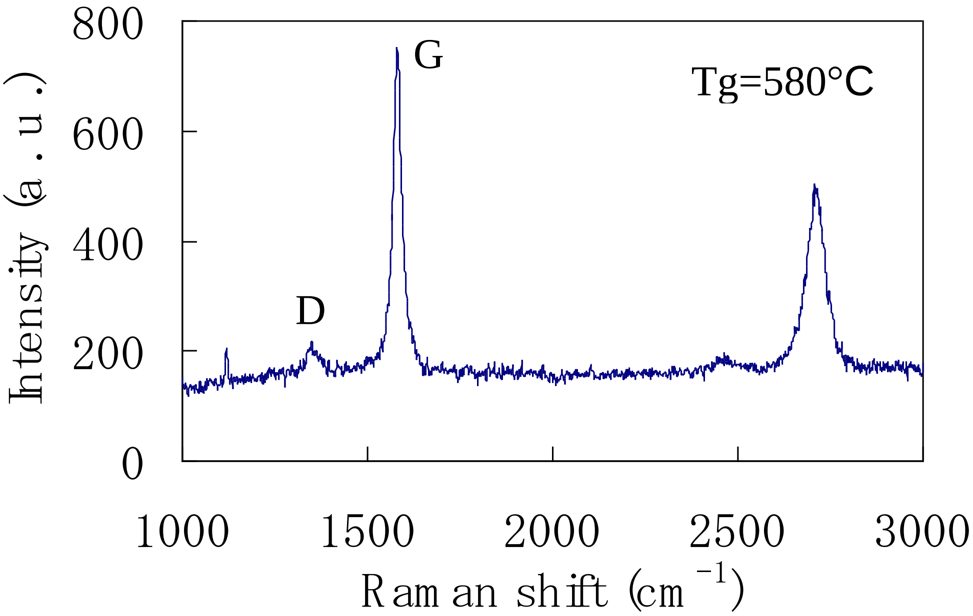

Fig. 1

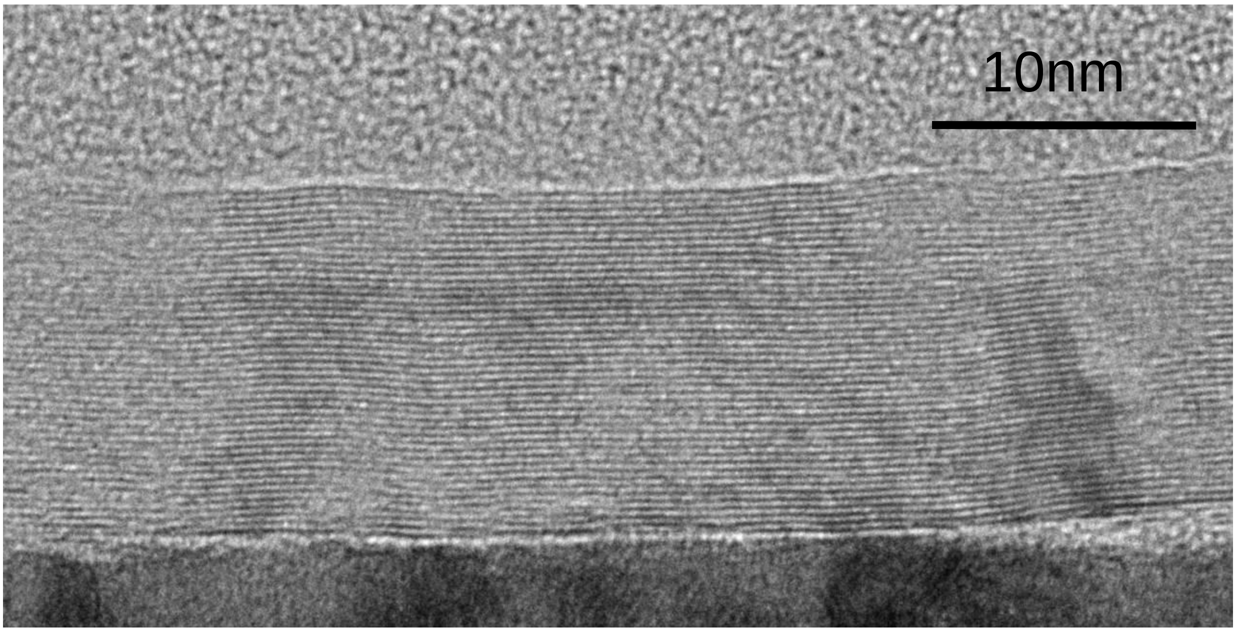

Fig. 2

Figure caption
Fig. 1 Raman spectrum. The G/D ratio was calculated to be about 12.
Fig. 2 TEM image. Number of layers of graphene was typically 30-40.