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Development of graphene and related materials in AIST

It is necessary to establish high-quality and high-throughput graphene synthesis technique for the practical application of graphene transparent films. In this talk development of high-throughput plasma-enhanced CVD for high quality graphene will be discussed.
The plasma CVD is characterized by high-growth rate graphene atomic membrane compared with conventional thermal CVD (fig.1), which is suitable for the high-throughput production for the industrial use [1,2,3]. We have achieved a graphene membrane with a transmittance of 95% (two-layer) for visible light and sheet resistance of 130Ω (gold chloride doped) by developing an original plasma CVD method. The establishment of the roll-to-roll CVD is one of the key factors for realizing the commercial application of graphene. The strain in graphene synthesized by plasma CVD with high-growth rate and tension to the substrate, which is necessary for winding, is analyzed by scanning transmission electron microscopy (STEM) and Raman spectroscopy [4]. The compressive strain generated during the growth by the tension to the substrate and the difference in thermal expansion coefficient between the graphene and the copper substrate is observed, which affects electrical conductivity. It was confirmed by STEM observation that no particularly large strain was accumulated at grain boundaries and their surroundings (fig.2).
This work is mainly based on results obtained from a project supported by New Energy and Industrial Technology Development Organization (NEDO).

References

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[2] Y. Okigawa, R. Kato, M. Ishihara, T. Yamada, M. Hasegawa, Carbon **82 (2015)** 60-66.
[3] R. Kato, S. Minami, Y. Koga, M. Hasegawa, Carbon **96 (2016)** 1008-1013.
[4] R.Kato, Y. Koga, K. Matsuishi, M. Hasegawa, Japanese Journal of Applied Physics **56 (2017)** 030307-1-5.

Figures

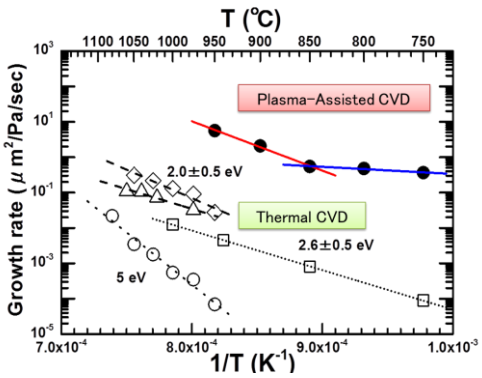

Figure 1: Temperature dependence of graphene growth rate for thermal CVD and plasma–assisted CVD which are normalized by CH4 partial pressure. [3]

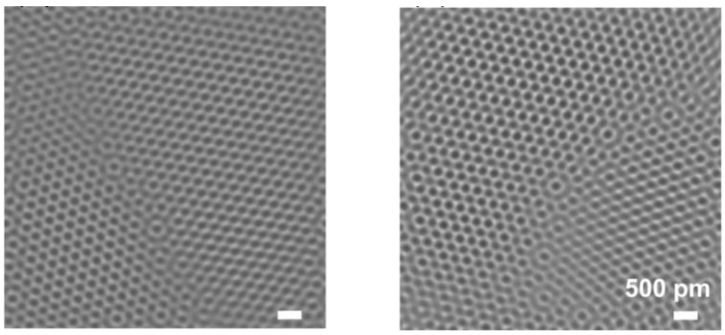

Figure 2: (Left) Domain boundary of graphene synthesized by slow growth (growth time 1200 sec) without tension to the copper foil substrate. (Right) Domain boundary of graphene synthesized by fast growth (growth time 10 sec) with tension to the substrate (2.9N/mm^2).