Graphene Synthesis by Solid Phase Reaction in Transmission Electron Microscope (TEM)

Masaki Tanemura [a]
M. S. Rosmi [a], S. Sharma [a], G. Kalita [a], Y. Yaakob [b], C. Takahashi [c] and M. Z. Yusop [d]

[a] *Nagoya Institute of Technology, Japan*
[b] *Universiti Putra Malaysia, Malaysia*
[c] *Aichi Gakuin University, Japan*
[d] *Universiti Teknologi Malaysia, Malaysia*

tanemura.masaki@nitech.ac.jp

Carbon-based nanomaterials, such as carbon nanotubes (CNTs) and graphene, are promising for the various devices of next generation. For the device applications, their synthesis should be controllable in structure and position. In order to achieve this, we challenged their in situ synthesis in TEM while observing their formation process.

For the *in situ* TEM observation, various metal-included carbon nanofibers (CNFs) were fabricated on edges of either graphite [1-3] or Cu [4] foils by Ar ion irradiation to the foil edge with a simultaneous supply of those metals or C, respectively, at room temperature. They were featured by the amorphous CNF with the inclusion of metal nanoparticles. For a comparison, Cu coated pure CNFs without metal inclusion were also prepared. For those samples, dynamic TEM observation (video mode) was performed during current-voltage (I-V) measurement or heating in TEM.

Depending on the catalytic property of the included metal, different types of nanocarbons, such as CNTs [1] and graphene [4, 5], formed during I-V measurements. In-situ I-V measurement in TEM for Cu-included CNFs (Cu-CNFs) and Cu coated CNFs, for example, revealed that current increased quite slowly at the beginning and suddenly steeply increased with applied voltage [4, 5]. Fig. 1 shows the graphene formation process during the I-V measurement for Cu-CNFs, disclosing the transformation from the amorphous carbon structure to agglomerated graphene flaks (about 3 layers in average thickness) catalysed by the dispersed Cu nanoparticles and the evaporation of Cu after the steep increase in current [4]. The transformation temperature was estimated to be ~750°C. After the formation of graphene wire of about 800 nm in length and 50-100 nm in diameter, current density as high as 10^6 A/cm^2 was achievable.

Thus, it is believed that the graphene formation by solid phase reaction is essential not only for the elucidation of the growth process but also for the growth area (position) control of graphene for practical device applications.

References

[1] M. Zamri Yusop, et al., ACS Nano 6 (2012) 9567.
[2] C. Takahashi, et al., Carbon 75 (2014) 277.
[3] Y. Yaakob, et al., RSC Advances 5 (2015) 5647.
[4] M. Rosmi, et al., RSC Advances 6 (2016) 82459.
[5] M. Rosmi, et al., Scientific Reports 4 (2014) 7563.

Figure

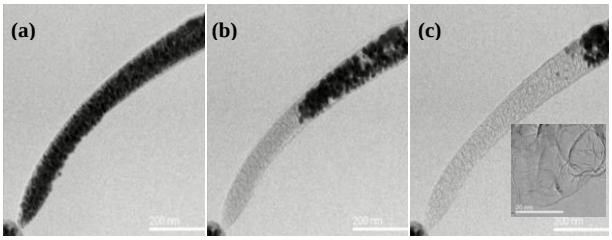

Figure 1: TEM images of the structural transformation process of a Cu-CNF with a gradual increase in applied voltage during I-V measurement. Inset in (c): magnified TEM image of the formed graphene [4].