# Chemical vapour deposition of graphene on 3-dimensional metal foams for energy-storage applications

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Several applications rely on the integration of 2-dimensional (2D) graphene sheets into 3D structures while keeping their unique properties, such as the high surface area and electrical conductivity. Metal oxide nanoparticles are typically mixed with the graphene sheets to avoid their stacking and to functionalize their surface, forming composites. A novel approach to fabricate graphene/metal oxide composites uses 3D Ni foams as templates where the graphene is grown by chemical vapour deposition (CVD) [1]. After removing the metal scaffold, the free-standing graphene foams can be coated with an electro-deposited layer of metal oxide [2] or with metal oxide nanoparticles dispersed in a solution [3]. These graphene 3D networks are being investigated, for example, as advanced electrode materials for sensors [4] and energy storage devices, such as supercapacitors [2] and lithium ion batteries [3].

In this communication, we report on the properties of graphene grown by CVD and plasma-enhanced CVD (PECVD) on 3D Ni and Cu foams using $CH_4$ or $C_2H_2$ as precursors. The temperature, pressure, and plasma conditions were varied to study their effect on the graphene properties. The graphene/metal foam structures have been characterized by Raman spectroscopy and scanning electron microscopy (SEM). The structural characteristics and the homogeneity of the graphene coating are discussed in terms of the growth conditions. We demonstrate an accurate control of the number of graphene layers by tuning the deposition conditions, not only by CVD at standard temperatures (T~ 1000ºC) but also by PECVD at reduced temperatures as low as 700ºC. Figure 1 presents the Raman spectra and SEM images of graphene layers grown by PECVD on Ni foams at 600ºC, 700ºC, and 800ºC. The quality and number of layers evolves with temperature as follows. At T = 600ºC (Fig. 1(a)) the D and D' Raman peaks indicate the presence of defects in the graphene coating, that are associated to the formation of nanocrystals, as confirmed by the textured morphology observed by SEM (Fig. 1(c)). At T = 800ºC (Fig. 1(g)) the 2D Raman peak presents a graphite-like shape, indicating a large number of layers. However, at T = 700ºC the Raman spectrum (Fig. 1(d)) indicates that defect-free bilayer (or few-layer) graphene is obtained. SEM images indicate an almost continuous coverage of the foam surface (Fig. 1(e)), with some influence from its grain structure. The optimum temperature of the PECVD process presented is much lower than that previously reported for CVD graphene foams [1-4].

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## References

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## Figures

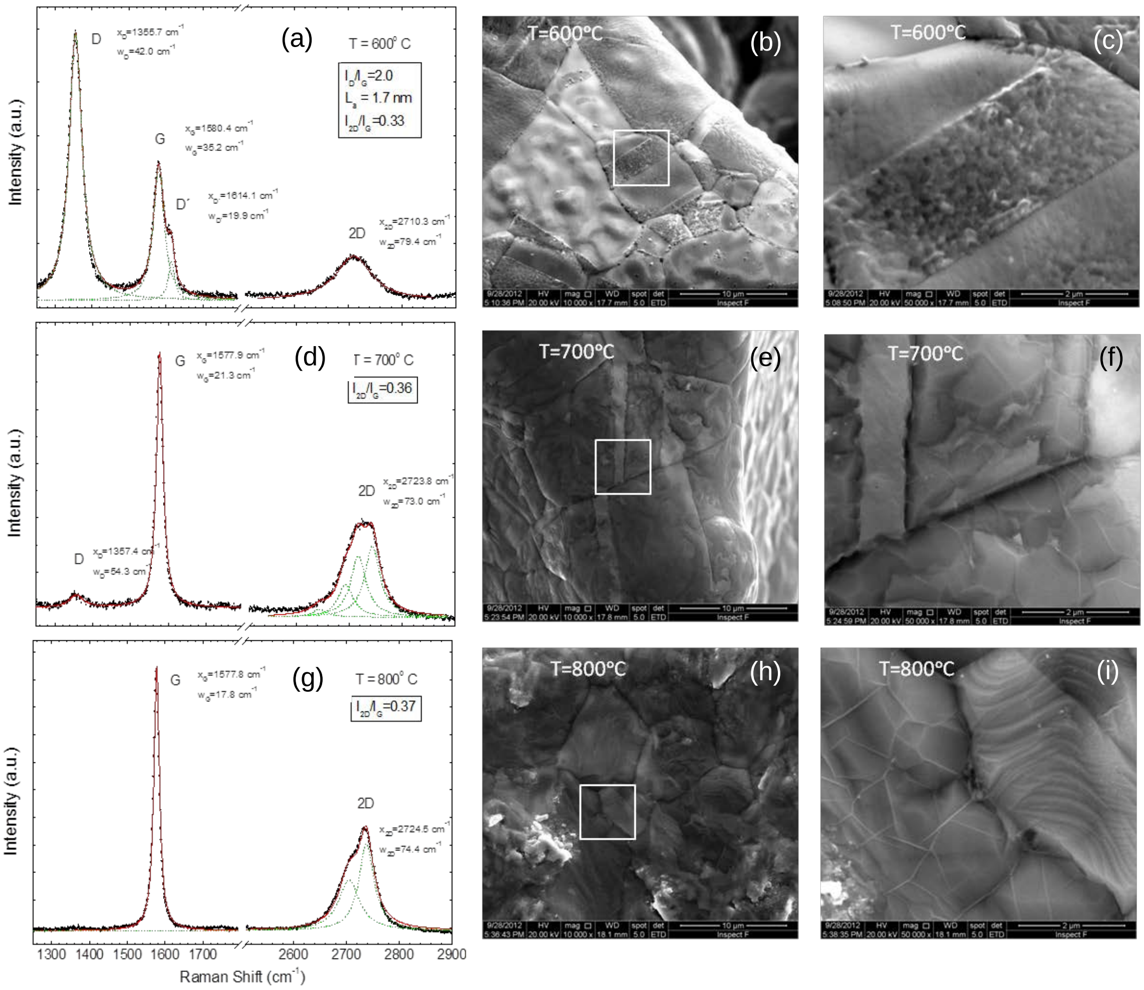


**Fig.1**