Atomic-Structure-Controlled Synthesis of Nanocarbon Materials with Nanoscale Plasma Processing

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Single-walled carbon nanotubes (SWNTs), graphene, graphene nanoribbons (GNRs), and transition metal dichalcogenides (TMDs) are known as atomic-scale and layered materials. Since the electrical and optical features of those materials are sensitive to their atomic structures, structural-controlled synthesis and functionalization of the layered materials with atomic resolution are very important issues for the practical use of those novel nanomaterials [1]. We have applied nanoscale plasma processing [2] to solve these issues and realized several innovative syntheses and functionalization for those nanomaterials. (i) The preferential growth of (6,4) chirality SWNTs has been realized with surface state control of Co catalysts (Fig. 1(a)) [3]. Through the precise control of oxidation degree of Co catalysts, drastic transition of main chirality species can be observed from (6,5) to (6,4) SWNTs. This chirality shift can be explained by the difference of nucleation provability between (6,5) and (6,4) SWNTs from oxidized Co and reduced Co catalysts. (ii) A novel method for the integrated synthesis of suspended GNRs is established with rapid heating plasma CVD using Ni nanobar as a catalyst [4]. The growth dynamics of suspended GNR is also investigated through the systematic experimental study combined with molecular dynamics simulation and theoretical calculations for phase diagram analysis [5]. The improvement of thermal stability of Ni nanobar can be a key to realize the GNR nucleation in our method, which can be given by supplying higher density of carbon from plasma to liquid-phase Ni nanobar. By following these growth models, precise tuning of growth conditions is carried out, resulting in the wafer-scale synthesis of suspended GNR arrays with a very high yield (over 98%) (Fig. 1(b)). We believe that our results can contribute to pushing the study of atomically thin layered materials from basic science into a new stage related to the optoelectrical applications in industrial scale.
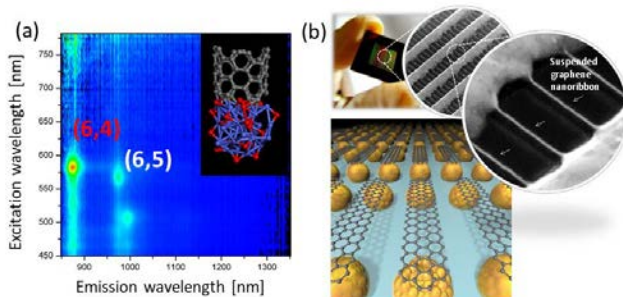

Figure 1: Typical results of (a) (6,4) dominant SWNTs synthesis and (b) large-scale integration of suspended GNR arrays.

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