Bottom-up synthesis of atomically-preciselow-dimensional nanocarbon materials by 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 electricaland optical features of those materials are sensitive to their atomicstructures, structural-controlled synthesis and functionalization of thelayered materials with atomic resolution are very important issues for thepractical use of those novel nanomaterials. We have applied nanoscale plasmaprocessing [1-3] to solve these issues and realized several innovativesyntheses and functionalization for those nanomaterials. (i) The preferentialgrowth of (6,4) chirality SWNTs has been realized with surface state control ofCo catalysts [4]. Through the precise control of oxidation degree of Cocatalysts, drastic transition of main chirality species can be observed from(6,5) to (6,4) SWNTs. This chirality shift can be explained by the differenceof nucleation provability between (6,5) and (6,4) SWNTs from oxidized Co andreduced Co catalysts. (ii) A novel method for the integrated synthesis ofsuspended GNRs is established with rapid heating plasma CVD using Ni nanobar asa catalyst [5]. The growth dynamics of suspended GNR is also investigatedthrough the systematic experimental study combined with molecular dynamicssimulation and theoretical calculations for phase diagram analysis [6]. Theimprovement of thermal stability of Ni nanobar can be a key to realize the GNRnucleation in our method, which can be given by supplying higher density ofcarbon from plasma to liquid-phase Ni nanobar. By following these growthmodels, precise tuning of growth conditions is carried out, resulting in thewafer-scale synthesis of suspended GNR arrays with a very high yield (over 98%)[6]. We believe that our results can contribute to pushing the study ofatomically thin layered materials from basic science into a new stage relatedto the optoelectrical applications [7-9] in industrial scale.

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