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Soft processing for nano carbons: Direct fabrication of functionalized graphenes and their hybrids inks via submerged liquid plasma and electrochemical exfoliation under ambient conditions

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Nano-carbons like graphenes have greatly been interested in various fields of researches, where the large scale synthesis of nano-carbon should be free from using excess energies for firing, sintering, melting, vaporizing and/or expensive equipments. We propose here soft processing of functionalized graphenes at ambient conditions. The soft processing provides number of advantages which includes: Simple reaction set up; at ambient conditions; simple procedure and; less operating costs and wastes. In the present study, we have utilized Submerged Liquid Plasma (SLP) and Electrochemical Exfoliation (ECE) methods. SLP methods results in the direct synthesis of nitrogen functionalized graphene nano-sheets from graphene suspension and/or graphite electrode in acetonitrile liquids. Products contains few layers (<5) graphene nanosheets. Unsaturated or high energy functional group (e.g., C=C, C=N and C≡N) have formed in the products. We could confirm those functionalized graphenes are electrochemically active. Using pencil rods instead of graphite rods, we have also succeeded to prepare the nano-clay/graphene hybrids by this SLP methods. Reduction and functionalization of graphene oxides and synthesis of graphene/Au hybrids also realized by SLP. In the ECE, graphite anode is exfoliated electrochemically by H_2O_2 -NaOH or glycine- H_2SO_4 aqueous solutions under ambient temperature and pressure for 5-30 minutes with +1 and +5 volt, into 3-6 layers graphene nanosheets (GNs). Those conditions are much milder than those reported before using other chemicals like ionic liquids and/or H_2SO_4 - $KMnO_4$, etc., because ions or ionic complex like glycine- HSO_4 would assist the exfoliation of graphite layers. Our products: GNs suspended in solutions can be transformed in the 2nd step in the same container using $BrCH_2CN$ /dioxane into N-FG, further into Au-hybridized N-FG by the sonification with Au nanoparticles. We have confirmed the excellent catalytic performance of those hybrids. It should be noted that soft processing can directly produce graphene ink and graphenes dispersed in various liquids, under mild conditions.

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