

Graphene Nanoribbons

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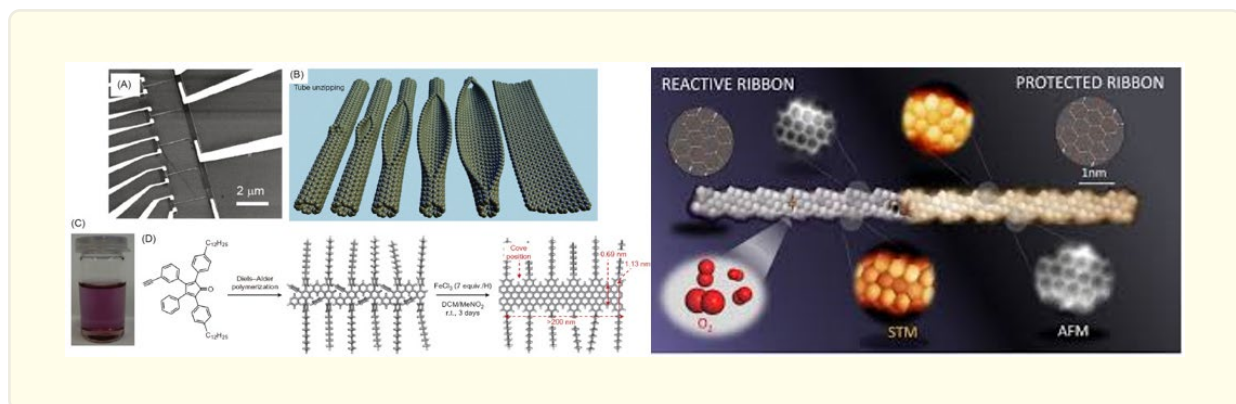
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Introduction

Graphene nanoribbons (GNRs) are quasi one-dimensional narrow strips of graphene comprised of sp^2 -hybridized carbon atoms arranged into hexagonal honeycomb lattice configurations. GNRs possess high mobility and current-carrying capability, sizeable band-gap and versatile electronic properties, which make them promising candidates for quantum electronic applications. The high aspect ratio, abundant edges, conductivity, and propensity for functionalization make GNRs an attractive material that draws interest from a wide range of fields, including chemistry, physics, materials science, and biology. GNRs have already found use in various applications such as sensors, conductive films, polymer composites, batteries, energy-conversion/storage devices, bioimaging, DNA sequencing, and neurophysiological recovery. With the advancements in the preparation technology of GNRs, GNRs with different structures have been prepared and studied. Results reveal that GNRs have good photoelectric characteristics, providing them broad application prospects in quantum computing and dissipative microelectronic devices.



Top-Down synthesis of GNRs from unzipping of nanotubes

Bottom-up and top-down methods are both currently used for the synthesis of GNRs. Bottom-up approaches allow for the synthesis of precise narrow ribbons due to the controllable assembly of small molecule building blocks. Although this method results in high-quality GNRs with minimal defects, the scalability of GNR synthesis via this route is less feasible; therefore, top-down methods are preferred when lower-cost mass-production is desired. Such top-down approaches often involve the longitudinal unzipping of multi-walled carbon nanotubes (MWCNTs) to produce GNRs that are as long as the starting MWCNTs had been. Redox chemistry is commonly used for such longitudinal splitting of MWCNTs with many publications reporting successful GNR fabrication under both

reductive and oxidative conditions. The former typically employs the use of potassium (K) vapor or sodium-potassium alloy (Na/K) reducing agents whereas the latter uses oxidizing agents, such as potassium permanganate (KMnO_4) or ammonium persulfate ($(\text{NH}_4)_2\text{S}_2\text{O}_8$). Each method of GNR synthesis necessitates the use of low-defect MWCNTs since defects act as termination sites that prevent completion of the unzipping reaction.

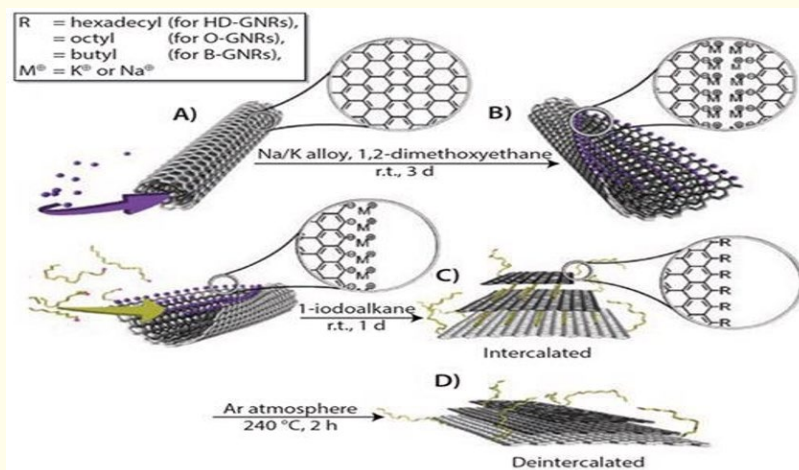


Figure 1: Reductive intercalation-driven synthesis of alkyl functionalized GNRs. A) The MWCNT is split by the intercalation of K between the walls of the nanotube due to strain along the carbon-carbon bonds induced by the metal atoms. B) Carbanions are formed along the nanoribbon edge after splitting of the MWCNT walls. C) Functionalization of the GNRs with alkyl moieties: the same process is used for the synthesis of H-terminated GNRs or PEGGNRs, but MeOH or ethylene oxide are added during the second step, respectively, instead of 1-iodoalkane.

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