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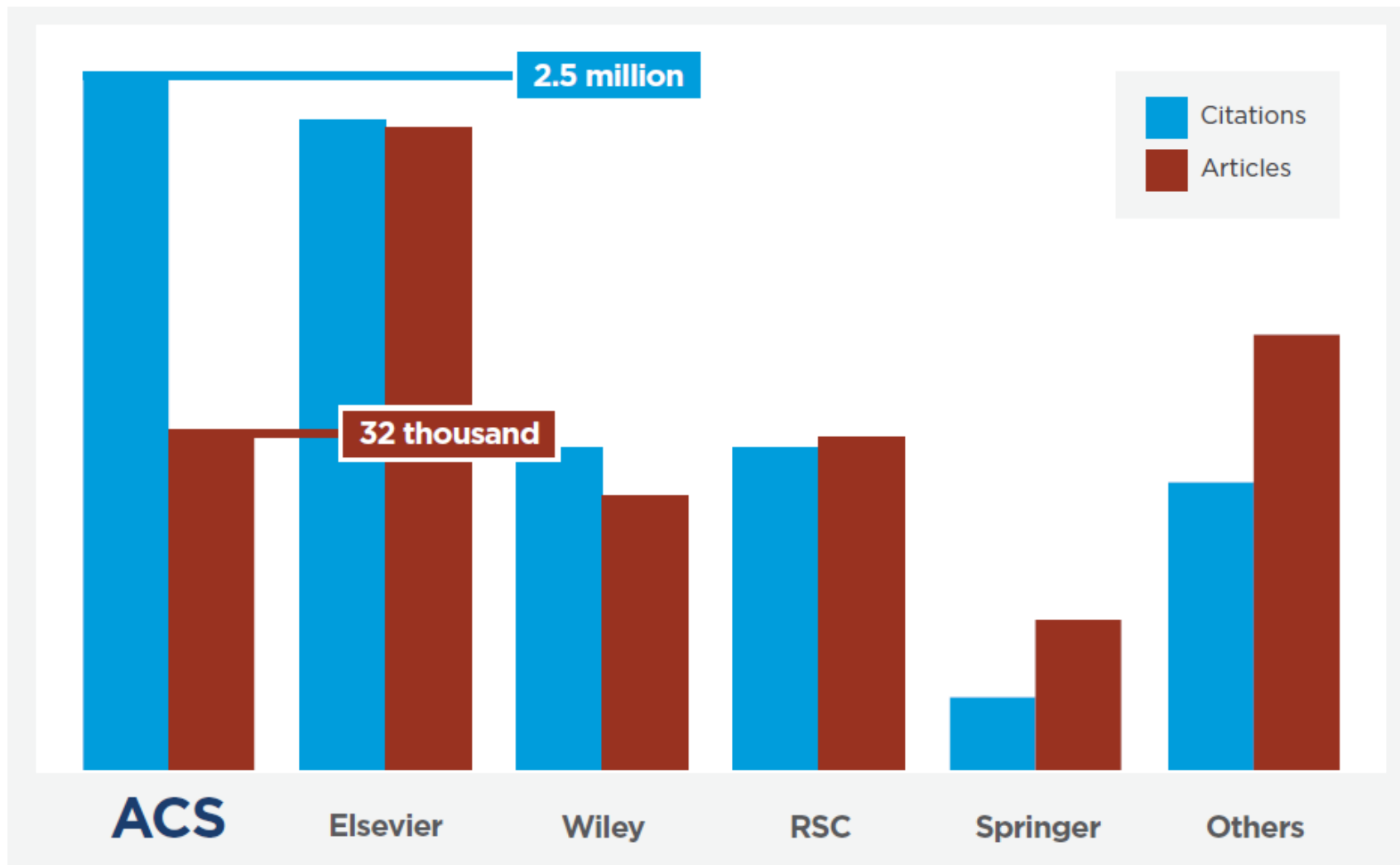
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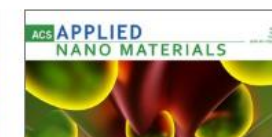
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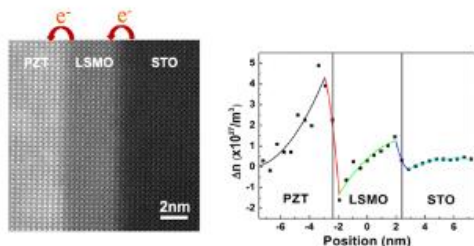
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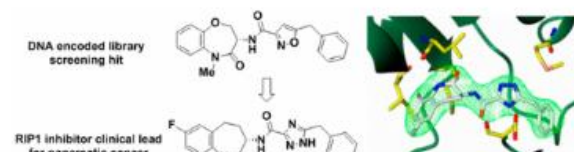
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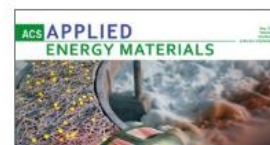
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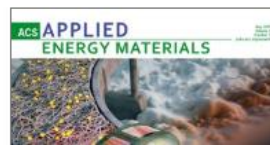
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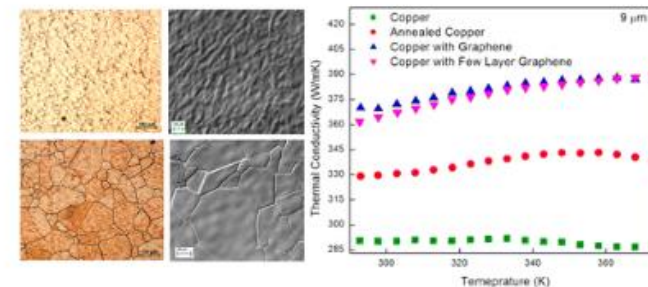
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Mohammed Alahmadi and Mohamed Sijaj*

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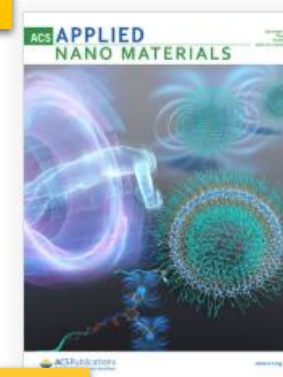
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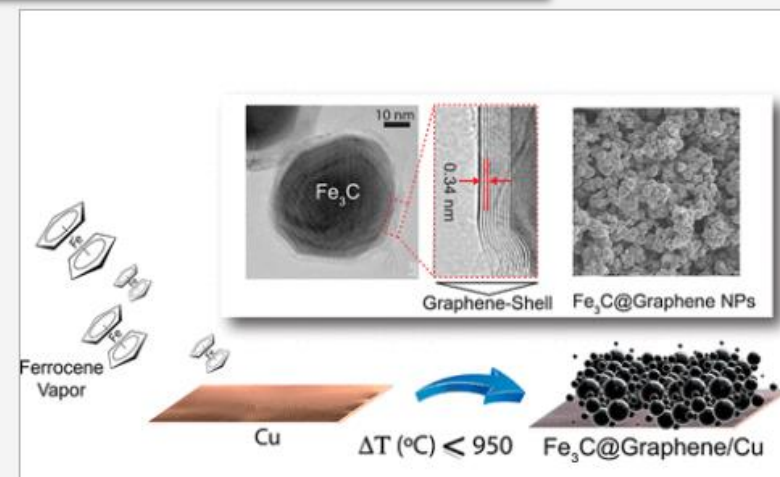


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Abstract

Iron carbide nanoparticles (NPs) encapsulated by multilayer graphene, $\text{Fe}_3\text{C}@$ graphene, were produced by one-step chemical vapor deposition (CVD) at high temperature (950°C) with ferrocene powder as a precursor and a copper foil surface as a catalyst. At high temperature, the ferrocene molecules adsorb dissociatively on copper catalysts, forming a layer of graphene decorated by core-shell $\text{Fe}_3\text{C}@$ graphene NPs. At high temperature, graphene has a low surface energy, allowing the lateral diffusion of iron atoms and carbon fragments to form NPs. The as-prepared core-shell $\text{Fe}_3\text{C}@$ graphene NPs have varying diameter from 50 to 80 nm, while the graphene shells vary from 8 to 40 graphene layers. The results demonstrate that the thickness of the graphene shell growth for NPs increases with increasing reaction time from 1 to 7 h. Graphene-assisted NP growth allows the formation of uniform core-shell $\text{Fe}_3\text{C}@$ graphene particles rather than carbon nanotube formation.



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Resumen y palabras clave



formation of uniform core-shell $\text{Fe}_3\text{C}@$ graphene particles rather than carbon nanotube formation. The synthesized NPs were analyzed via different surface-sensitive techniques and magnetic measurement methods to determine their structural and magnetic properties. Our work provides a rapid and general procedure for core-shell $\text{Fe}_3\text{C}@$ graphene synthesis by using a CVD technique.

KEYWORDS: graphene, magnetic nanoparticles, iron carbide, $\text{Fe}_3\text{C}@$ graphene, chemical vapor deposition

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Carbon-encapsulated magnetic nanoparticles (NPs) capture much attention due to their remarkable chemical and magnetic properties. The growth of straight carbon nanotubes (CNTs) encapsulated graphene layers with a metallic core (iron, nickel, and cobalt) is an important step toward real applications for drug delivery,⁽³⁾ immobilization of enzymes,⁽⁴⁾ biosensors,⁽⁵⁾ electronic devices,⁽⁶⁾ environmental areas,⁽⁷⁾ information storage,⁽⁸⁾ magnetic resonance imaging,⁽⁹⁾ hyperthermia,⁽¹⁰⁾ and label-free DNA detection.⁽¹¹⁾ Carbon-encapsulated magnetic NPs can be generated by several methods, such as metal-organic chemical vapor deposition (CVD),⁽¹²⁾ hydrothermal reaction,⁽¹³⁾ pyrolysis by detonation,⁽¹⁴⁾ thermolysis,⁽¹⁵⁾ gas condensation,⁽¹⁶⁾ arc discharge,⁽¹⁷⁾ high-energy electron-beam irradiation,⁽¹⁸⁾ cocarbonization of durene,⁽¹⁹⁾ and photoablation.⁽²⁰⁾ However, magnetic NPs should be encapsulated prior to several applications to prevent possible aggregation in a liquid medium and to promote fast biodegradation.^(17,21) Carbon-based materials such as shells are preferred over silica or polymers because of their elevated chemical and thermal stability,⁽²²⁾ suitable conductivity and biocompatibility,⁽²³⁾ and possible functionalization with various ligands.⁽²⁴⁾ Encapsulation of metals or carbides inside graphitic shells was carried out by several methods, such as the evaporation of metals together with carbon in an

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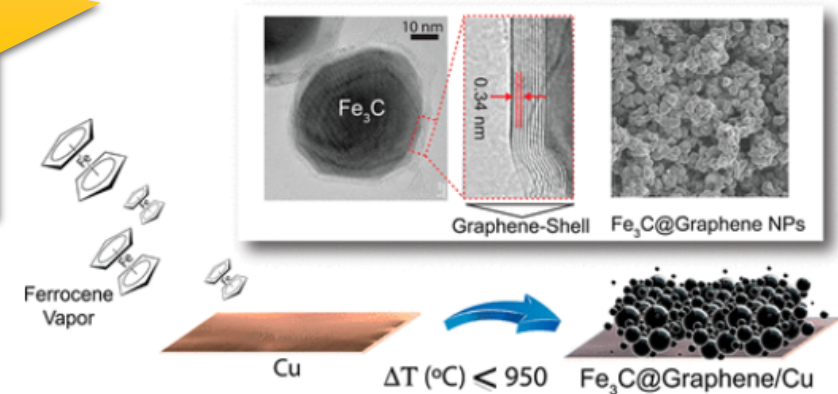


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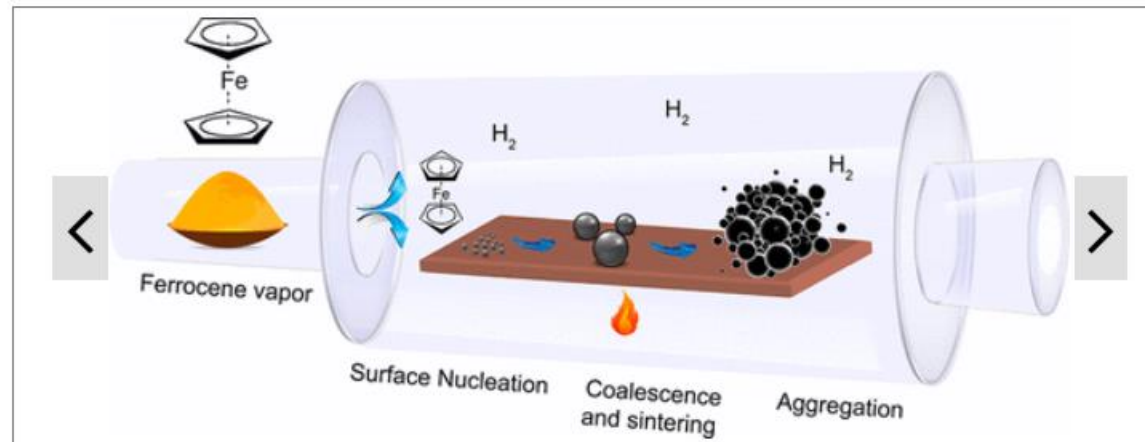
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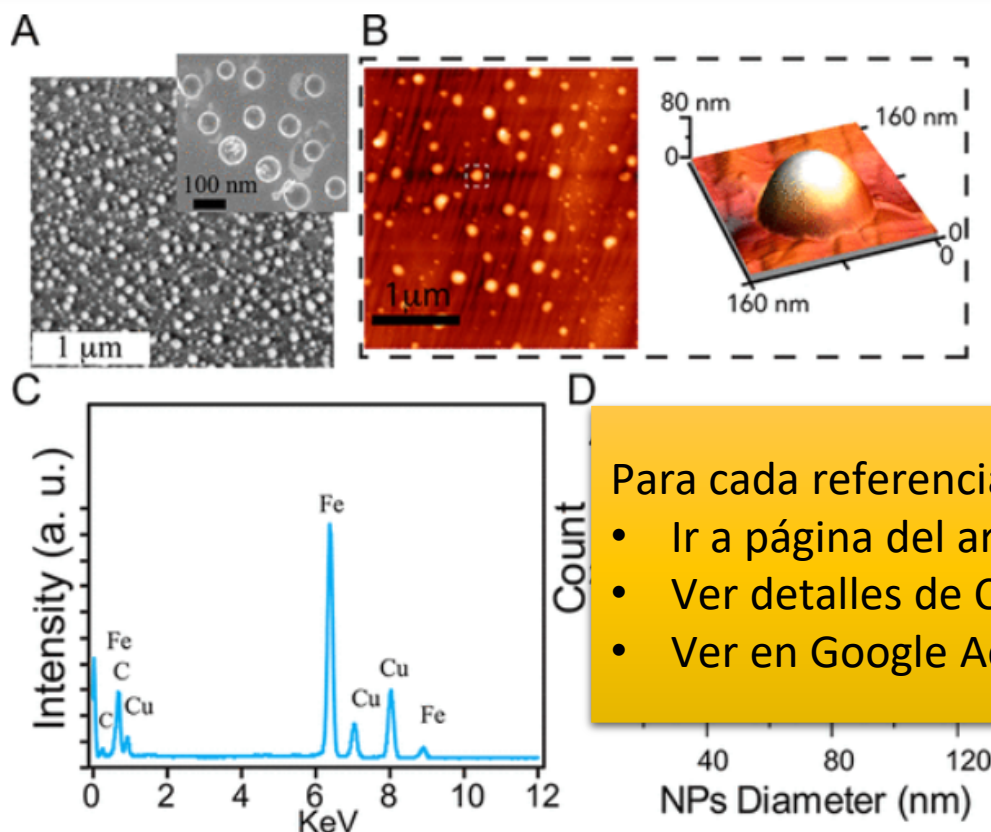
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Figure 2. (A) SEM image of the core-shell $\text{Fe}_3\text{C}@$ graphene NPs on copper substrate. The magnified areas are provided as insets showing well-defined spherical structures of NPs. (B) AFM images of the NPs with several particle clusters (right image) and a single NP cluster with height ~80 nm and width ~160 nm (left image). (C) EDS spectrum of the $\text{Fe}_3\text{C}@$

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