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Green synthesis of bi-functional iron embedded carbon nanostructures from collagen waste for energy and environmental remediation applications

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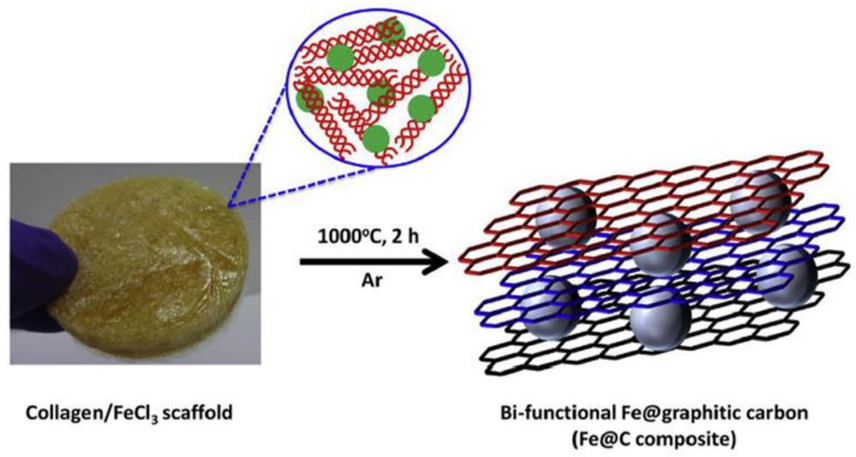
Poster No.

Introduction

- Increasing industrial growth produces large quantities of biomass wastes that loomed as a significant concern to the environment as they are disposed of through the burning or burying inland sites.
- Recent developments have shown that the biomass sources are served as a raw material to prepare carbon materials and favorably employed for dye adsorption, photocatalysis, heavy metal removal and water treatment applications.
- Carbon-iron nanomaterials with magnetic and conducting properties is among the organic-inorganic hybrid nanostructures explored by researchers in recent decades due to their convincing applications in many fields of applications such as Lithium-ion battery applications and photocatalysis.
- A significant number of synthetic protocols have been reported to fabricate the magnetic metal or metal oxide encapsulated carbon nanoparticles.
- However, most of the methods employ expensive precursors and rigorous process conditions, which pose considerable challenges for most applications.
- Carbonaceous biomass precursors with negligible cost will have an added advantage.
- Among the various carbonaceous biomasses, collagen is one of the potential carbon precursors and provides 70 - 88% carbon content after high-temperature treatment.
- The leather industry, on the other hand, generates voluminous collagenous solid wastes at a level of 750 kg per ton of skins/hides processed.
- The utilization of such huge quantities of collagenous waste for making high-value multifunctional materials not only benefits from a reduction in the environmental impact but also provides economic value. the synthesis of bi-functional.
- Here we report the synthesis of iron embedded carbon (Fe@C) nanoparticles with both conducting and magnetic functionalities using a simple heat treatment of collagen/$FeCl_3$ scaffolds for photocatalysis and Li-ion battery applications.

Materials & Methods

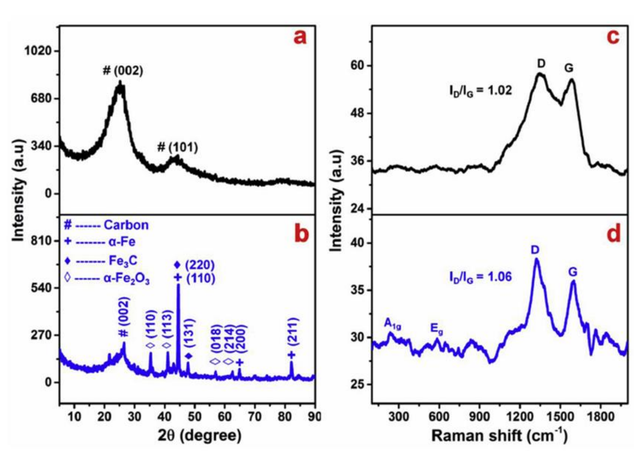
- **Preparation of Collagen/$FeCl_3$ Scaffold:** Skin trimming wastes collected from tannery were prepared as hide powder. Then the hide powder was weighed and dissolved in 0.5 M glacial acetic acid at 4 °C. Anhydrous $FeCl_3$ (15% wt/wt of collagen) was dissolved in 60 ml of deionized water and added dropwise to the collagen solution. The $FeCl_3$/collagen mixture was homogenized for 2 h at room temperature and then freeze-dried.
- **Synthesis of the bi-functional iron embedded carbon nanostructures:**



Results

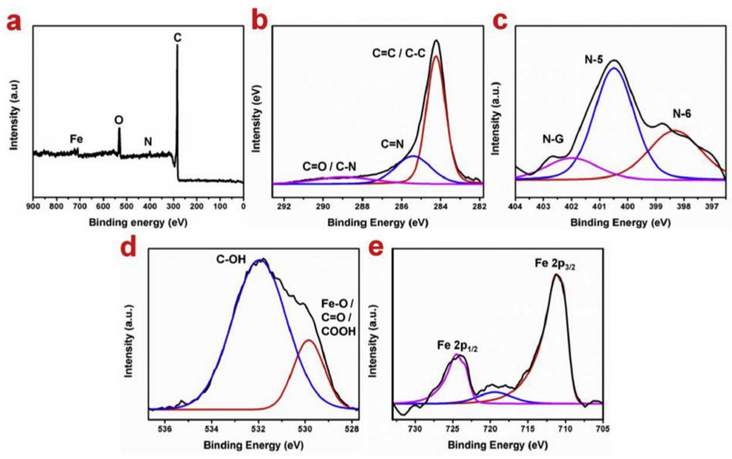
Structural and morphological studies

(i)



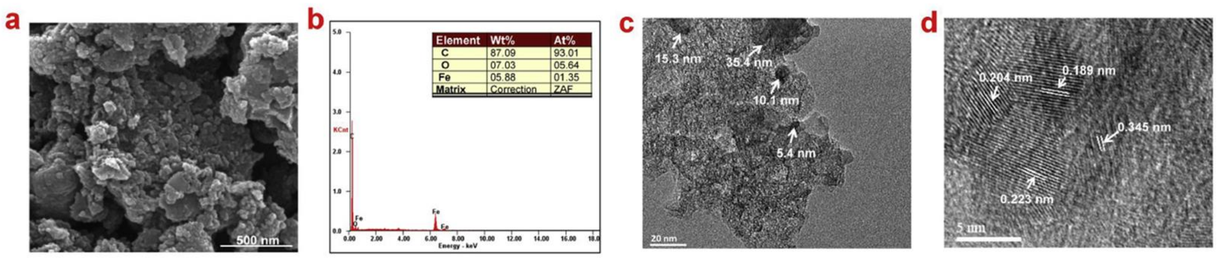
XRD and Raman Spectra of control carbon ((a) & (c)); and as-synthesized iron embedded carbon (Fe@C) nanoparticles ((b) & (d)).

(ii)



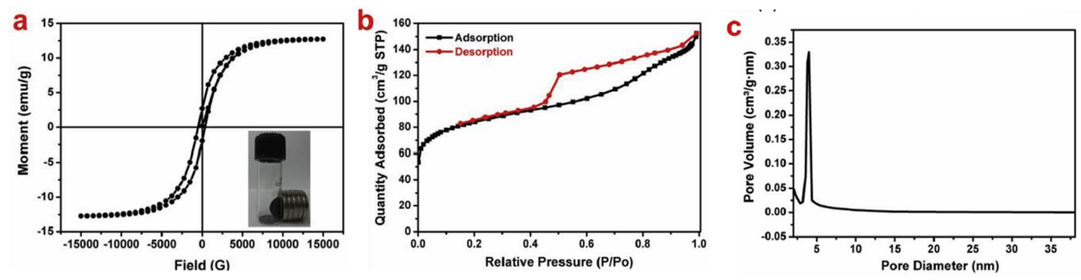
(a) XPS survey spectrum and XPS high resolution (b) C1s, (c) N1s, (d) O1s and (e) Fe2p spectra of the as-synthesized iron embedded carbon (Fe@C) nanoparticles

(iii)



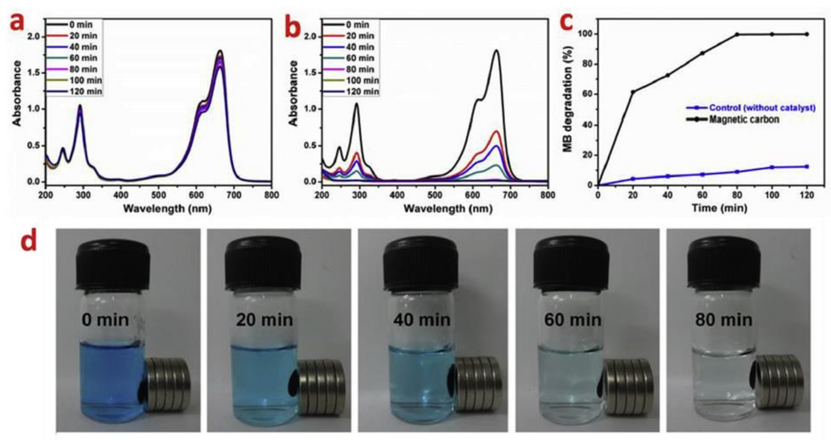
(a) HRSEM image, (b) EDX analysis, (c) TEM and (d) HRTEM images of the as-synthesized Fe@C nanoparticles.

VSM and BET analysis of the Fe@C nanoparticles



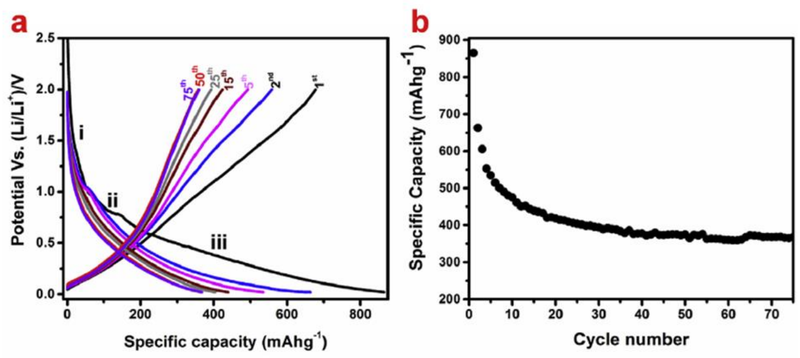
(a) Room temperature magnetization curve of the Fe@C nanoparticles. The inset shows the magnetic response of samples to an external magnetic field (~1000 Oe) induced by permanent magnets; (b) BET observation of nitrogen adsorption-desorption isotherm hysteresis curve and (c) pore size distribution curve of the as-synthesized Fe@C nanoparticles.

Photo catalysis studies



UV-Vis absorption spectra of MB degradation (a) in the absence of the catalyst, (b) catalyzed by the Fe@C nanoparticles; (c) percent degradation of MB in the absence/presence of the catalyst and (d) digital images showing the extent of the 10 ppm MB degradation within 80 min of sunlight irradiation and the magnetic separation of the catalyst from the treated solution.

Li-ion battery electrode applications of Fe@C nanoparticles



(a) Voltage vs specific charge-discharge capacity of Fe@C electrode cycled at C/20 rate between voltage range of 0.05e2.0 V and (b) cycling stability of the Fe@C nanoparticles during discharge vs cycle number.

Conclusions

- Electric conducting and magnetic bi-functional Fe@C nanoparticles were synthesized from collagen/$FeCl_3$ scaffold using a simple high temperature treatment technique.
- The as-synthesized Fe@C nanoparticles display a mesoporous structure with a surface area of 307.5m2/g, a pore size of 5 nm, the saturation magnetization of 12.3 emu/g and electrical conductivity of 3.64 ± 0.13 103 S/cm.
- The photocatalytic results indicate that the as-prepared Fe@C nanoparticles are efficient catalysts towards the complete degradation of MB under sunlight within a short duration and can be recycled up to 5 runs without significant reduction in the degradation efficiency.
- Further, we demonstrated that these hybrid nanostructures could be potentially used as an anode in Li-ion battery with high reversible capacity and excellent cycling stability.
- Thus, the as-prepared Fe@C nanoparticles are promising as a sustainable, functional material for a wide range of applications such as catalysis, Li-ion battery electrode, EMI shielding and environmental remediation with magnetic separation.

Acknowledgement

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