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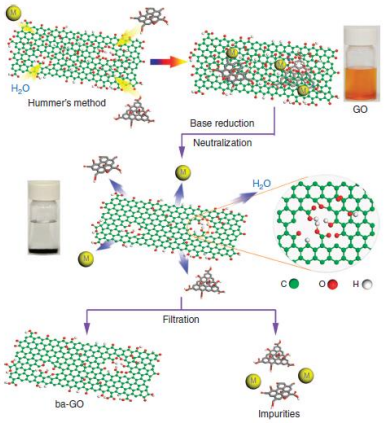
JOINT DEVELOPMENT OPPORTUNITY

Porous Graphene Oxide Materials



Schematic diagram of graphene oxide separation through base reduction and acid reprotonation under reflux conditions

Ref: C. Su, M. Acik, K. Takai, J. Lu, S.-J. Hao, Y. Zheng, P. Wu, Q. Bao, T. Enoki, Y. J. Chabal and K. P. Loh, *Nature Comms.* 3:1298 doi: 10.1038/ncomms2315 (2012).
U.S. Patent No: US 9,180,442 B2 issued on 10 Nov 2015

TECHNOLOGY BACKGROUND

Many industrial chemical reactions depend on catalysts to start, proceed and carry on to full completion. These reactions are the bedrock of pharmaceutical, specialty chemical, and food processing industries. Therefore, their economic significance and value cannot be underestimated. Unfortunately from the perspective of the environment, the vast majority of these reactions are catalyzed by metals like platinum, nickel, gold, palladium and rhodium. These metals need to be removed after the end of the reaction. They form a growing environmental hazard that is costly to manage. The supply of these metals is becoming more limited especially in the case of precious and rare-metal catalysts leading to rising prices.

There is a growing trend towards metal-free catalyzed reactions. Research has focused on tweaking the reaction conditions, i.e. increasing reaction times, involving more heat and changing the ambient gases and pressures. Alternative reaction pathways to achieve the same outcomes are also explored, e.g. bioinspired catalysts. The shift towards a green consciousness is also an impetus to seek solutions that do not increase the carbon footprint and do not impact the environment adversely. At the same time, achieving high yields while reducing usage of chemicals, and increasing the possibility of large-scale industrial applications is surely the culmination of such scientific work.

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Problems solved

A new porous graphene oxide (GO) catalyst has been developed using a one-step process. This is a metal-free, multifunctional and low-cost alternative to existing industrial catalysts.

a) High catalytic efficiency of up to 98% achieved through sequential base and acid treatments to activate the catalytic sites (i.e. carboxylic acid groups and edge sites) in the GO catalyst
b) Contaminants in graphene oxide removed by base treatment
c) Carboxylate anions ($–COO^-$) reduced to carboxyl acid groups and phenolate anions (ArO^-: Ar = aromatic radical) are neutralized to phenol groups (ArOH) to form porous graphene oxide material free of both types of anions
d) Low loading of catalyst required (5 wt % only compared with 60–400 % as reported elsewhere)
e) Massive potential reduction in processing costs by avoiding high metal usage, retrieval and disposal
f) Low impact on environment in using natural carbon sources

Application Areas

- Alternative high catalytic and highly magnetic catalysts in place of current expensive metal catalysts in various reactions, e.g. oxidations, reductions, Suzuki coupling reactions, oxygen reduction reactions and oxidation-reduction tandem reactions;
- Bifunctional catalysts that contain a second catalyst such as Pd, Pt, Au, Cu, V_2O_5, Co, Rh, Ru, Ni and Fe, for tandem oxygen activation and hydrogen action reactions.

Benefits Offered from Porous GO

- Low cost and naturally abundant carbocatalyst;
- Multi-faceted uses as an oxidant (oxidation of sulphides, olefins, hydrocarbons), an acid (hydration, Friedel-Crafts reaction, Aza-Michael additions, condensation and ring-opening polymerization);
- Base-acid treated graphene oxide catalyst can be used under solvent-free, open-air condition
- Catalyst is recyclable up to at least 6 cycles (with still very high yields of at least 92%) which makes it a good candidate for green catalysis.
- Unlike normal GO, the base-acid treated porous GO (ba-GO) suffers from a less than 50% mass loss at 600 ^oC and a less than 55% mass loss at 800 ^oC. This is indicative of ba-GO's thermostability.
- Porous GO material is also highly magnetic.
- Potential for conversion into bifunctional catalyst that further extends the applications of materials

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