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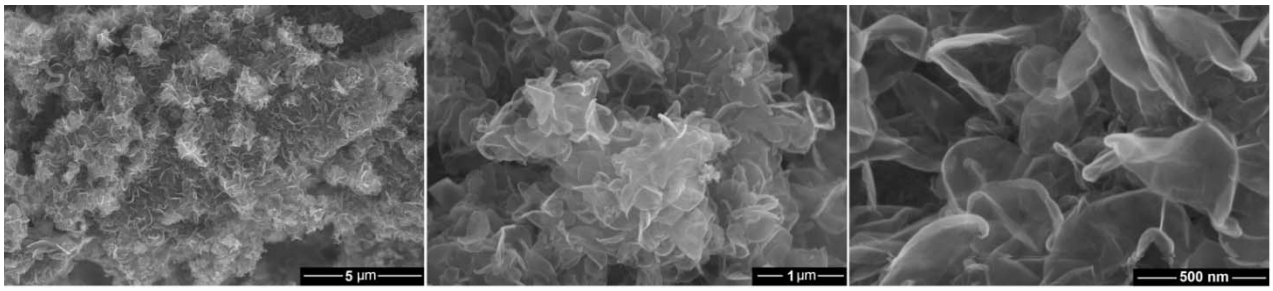
enterprise

Mass production of graphene

Electrolytic process to produce high quality graphene



A new method has been developed for the production of graphene with exceptionally high electrical and thermal conductivity. It is envisaged that the electrochemical method could be readily scaled up using commercially available graphite electrodes to produce 450kg/day in a 100 litre molten salt reactor, outperforming the current state of the art graphene manufacturing technologies.

Key benefits of method:

- Cost per tonne of graphene could be significantly reduced
- Very high production rate compared to alternative methods
- Very high quality graphene as shown by SEM images above and TEM image overleaf

Professor Derek Fray, FREng FRS, Director of Research

- Prof Fray is highly respected for his work in molten salt chemistry, much of which has commercial applications from titanium smelting to battery anodes.

Professor Ali Kamali, FRSC

- Expert in the innovative synthesis of advanced materials and nanostructures
- Collaborator with Prof Fray and others on many academic papers and patent applications

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Background

Methods of production of significant quantities of high quality graphene have not kept pace with its numerous applications, so supply remains restricted. Common methods are: mechanical unpeeling of graphite; chemical vapour deposition; exfoliation in low melting point ionic liquids. Many of these methods are highly expensive, use toxic materials and often create low quality graphene powder characterised by low electrical and thermal conductivities, which limit their potential applications. Rates of production tend to be low, and there are significant barriers to scaling up the production process.

High quality graphene has remarkable electrical, mechanical and thermal properties. The high charge carrier mobility allows graphene to be used where very high conductivity is required or, alternatively, to be added in small quantities to materials in order to improve their electrical properties. Similarly, the very high mechanical properties of graphene allow small quantities to be added to improve the mechanical properties of other materials. The thermal conductivity of polymers can also be increased by the addition of graphene, or graphene could be used as a standalone thermal conductor.

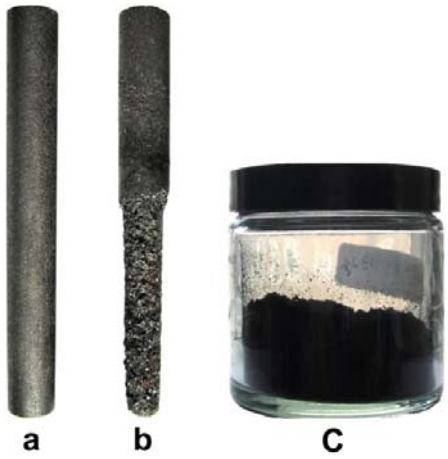
Technology

In this new electrochemical process, two graphite electrodes are immersed in a molten salt electrolyte under a controlled environment. On the cathode exfoliation takes place and the salt becomes black in appearance. The electrodes are then removed and the salt dissolved in water to be used again. The suspension of graphite particles is dried and then heated at elevated temperature. The Raman spectrum of the material confirms that it is high quality graphene. The appearance of the eroded rod and the product is shown in images a,b,c.

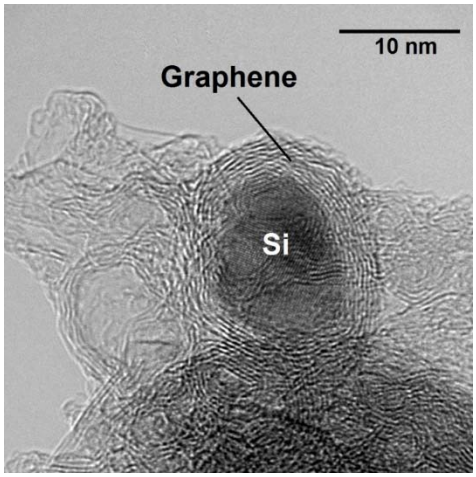
The graphene production rate is 50kg/m^2/day. An A4-sized block of graphite could produce 1 tonne/yr. It should be noted that the potentials, current densities and yields are very similar to those characteristic of conventional aluminium smelting.

Applications

Graphene produced by this route has been shown to improve the performance of energy storage systems such as Li-ion battery anodes and supercapacitors, mechanical and physical properties of ceramics, and the electrical properties of polymers. The graphene product has also shown an excellent performance in water purification systems as well as antibacterial and many other applications including manufacturing of carbon fibres.



Pictures of graphite rod (15mm in diameter) (a), graphite rod after 1 hour of erosion (b) and graphene product (c)



TEM image of a graphene-encapsulated Si nanoparticle, which exhibits high and stable performance as a lithium ion battery anode material.

Commercialisation

It is the combination of three key benefits (high production rate, low production cost, high quality graphene) that makes this invention exciting. The analogy with conventional aluminium pot lines indicates a relatively straightforward route to large-scale industrialisation.

This technology is protected by granted patents and applications. We are seeking industrial partners to collaborate with us both on production method and for specific applications. Please contact us to explore this opportunity.