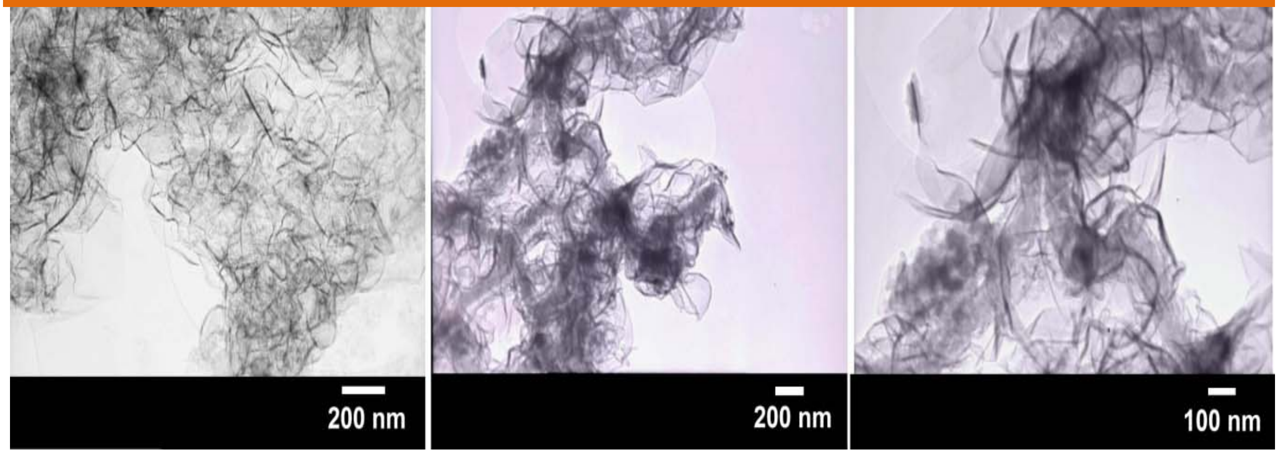
Mass production of graphene

Electrolytic process to produce high quality graphene



A new method for low cost, high yield and quality graphene has been developed. It is envisaged that the electrochemical method could be readily scaled up using a multi-electrode cell with planar electrodes to produce 10kg/day which is more than current methods of chemical vapour deposition and exfoliation.

Key benefits:

- Cost per tonne could be reduced by over two orders of magnitude
- Very high production rate compared to existing methods
- Very high quality graphene as shown by TEM images above and SEM 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.

Dr Ali Kamali, MRSC

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

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Background

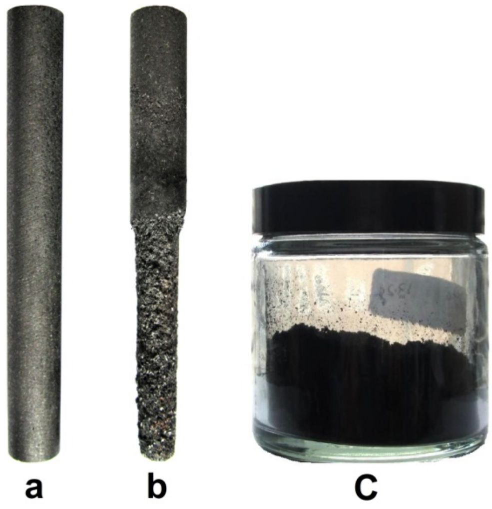
Methods of production of significant quantities of high quality graphene have not kept pace with its innumerable applications, so supply remains restricted to lab quantities. Common methods are: physical unpeeling of graphite; chemical vapour deposition; exfoliation in low melting ionic liquids; and, more recently, production in a domestic blender. Many of these methods do not create high quality graphene and the product simply consists of several layers of graphene more characteristic of thin graphite than of true graphene. Rates of production are low and there are significant barriers to upscaling.

Graphene has remarkable electrical, mechanical and thermal properties which offer the opportunity to replace existing materials. 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.

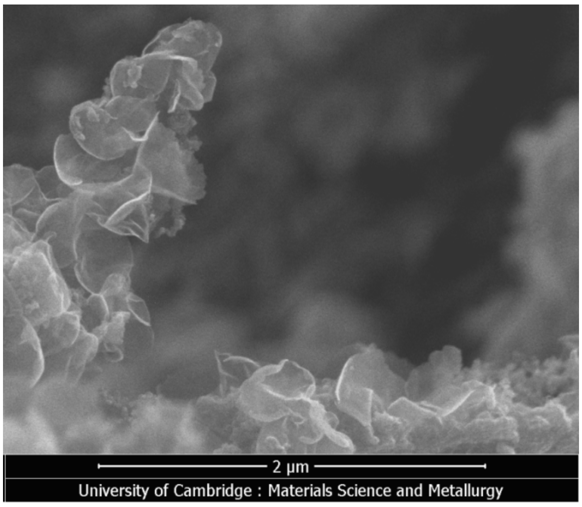
Technology

In this new electrochemical process, two graphite electrodes are immersed in a molten salt electrolyte under a controlled environment. On applying a potential between the electrodes, it is found that on the cathode, the graphite is simply eroded away and the salt becomes black in appearance. The electrodes are 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 confirmed that it was graphene. The appearance of the eroded rod and the product is shown in images a,b,c.

The graphene production rate is 5g/cm^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.



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



SEM image of graphene product

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.

Cambridge Enterprise is seeking partners to assist in the commercialisation of this technology.