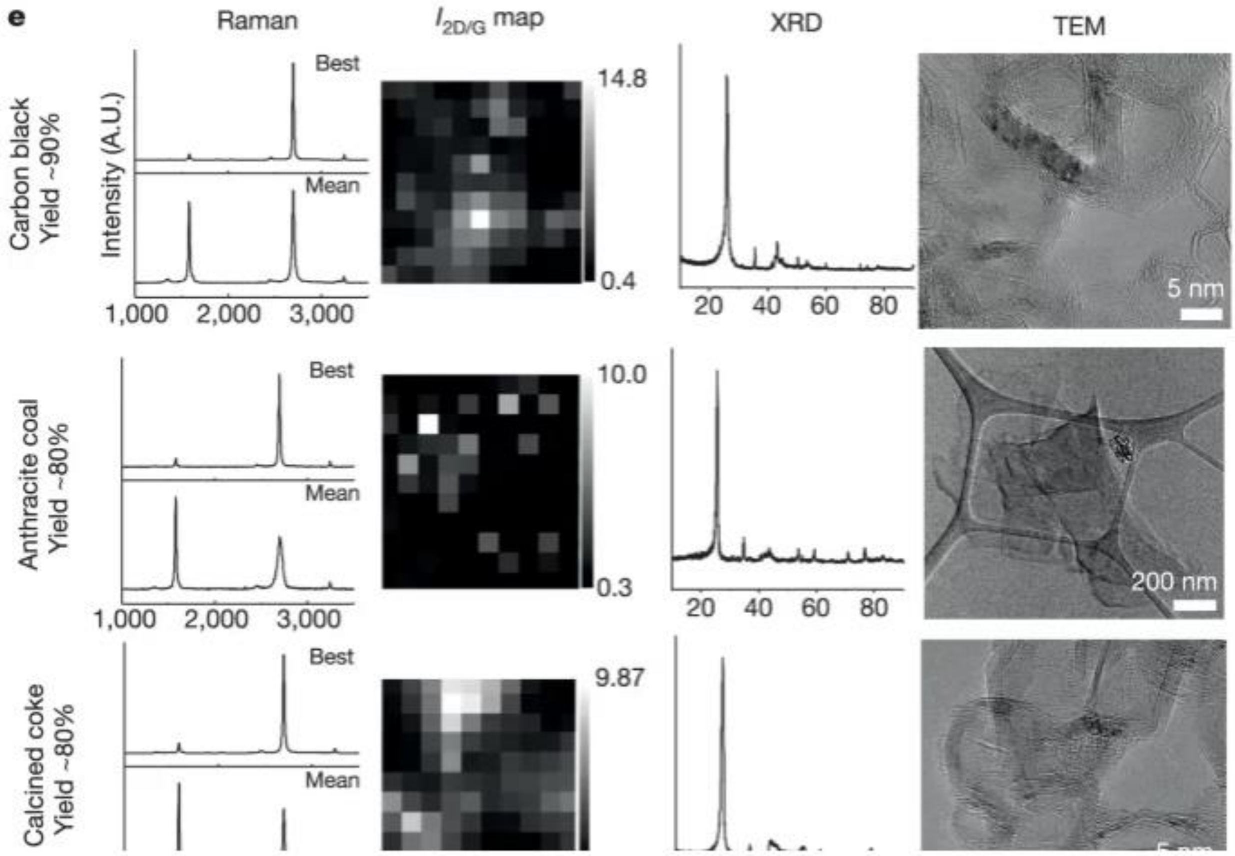
Organic waste turned into graphene: high quality at a low price

August 27, 2021 mikandersen



Reference

- Luong, DX; Bets, KV; Algozeeb, WA; Stanford, M.G.; Kittrell, C.; Chen, W.; Tour, J.M. (2020). Gram-scale bottom-up flash graphene synthesis. Nature, 577(7792), p. 647-651. https://doi.org/10.1038/s41586-020-1938-0

Facts

- The article by (Luong, DX; Bets, KV; Algozeeb, WA; Stanford, MG; Kittrell, C.; Chen, W.; Tour, JM 2020) is of special relevance, as it demonstrates that the large-scale production of graphene it is perfectly feasible, without requiring a high degree of sophistication or chemical procedures. In their abstract they reveal the object of investigation « *here we show that instantaneous Joule heating of cheap carbon sources, such as coal, petroleum coke, biochar, carbon black, discarded food, rubber tires and mixed plastic waste, can allow quantities of graphene on a gram scale in less than a second*«. The researchers managed to produce high-quality graphene in milliseconds with low energy expenditure, using quartz electrodes and tubes, as will be explained below.
- The product named Flash Graphene or FG " *does not use an oven, solvents or reactive gases. Yields depend on the carbon content of the source; when using a high-carbon source such as soot, anthracite coal, or calcined coke, yields can range from 80 to 90 percent with carbon purity greater than 99 percent* ." To confirm this, the researchers analyzed the graphene samples

with Raman spectroscopy, obtaining " *a low-intensity or absent D-band for FG, indicating that FG has one of the lowest defect concentrations reported so far for graphene* ."

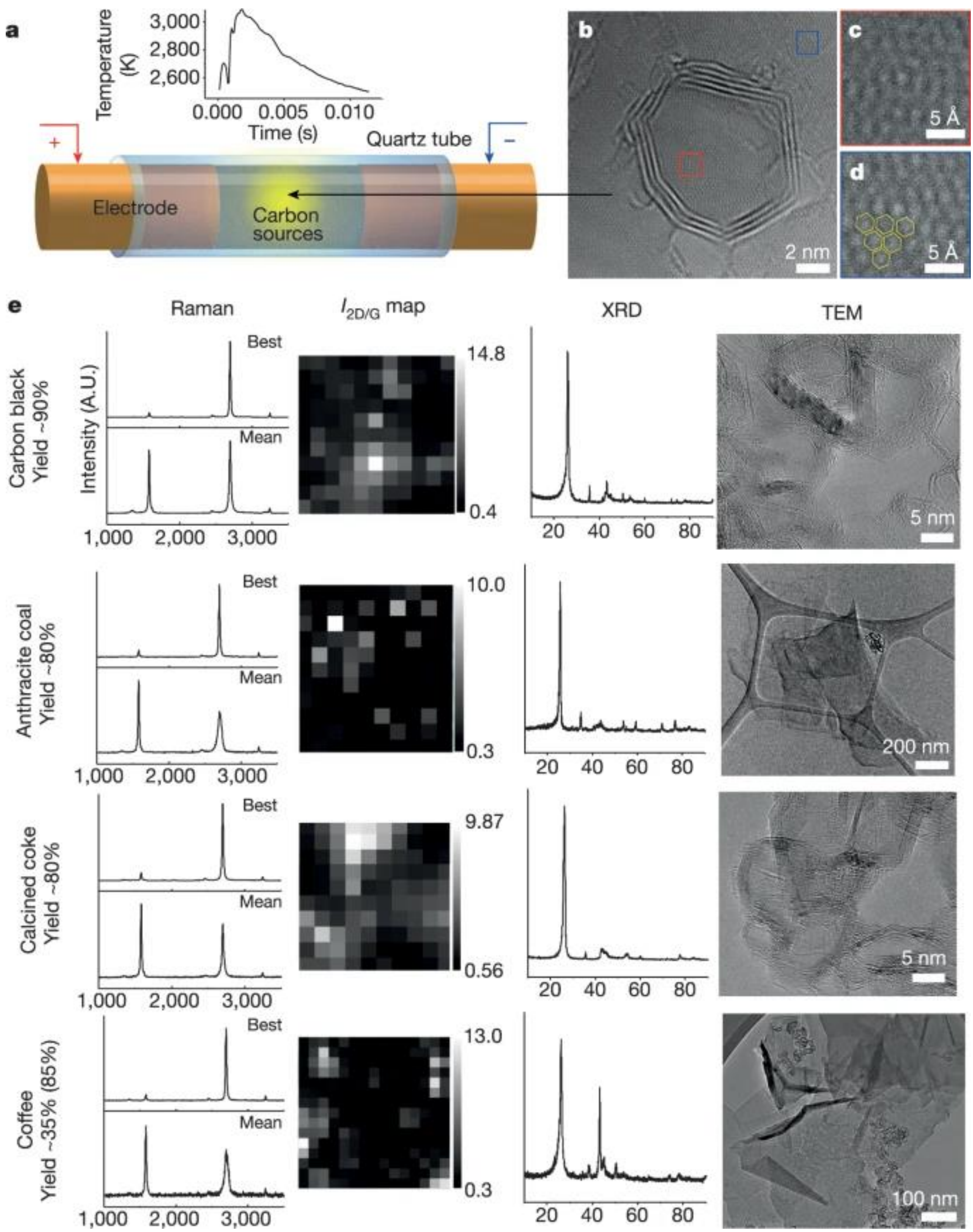


Fig.1. Synthesis of graphene from various carbon sources. (Luong, DX; Bets, KV; Algozeeb, WA; Stanford, MG; Kittrell, C.; Chen, W.; Tour, JM 2020)

- The FJH (Instantaneous Joule Heating, or Flash Joule Heating) process consists of the compressed encapsulation (in a thin quartz tube) of the material with the high carbon content that is to be converted into graphene, closed in a stack of electrodes, that generates a current that drastically increases the temperature (3000ºK = 2726ºC) in a temporary burst (flash) of a few milliseconds. This generates the crystallization of carbon in graphene. In the cost section, the authors state that " *Only 7.2 kilojoules per gram are required for the synthesis of FG, which could make FG suitable for use in bulk composites of plastics, metals, plywood, etc. concrete and other building materials*«. The 7.2 kilojoules are equivalent to 0.002kWh. If it is considered that the production of graphene is nocturnal, a night rate of €0.16/kWh (approximately in Spain) would be applied, which means that the production of 1 gram of high-quality graphene would have a net cost of 0. €00032 and therefore 1 metric ton €320.

- To demonstrate the validity of the method with organic waste, the case of coffee was taken, which " *has approximately 40% carbon, so the yield based on the initial carbon content is ~85%* ". This is because they are predominantly carbohydrates, so any organic waste with a high carbohydrate content is likely to be used in these processes. Despite this, the highest yield is found directly in the coal « *The yield of the FJH process is as high as 80% to 90% from sources with high carbon content, such as carbon black, calcine coke or anthracite coal* ." Other materials that can be used for this purpose are «*charcoal, biochar, humic acid, keratin (human hair), lignin, sucrose, starch, pine bark, olive oil soot, cabbage, coconut, pistachio shells, potato skins, rubber and mixed plastic tires, including polyethylene terephthalate (PET or PETE), high or low density polyethylene, polyvinyl chloride, polypropylene, and polyacrylonitrile* ."
- As for the quality of the 2D graphene « *it is optimized by adjusting the compression of the sample between the electrodes (which affects the conductivity of the sample), the voltage of the capacitor and the duration of the switching to control the temperature and the duration of the flash. The outgassing of hydrogen, nitrogen, and oxygen during the FJH process could contribute to the formation of large, thin graphene sheets… could prevent stacking of graphene layers, thus allowing further growth* ."

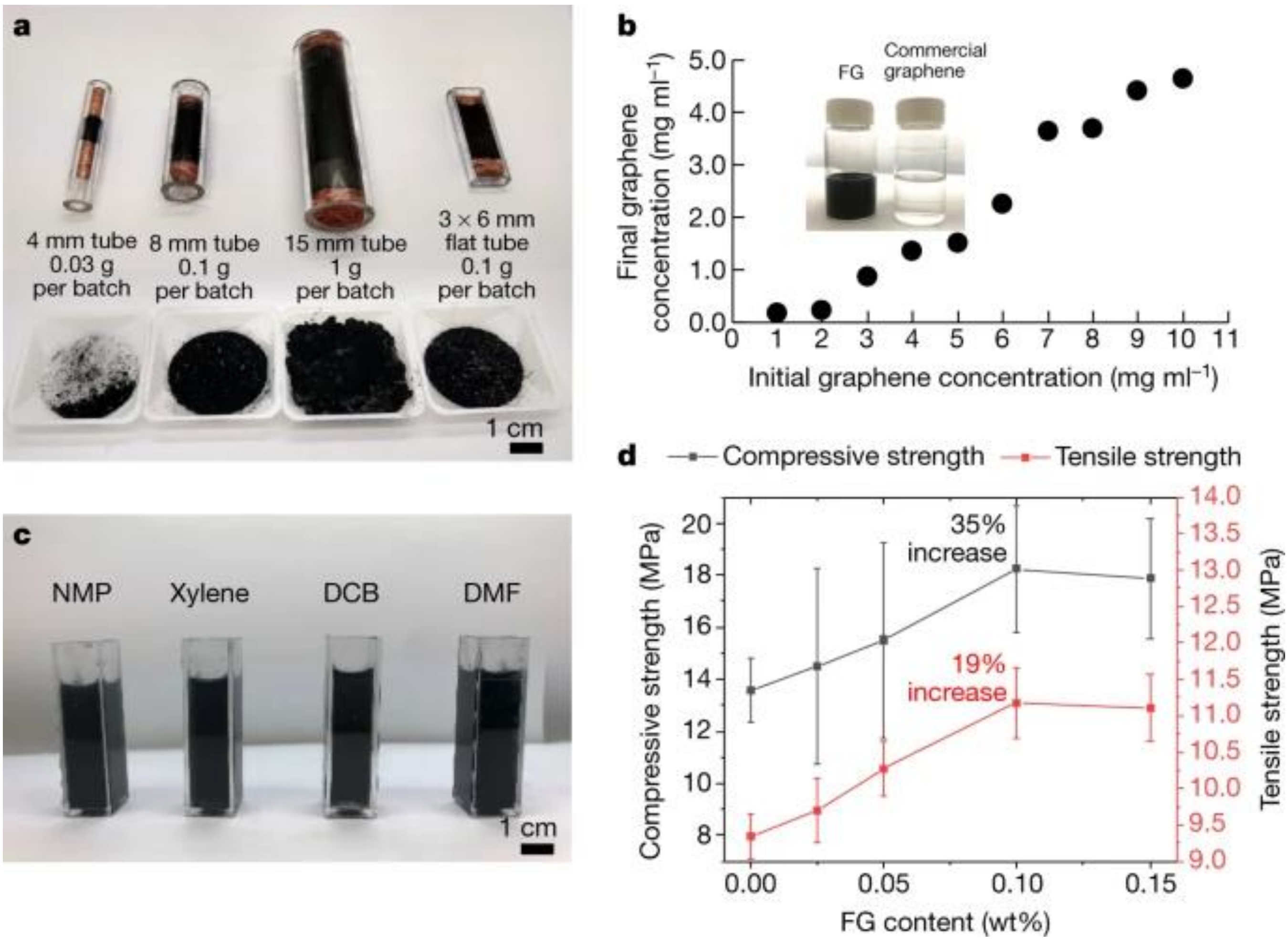


Fig.2. Graphene manufacturing tests in different types of tube, combinations of temperature, compression and their results. (Luong, DX; Bets, KV; Algozeeb, WA; Stanford, MG; Kittrell, C.; Chen, W.; Tour, JM 2020)

- Another interesting property revealed by the study is that the FG « *was dispersible in a water/surfactant solution to offer highly concentrated dispersions that reached 4gl -1* «. This was possible because the FJH method is effective in exfoliating graphene layers, which is ideal for the fabrication of aerogels, hydrogels, and physiological solutions.
- Among the applications of the discovery is the mixture of graphene in construction products such as cement or concrete. It was proven that when mixing the cement with graphene, its resistance improved by 25%, compared to other compounds with commercial graphene. " *These improvements are almost three times greater than those of other reported cement-graphene composites at the same loading…microscopy images show a homogeneous distribution of FGs in the cement matrix* ." These properties are extensible to other materials such as polymers, widely used in industry, such as polyethylene glycol.

Opinions

- The production costs of high-quality bulk graphene are very low, considering that it can be synthesized from organic waste. This article demonstrates that manufacturing results is easy and scalable. The large-scale production of graphene, necessary to meet the demand for vaccines, serums, fertilizers, phytosanitary products and products for fumigation and injection of atmospheric aerosols, could be satisfied without shortage problems. In the absence of coal and its derivatives, organic and plastic waste that is already separated for recycling in containers by citizens can be used.
- Any industry could easily convert to graphene production, given the simplicity of the materials required for its production with the FJH (Flash Joule Heating) method. On the other hand, it seems like a lucrative business if you take into account that the production of 1 ton of graphene could cost €320. To get an idea about the benefits that the industry obtains with the production of graphene, it is enough to take the information on the sale of graphene in bulk , which is situated at €0.85/gram in orders over 25 kg. This means that for each ton sold, net profits of more than €670,000 would be obtained if logistics costs, transport/distribution, acquisition of raw material for the manufacture of graphene, marketing, and taxes are considered.