GRAPHENE: A LIFE CYCLE THINKING APPROACH FOR A SUSTAINABLE PRODUCTION

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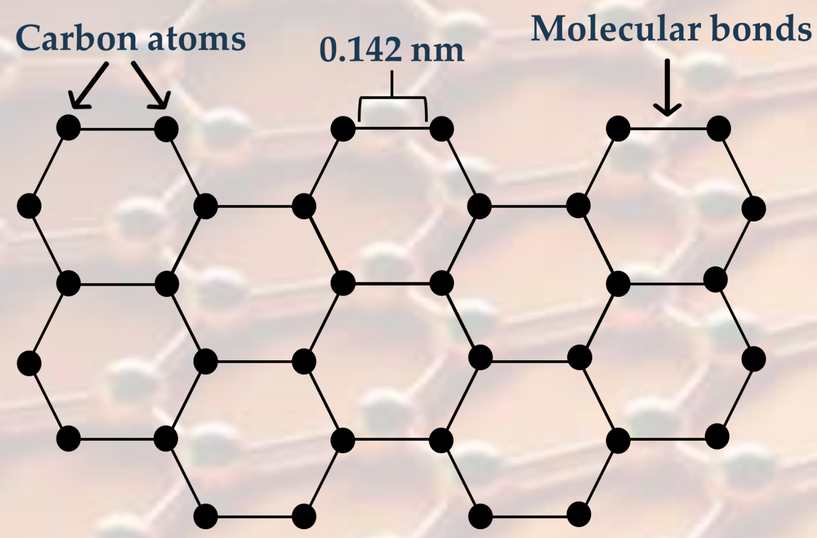
- Graphene is a material consisting exclusively of carbon atoms arranged in a honeycomb in hexagonal geometry, joined by a covalent bond, at a length of 0.142 nm.
- It is a "sheet" of matter with a thickness of one atom (0.345 nm) [1] which means the closest physical approximation to the mathematical concept of two-dimensionality.



The structure of Graphene gives him exceptional and unique properties [2]

Regulation

To facilitate Graphene industrialization and its large-scale commercialization, some standards have been issued to regulate its applications.

Therefore, in 2017, the critical evaluation criteria for the safe use of nanomaterials, including Graphene, were defined, both from the point of view of the degree of danger for living organisms, and from the point of view of environmental safety. The standardization of Graphene was carried out with the ISO 80004-13 standard (*Graphene and other two-dimensional materials*) [3] which had the objective of promoting and allowing the effective industrialization of these types of materials.

The need for a standardization of Graphene has also arisen because it is a material that is generally produced from precursors such as Graphite, Methane, Ethanol and Benzene, that are expensive, toxic and polluting materials.

The Life Cycle Thinking for a sustainable production and consumption

1) Life Cycle Thinking (LCT) is a philosophy of thinking that aims to make efficient use of the resources employed to produce a good, improve its socio-economic performance throughout its life cycle and reduce its climate-changing emissions [4].

2) Taking LCT as an approach means going beyond the traditional narrower focus on a company's production facility. In fact, the life cycle of a product can begin with the extraction of raw materials from natural resources in the ground to involving the generation of energy.

3) The environmental and socioeconomic impacts of all these inputs must be analysed, and the process for understanding what impacts occur and what materials cause them is called a Life Cycle Assessment (LCA).

4) This is a complex and deeply detailed process that analyses the impact of all input and output streams during the product life cycle. These streams are measured against several impact categories related to ecosystem health.

Case studies

	PRECURSOR	PRODUCT	TEMPERATURE	TIME REQUIRED	FEATURES	POSSIBLE APPLICATIONS
	Coffee grounds [A]	Pure Graphene (99%)	2800°C	100 ms	High quality Graphene	Cement composites, building materials
	Coconut husks [B]	Reduced graphene oxide (RGO)	300°C	15 minutes	-	Supercapacitor electrodes
	Exhausted palm oil [C]	Pure Graphene	350°C/850-1110°C	15 minutes	-	Supercapacitors
	Bread waste [D]	Pure Graphene	70°C-180°C	24 hours	High quality monolayer Graphene	Supercapacitors, water desalination
	Cookies and Chocolate [E]	Pure Graphene	1050°C	15 minutes	High quality Graphene, few cracks, 97% transparency	-
	Chicken fat [F]	Pure Graphene	200°c		High quality monolayer Graphene	Lithium Ion Batteries (LIB)

Conclusions

- Graphene presence in the industry is still minimal. Many challenges should be met before its potential is successfully implemented on a large scale. It is vital to create new sustainable methods to produce it, and LCT could help to find some ways to reduce the environmental impact resulting from its production.
- Through an LCT approach, it was possible to investigate what could be sustainable sources to produce Graphene. Moreover, particular attention should be paid to Graphene's production from biowaste.
- In fact, producing Graphene from organic waste biomass could, on the one hand, reduce the pollution, the cost, and the time deriving from the typical precursors (Methane, Graphite, Ethanol, Benzene), on the other hand it could help to reduce the quantity of waste and the resulting disposal problems.

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