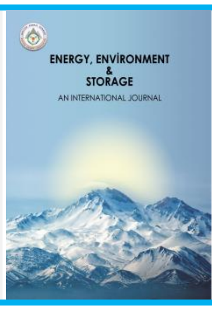
Research/Review Article *Energy, Environment and Storage* (2024) 04-01:13-17

Energy, Environment and Storage

Journal Homepage: www.enenstrg.com



The Future of 2D Materials Production: Graphene and Borophene on larger scale

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ABSTRACT. *The production of graphene and borophene, two distinct materials with remarkable properties, is investigated through the manipulation of charged ions in a plasma environment. Plasma, characterized by ionized atoms or molecules, offers a unique setting where diverse chemical reactions can take place. This research focuses on utilizing this environment to create longer-chain graphene and carbon nanotubes by manipulating charged carbon ions. When positively and negatively charged carbon ions coexist within the plasma, they have the potential to interact and form bonds. This interaction results in the growth of extended carbon structures, particularly graphene. By carefully controlling plasma conditions such as temperature, pressure, and composition, scientists can guide the formation of longer-chain graphene and carbon nanotubes from these charged carbon ions. Similarly, the production of borophene, a material composed of boron atoms, also takes place in a plasma state. By introducing positively and negatively charged boron ions into the plasma, these ions interact and potentially form bonds, leading to the growth of extended borophene structures. This innovative approach unlocks the potential for tailored materials with enhanced property*

Keywords: *Graphene ; Borophene ; Atomic-level manipulation ; Charge Particle ; Scalable production*

Article History: Received: 02.01.2024; Accepted: 29.01.2024

Doi*:* https://doi.org/10.52924/VFXC5133

1. INTRODUCTION

The Production of graphene and borophene, two extraordinary materials renowned for their exceptional properties, has become a focal point in scientific inquiry. Scientists, seeking innovative approaches to their production, have delved into the intriguing realm of plasma, where ionized atoms or molecules create a distinctive environment conducive to diverse chemical reactions. Graphene, a two-dimensional lattice of carbon atoms, boasts remarkable mechanical, electrical, and thermal properties, holding immense promise for various applications. This study concentrates on generating longer-chain graphene and carbon nanotubes by manipulating charged carbon ions within a plasma. The interplay between positively and negatively charged carbon ions facilitates bond formation, fostering the growth of extended carbon structures. In the case of borophene, a material composed of boron atoms, it has recently emerged as a captivating subject for scientific exploration. Researchers aim to exploit the plasma state of boron, where both positively and negatively charged boron ions coexist, to encourage potential bond formation between these ions. This interaction within the plasma environment creates an opportunity for the development of extended borophene structures. In employing plasma-based techniques for synthesizing these extraordinary materials. The use of plasma as a medium provides several advantages, including precise control over the growth process and the ability to produce unique structures that are challenging to achieve through conventional methods. To further explore this captivating field, researchers are investigating various aspects of plasma-based synthesis, such as optimizing plasma parameters, controlling ion energy, and experimenting with different precursor molecules. These endeavors aim to unlock the full potential of plasma-enabled material synthesis, paving the way for groundbreaking applications in electronics, energy storage, and beyond. Furthermore, the versatility of plasma-based synthesis extends beyond graphene and borophene. This research holds the promise of revolutionizing the landscape of advanced materials, driving innovation across numerous industries.

2. MATERIALS AND METHODS

For the successful implementation and elucidation of this concept, reliance on information from peer-reviewed journals and pertinent websites is essential to provide a comprehensive explanatory perspective. The scaling up of graphene and borophene production is achieved by altering the charged particles at the atomic level. Both materials are synthesized on a larger scale by manipulating their charged particles in a plasma environment, facilitating unique chemical reactions. Specifically, in the production process of graphene, carbon ions within the plasma are manipulated to generate graphene structures. The plasma state, where atoms exist as either positive or negative, is leveraged by inducing ionization to create positive or negative carbon and boron ions. A potential difference is also applied to establish distinct positive and negative regions. Carbon atoms, present in the plasma state, undergo manipulation, enabling the formation of extended carbon structures, such as graphene or carbon nanotubes. When positively and negatively charged carbon ions coexist in the plasma, they have the potential to form bonds, fostering the growth of larger carbon structures. This controlled manipulation of charged carbon ions in the plasma facilitates the creation of extended graphene and carbon nanotube chains. Similarly, the production of borophene involves a plasma environment where boron atoms, in the plasma state, coexist as positively and negatively charged ions, allowing for interaction and bond formation. By manipulating these charged boron ions, extended borophene structures can be synthesized. It is important to note that the explanation provided is currently within a theoretical framework, offering a novel approach for the scalable production of graphene and borophene.

3. Literature review

For both graphene and borophene, a similar process is used for their production. When carbon is used to produce graphene, first, carbon is heated to a very high temperature. During this process, copper or another substrate is used, and the carbon at high temperature adheres to the surface of the copper. This results in the formation of a layered structure for graphene. Similarly, for borophene, a similar method is employed. Boron is heated at high temperatures, and it bonds to a gold substrate. This bonding process on the gold substrate leads to the formation of borophene. It's important to note that while the production processes are similar due to use of substrate but are very different process to make it, graphene and borophene are two very different materials.

CVD is a widely used technique for synthesizing graphene, a two-dimensional carbon allotrope with remarkable electronic, thermal, and mechanical properties. The process involves introducing precursor gases onto a substrate, where carbon atoms are deposited to form a graphene layer.

Substrate Selection: The choice of substrate is crucial for the quality and properties of the resulting graphene. Common substrates include copper, nickel, and silicon carbide.

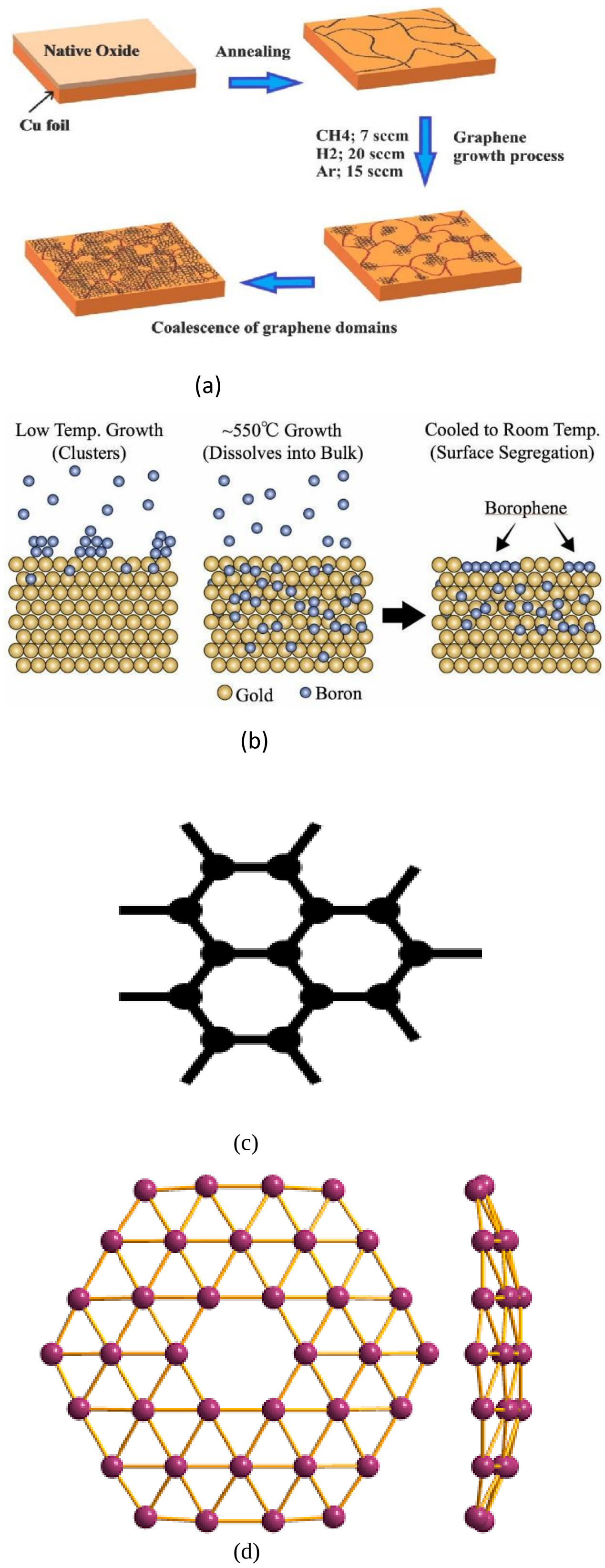


Figure 1. (a) Graphene production by using chemical vapor deposition (CVD) substrate of copper; (b) Borophene production by physical vapor deposition (PVD); (c) Graphene; (d) Borophene

Precursor Gases: Methane or ethylene is often used as carbon precursor gases in CVD processes. The choice of the precursor affects the growth rate and quality of graphene.

Temperature and Pressure: Optimizing temperature and pressure conditions is essential for controlling the growth kinetics and structure of graphene. Low-pressure CVD is commonly employed for large-scale production.

Catalysts: Catalysts such as copper foil or films are commonly used to facilitate the growth of graphene. The choice of catalyst influences the nucleation and growth of graphene layers [9].

Advances and Challenges: Recent research has focused on enhancing the scalability, reproducibility, and cost-effectiveness of CVD graphene production. Challenges include achieving high-quality, single-layer graphene over large areas and minimizing defects.

Borophene Production: Overview: Borophene is a 2D sheet of boron atoms with unique electronic and structural properties. Its production involves similar techniques as graphene but with specific considerations due to boron's different bonding characteristics.

Key Considerations: Substrate and Growth Surface: Substrates like silver and copper are often used for borophene growth. The choice of substrate influences the stability and structure of borophene.

Precursor Molecules: Boron precursors are typically used, and the selection of precursor molecules impacts the growth kinetics and properties of borophene.

Temperature and Atmosphere: The growth temperature and atmosphere play a crucial role in determining the stability and crystalline structure of borophene.

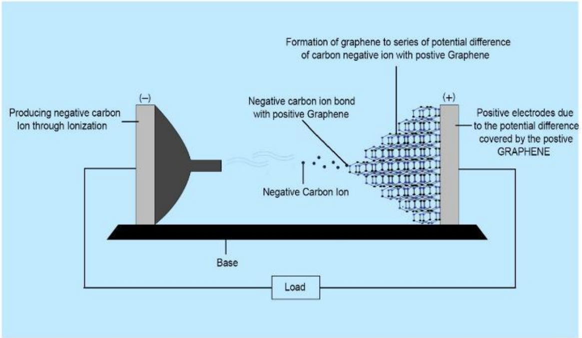
Post-Processing Techniques: Various post-processing techniques are employed to transfer borophene from the growth substrate to desired target substrates while maintaining its integrity.

Advances and Challenges:

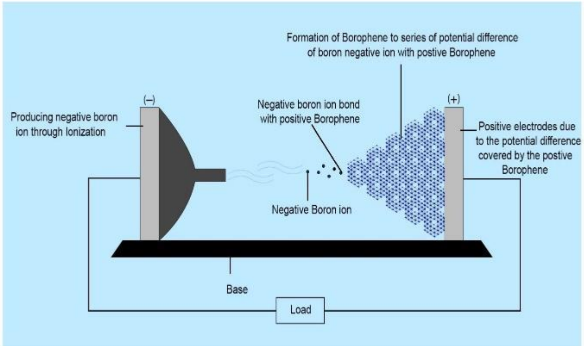
Borophene is a relatively new material, and research is ongoing to understand its properties and potential applications. Challenges include achieving large-scale production and developing techniques to control the synthesis of different borophene polymorphs.

For Graphene Production chemical vapor deposition (CVD):Layers of graphene will form on the copper's surface from the plentiful carbon atoms in the methane gas, a process called chemical vapor deposition (CVD) [1]whereas Brophene production by physical vapor deposition (PVD) :when heated in a furnace and place on a gold surface, boron atoms dissolve into a bath of gold and when the materials cool down, they resurface in the form borophene [2],Overall, in both cases, one thing is the same for all, and that is to make borophene and graphene by using substrate.

4. Research overview



(e)



(f)

Figure 2. (e) Graphene production by negative carbon ion bonding with positive carbon; (f) Borophene production by boron negative ion bonding with positive boron.

In this research work, there are two of the The production of graphene and borophene, two remarkable materials with exceptional properties. By same method by which atom is in plasma stage change their charge particle in which opposite charge attract by which form a long chain of it When in plasma stage (ionization) the atom is become negative due to ionization of it - a small of part of atom which already a graphene or borophene is become positive because of energy potential difference energy applied to it , Ionization (charge of charged particle) Adiabatic ionization : Ionization is the process by which ions are formed by gain or loss of an electron from an atom or molecule. If an atom or molecule gains an electron, it becomes negatively charged (an anion), and if it loses an electron, it becomes positively charged (a cation). Energy may be lost or gained in the formation of an ion [3] , During this process of making graphene and borophene, overall it will lead to continuous bonding where a negative carbon ion bonds with a positive carbon, resulting in the formation of graphene. Similarly, a negative boron ion will bond with a positive boron ion, leading to the creation of borophene

In graphene production, both negative carbon ions and positive carbon ions can be created electrically. Similarly, in borophene production, negative boron ions and positive boron ions can be made from borophene. In both cases, the generation of positive and negative ions is due to the potential difference in charged particles, Potential difference is the difference in the amount of energy that charge carriers have between two points in a circuit [4] & The difference in charge between higher potential and lower potential is called a voltage or potential difference [5]. But the difference is in the format; one stage will be in a plasma state, and another will be in a solid state due to potential differences. From that perspective, the chemicals are of the same element but have different charged particles that bond, Opposite charges attract both within the same atom and between atoms. This attraction forms chemical bonds between different elements [6].

An ion is an atom or group of atoms in which the number of electrons is not equal to the number of protons, giving it a net positive or negative electrical charge [7]. The presence of charged particles makes plasma electrically conductive, with the dynamics of individual particles and macroscopic plasma motion governed by collective electromagnetic fields and very sensitive to externally applied fields [8].

For graphene as per the figure 2 (e): Plasma, consisting of ionized atoms or molecules, serves as an intriguing medium for graphene production. In this process, carbon atoms are introduced into a plasma environment, where they become charged carbon ions. This plasma environment provides a highly reactive atmosphere, enabling various chemical reactions to occur. The presence of charged carbon ions within the plasma opens up the possibility of manipulating and controlling their behavior to induce specific reactions, one of the key aspects of plasma-based graphene production is the coexistence of both positively and negatively charged carbon ions within the plasma. These charged carbon ions have the potential to interact with each other, facilitating bond formation and the subsequent growth of extended carbon structures, including graphene and carbon nanotubes. By manipulating the trajectories and energies of these charged ions, researchers can guide their interactions and promote the formation of desired carbon structures. The ability to create longer-chain graphene structures and carbon nanotubes through plasma manipulation holds significant promise. By carefully controlling the plasma parameters, such as gas composition, pressure, and energy input, this level of control provides opportunities for tailoring the properties of graphene, such as its electrical conductivity, mechanical strength, and thermal stability, to suit specific applications. The advantages of plasma-based graphene production lie in the unique environment it offers. Plasma provides a versatile platform for generating a wide range of chemical reactions, allowing for the synthesis of graphene and related carbon structures. Moreover, the ability to manipulate charged carbon ions within the plasma enables precise control over the growth process, leading to the formation of extended carbon structures with desired characteristics. In summary, research in plasma Ionization -based graphene production focuses on utilizing the reactive environment of plasma to manipulate charged carbon ions and facilitate the growth of extended carbon structures. By controlling the interactions and potential bond formations between positively and negatively charged carbon ions, researchers aim to create longer-chain graphene structures

For Borophene as per the figure 2 (f) : similarly , the Borophene will be produced in longer format .In the plasma(ionization) -based approach for borophene production, boron atoms are introduced into a plasma environment, where they enter a charged state, becoming positively and negatively charged boron ions. The plasma state offers a conducive environment for chemical reactions, facilitating the interaction of these charged boron ions and potential bond formation-which will make a borophene where the ions are often near the ambient temperature while electrons reach thousands of kelvin [10].

The advantages of plasma (ionization)-based borophene production lie in the unique environment that plasma provides. Plasma serves as a reactive medium where boron ions can interact and form bonds, leading to the growth of extended borophene structures. The ability to manipulate charged boron ions within the plasma offers researchers a means to precisely control the growth process, resulting in the production of borophene with desired properties

Overall the research work is to make a contioous bond of same element by change their charge particle by particle via electrical mean, which mean that there is no need of substrate to produce a borophene and graphene, since substrate reduces the properties of graphene and borophene, such as the substrate can affect the band gap of graphene, which can make it less useful for certain applications. Also, to remove the substrate, various chemical processes are needed, and this will lead to a more expensive production of graphene and borophene

5. Results

In the manufacturing of graphene and borophene, we've established that a substrate is dispensable. Instead, we employ carbon gas, which assumes a negative charge in the plasma stage, to establish bonds with graphene in a sodiated state. Likewise, boron gas, also attaining a negative charge in the plasma stage, can form bonds with sodiated borophene. The manipulation of charges is achieved by controlling the potential difference during the ionization of plasma gas atoms, converting them into negatively charged entities conducive to bonding with sodiated graphene and borophene.

6. Discussion

Plasma Generation and Control: One of the primary challenges in the production of graphene and borophene using plasma is the generation and control of the plasma itself. Creating and maintaining a stable plasma environment with the desired properties requires careful control of parameters such as gas composition, pressure, temperature, and energy input. Achieving optimal plasma conditions for the growth of graphene and borophene structures can be a complex task that requires advanced plasma generation techniques and precise control mechanisms.

Challenges: The plasma stage occurs during ionization, transforming the atom into a highly charged particle stage. Ionization generation requires a magnetic field for control and the ability to bond graphene or borophene. Higher temperatures are also necessary for proper control, including managing excess heat.

Benefits: No substrate is required for chemical bonding because bonding is achieved through charge manipulation. Various chemical processes are not needed, making graphene and borophene production simple and easy.

7. Conclusion

The application of a plasma environment in the synthesis of graphene and borophene creates a versatile platform that allows precise control over the growth and characteristics of these materials. By manipulating charged carbon or boron ions within the plasma, interactions and bond formations are facilitated, leading to the creation of extended structures like graphene or borophene. This pioneering approach shows great potential for achieving scalable production of high-quality graphene, carbon nanotubes, or customized extended borophene structures. These advancements carry substantial implications for a wide range of applications, including electronics and energy storage, ushering in groundbreaking developments in materials science and technology.

Author contributions

Ryan Nadar is a researcher currently focused on multiple sectors, including Energy, Propulsion, Materials, and Software-Based Platforms. He is pursuing a degree in Aerospace Engineering at Ajeenkya DY Patil University in Pune, India. Additionally, Mr. Vijaya Kumar Varadarajan serves as the Dean of the International Division at Ajeenkya DY Patil University in Pune, India. He has been instrumental in assisting Ryan Nadar by providing various links to conferences, events, and other topics relevant to his research work. Importantly, Vijaya Kumar Varadarajan has been a research advisory for Ryan Nadar, guiding him through conference formats, helping with the publication of his research work, and facilitating collaboration opportunities at both the international and national levels. This paper was primarily authored by Ryan Nadar, and Ryan Nadar is the owner of this work.

Funding

The research is funded by Emergent Ventures, a division of EV India, with a grant amount of $4,500 awarded to Ryan Nadar. The funding has been allocated for research in the Energy Sector, as well as other sectors such as Propulsion, Materials, and Software-Based Platforms. Ryan aims to leverage these resources to enhance the intensity and global outreach of his research work.

Acknowledgments

Ryan Nadar is immensely grateful to two individuals and organizations, namely, Vijaya Kumar Varadarajan and Emergent Ventures Mercatus center. Vijaya Kumar Varadarajan provided valuable conference links, enabling Ryan to effectively communicate his research findings. On the other hand, Emergent Ventures has been instrumental in sharing Ryan's research work with the global academic community and funding for Graphical representation work.

Conflict of interest

The main reason why Ryan Nadar has shown interest in graphene and borophene is that in the future, it will be produced without needing a substrate, reducing various chemical processes as well as production costs. This will be useful in various platforms such as the Electronics Industry, Energy Storage, Aerospace and Aviation, Medical Devices, Water Purification, Flexible Electronics, Automotive Industry, Coatings and Composites, Solar Panels, Construction, and many more

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