Introducing Hyper-Cold Fusion

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Abstract

We present hyper-cold fusion, an innovative nuclear fusion approach that exploits the unique electronic properties of 2D materials. Unlike conventional cold fusion occurring in hydrogen-occluded metals, our method operates on graphene surfaces under elevated gas pressures while maintaining low-energy states. The mechanism relies on graphene's ability to emit terahertz radiation [1], creating an excited electron-rich environment where plasmons with Fermi velocities of 6000 km/s interact with hydrogen nuclei. High-pressure hydrogen gas on graphene surfaces shows enhanced mobility, allowing hydrogen atoms to move freely and increasing the probability of fusion interactions. The proposed electron capture mechanism [2] involves ground-state hydrogen atoms interacting with graphene plasmons, potentially enabling fusion reactions on the material surface. This approach addresses fundamental limitations of traditional cold fusion by providing a more controlled and potentially scalable fusion pathway through strategic utilization of 2D material properties.

1. Introduction

In 1989, two electrochemists, Fleischmann and Pons, reported their electrolysis experiment with palladium and deuterium that generated nuclear energy in the form of heat [3]. Since then, research on cold fusion has been conducted by numerous experts worldwide. Although cold fusion has not gained widespread mainstream attention in the scientific community, there have been significant developments in recent years indicating the potential of cold fusion. In 2022, the US Department of Energy began funding cold fusion projects as part of its Exploratory Topics program. Several academic institutions that had received this funding were conducting cold fusion research [4].

Nano Fusion Design was established with a clear mission: to harness the potential of graphene materials for nuclear fusion. While reviewing past experiments, we discovered that excess heat has not been confirmed with graphite powder and hydrogen under pressures below 1 MPa [5]. On the other hand, excess heat has been confirmed with hydrogenation of carbon under pressure at 5.4 MPa [6]. The pressure threshold of 5.4 MPa appears critical for achieving sufficient hydrogen density on carbon surfaces to enable electron capture mechanisms. At lower pressures, the hydrogen coverage is insufficient to create the electron-rich environment necessary for the proposed fusion pathway. Additionally, research indicates that excess heat has been achieved using terahertz pulses [7]. Building on this, we are planning further experiments with terahertz-emitting graphene and borophane —a material with a high hydrogen density [8]. These materials may hold the key to unlocking the potential of cold fusion.

2. Design of Hyper-Cold Fusion

Hyper-cold fusion represents a significant evolution from traditional cold fusion. While traditional cold fusion relies on 3D metals to absorb hydrogen in near-vacuum conditions, hyper-cold fusion operates on 2D material surfaces under high-pressure gas environments, giving rise to the term 'hyper.' This innovative approach leverages the unique properties of 2D materials like graphene and borophane to achieve fusion reactions more efficiently. Fig. 1 illustrates how 2D materials are revolutionizing the cold fusion landscape, contrasting traditional methods with this ground-breaking new approach.

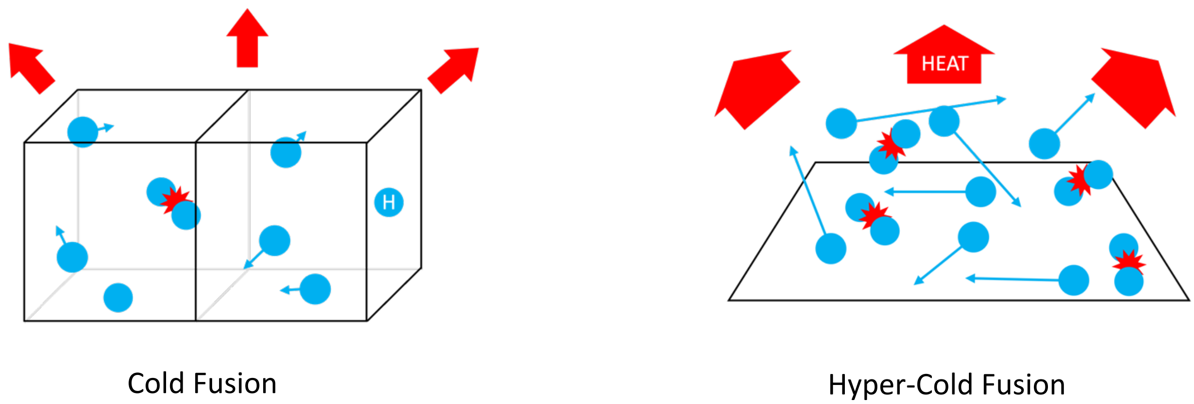

Figure 1. Conceptual Comparison of Energy Density and Efficiency in Cold Fusion vs. Hyper-Cold Fusion

In this experiment, we also introduce borophane (a borohydride sheet), a 2D material composed of boron and hydrogen atoms with a composition ratio of H:B = 1:1 [8]. When heated above 200 °C, borophane undergoes temperature-programmed desorption, releasing hydrogen atoms from its surface. This process enables proton-boron fusion reactions through electron capture mediated by graphene. By irradiating the graphene-borophane system with electromagnetic waves, we aim to generate excess heat or electrical power in future developments under rigorously controlled conditions. Compared to loading high-pressure hydrogen gas as fuel, this approach makes it easier to initiate experiments and provides better fuel mobility and shelf life.

We hypothesize a three-step reaction pathway: (1) Borophane releases hydrogen at 200°C. (2) These hydrogen atoms collide with the high-speed electrons in graphene, producing neutrons. (3) These neutrons then fuse with boron to form helium, releasing 8.68 MeV of energy per reaction. 1 gram of borophane could yield thermal energy equivalent to burning 600 kg of oil—enough to power a small home for months without producing problematic nuclear wastes or radiations.

1. Hydrogen desorbs from borophane heated above 200°C.

2. Hydrogen collides with fast electrons on graphene and converts to neutrons.

   $$\mathrm{p} + \mathrm{e}^- \rightarrow \mathrm{n} + \nu_e$$

3. Neutrons fuse with boron and convert to helium, releasing nuclear energy.

   $$\mathrm{n} + \mathrm{B} \rightarrow 3\mathrm{He} + \mathrm{e} + \bar{\nu}_e \quad (\mathrm{Q} = 8.68\ \mathrm{MeV})$$

3. Experimental Setup

A schematic of the experimental setup is shown in Fig. 2. Our experimental setup involves encapsulating a mixed powder of graphene and borophane in a 100 mL pressure-resistant chamber.

The chamber is evacuated to a vacuum level ranging from 1Pa to a maximum of 150 MPa. The outer wall is heated to several hundred °C using an electric heating wire, causing borophane to release hydrogen gas. Under these conditions, hydrogen exists as a supercritical fluid, a state where the distinction between liquid and gas phases disappears. We anticipate that this hydrogen will interact with graphene and boron, initiating fusion reactions through electron capture. Detection of excess heat or fusion by-products (e.g., alpha particles) will be used to validate the proposed mechanism.

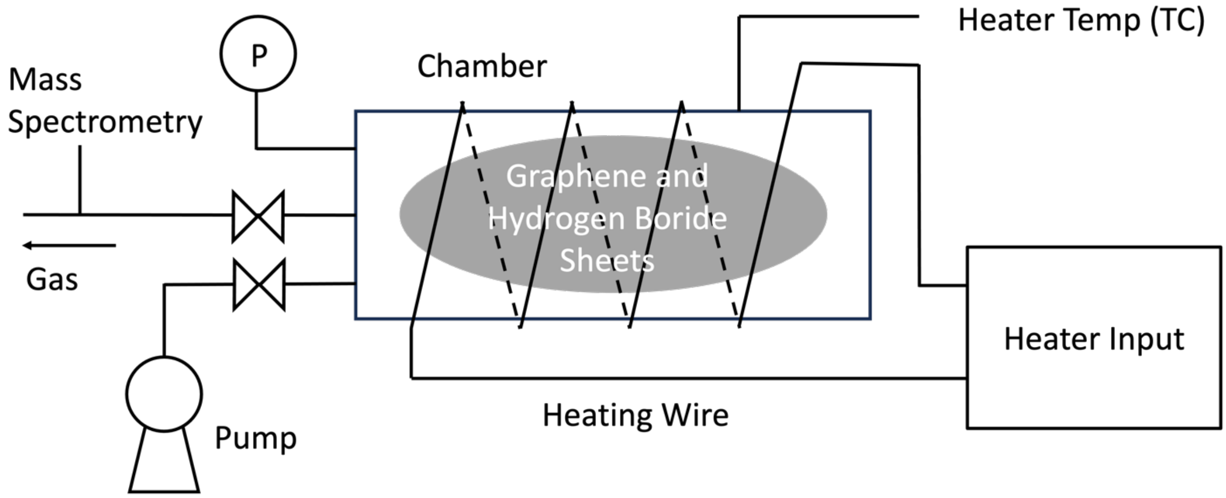

Figure 2. Schematic of the Experimental Setup

Our first prototype features a container made of Hastelloy X, a high-performance alloy. Designed to withstand pressures up to 150 MPa and temperatures up to 1,000°C, it operates at 135 MPa and 750°C. The 100 mL chamber accommodates 50 mL of fuel—graphene and borophane—using core sockets for precise loading control, as shown in Fig. 3. These specifications strike a balance between safety and performance, providing a solid foundation for future iterations.

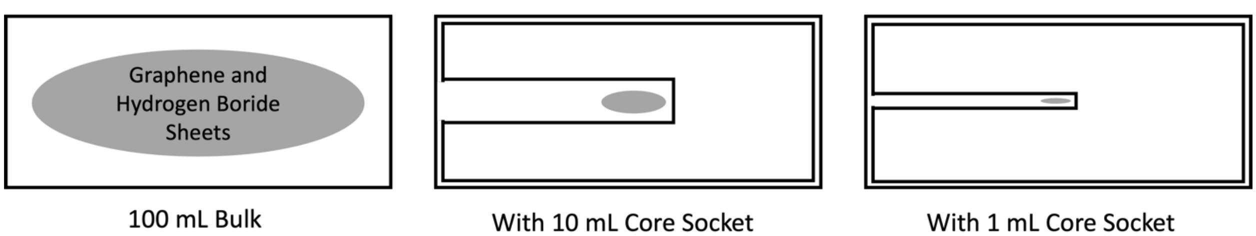

Figure 3. The Chamber with Core Sockets

4. Experimental Procedures

In the experiment, high-pressure hydrogen gas is generated at temperatures of several hundred °C from solid fuel. If it leaks outside the container, there is a risk of hydrogen explosion. We will conduct the experiment with appropriate equipment and safety measures to anticipate such risks, in accordance with the relevant laws. The possibility of excess heat generation due to nuclear reactions should also be considered. The quantity of this heat has not been theoretically determined yet.

High-pressure gas and residual powder generated during the experiment may contain trace amounts of tritium and the radioactive carbon isotope ^{14}C. In the initial stages of the experiment, the residual amount is expected to be below regulatory limits, but the experiment should be conducted under a management system that includes mass spectrometry analysis of waste.

We will incorporate essential safeguards for high pressure temperature hydrogen systems, primarily comprising explosion-proof enclosures, an inert gas system, a cooling system, and leak detection & monitoring as well as various nuclear detection sensors as shown in Fig. 4.

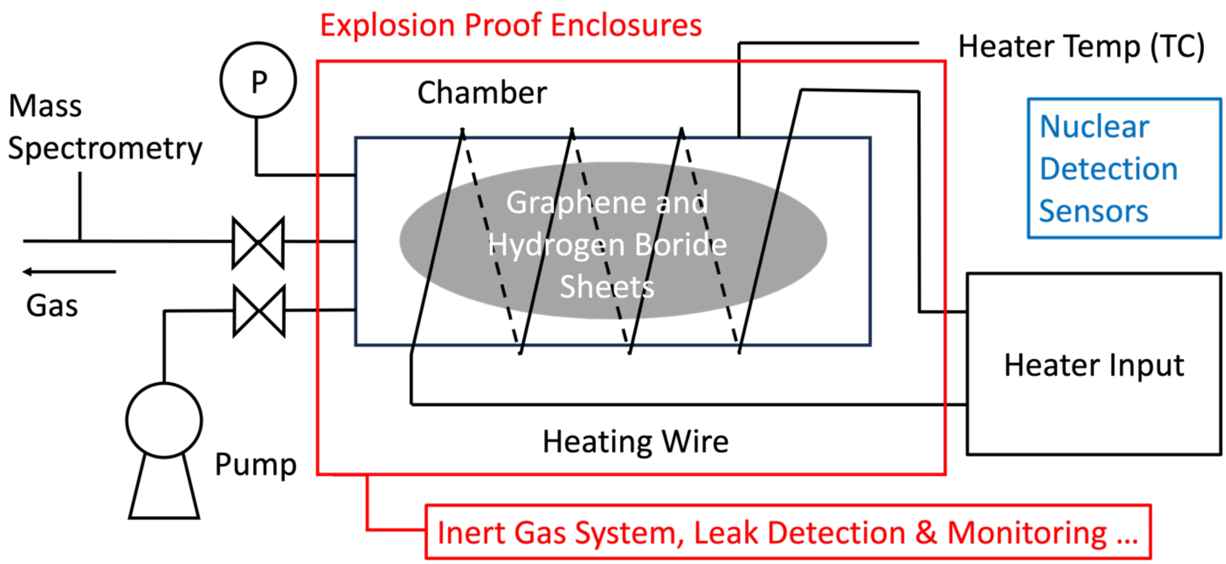

Figure 4. The Experimental Setup

The fundamental experimental procedure follows 5 steps at initial stage; however, we will add further steps for safety precautions as described above.

1. Encapsulate 1 gram of powdered graphene and 0.02 gram of borophane in a pressure-resistant container of 100 mL without core sockets, with a vacuum level of 1 Pa to 150 MPa, and perform vacuum evacuation.

    - During the initial stages of the experiment, the container performance can be low-spec, gradually increasing in stages.
    - We estimate 0.02 gram of borophane produces about 5 MPa hydrogen gas in 100 mL chamber.)

2. Heat the container's outer wall to 300 °C for three hours with an electric heating wire wrapped around.

    - 300 °C and three hours are considered to be sufficient condition that hydrogen desorbs from borophane and reaches equilibrium.)

3. Confirm excess heat on the outer wall.

- Monitor temperature using calibrated thermocouples with ±0.1°C precision, recording data every 10 seconds to detect excess heat above baseline electrical input.
- We must take into account the Joule-Thomson effect which lowers hydrogen temperature as its pressure gets high.
- Three Control Experiments are considered: Control 1: Graphene only (1 gram) under identical conditions, Control 2: Borophane only (0.02 gram) under identical conditions, Control 3: Empty container baseline measurement.

4. After stopping heating, cool to room temperature.

5. Collect and conduct mass spectrometry analysis on the gas inside the container.

   - Mass spectrometry analysis will specifically detect: (1) Helium isotopes (^{3}He, ^{4}He) as fusion products, (2) Tritium (^{3}H) as potential byproduct, (3) Carbon isotopes (^{12}C, ^{13}C, ^{14}C) for contamination assessment.

5. Future Work & Optimization

Once we have successfully demonstrated proof-of-concept, our next steps will focus on optimizing the fusion reaction. This includes determining the optimal mixing ratio of graphene and borophane, as well as refining the powder shape and furnace temperature through experiments and computer simulations. We also plan to develop fuel rods that can withstand high loads and long-term operation. Finally, we plan to introduce fuel rods that can be operated as heat sources into reactors optimized for their output, and develop complete packages such as boilers or small module reactors aimed at power generation.

Concluding Remarks

Despite longstanding skepticism about cold fusion viability, recent experimental research has shown significant progress, leading many experts and enthusiasts to question whether this technology can ultimately sustain our modern lifestyle and provide hope for future generations. Hyper-cold fusion, leveraging the unique properties of 2D materials under high pressure, represents a promising pathway to overcome historical limitations of cold fusion and potentially unlock a new clean energy source.

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