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The Design of a Low-Energy Nuclear Battery

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This study presents a new battery design that harnesses the potential of low-energy nuclear reactions (LENR) as a clean and efficient energy source. Rather than focusing on maximizing the heat generation capabilities of LENRs, we aim to integrate them into a low-energy nuclear battery (LENB) that offers higher energy density, longer lifetimes, and lower costs than existing battery technologies. To achieve this, we propose using hydrogen gas as the fuel and incorporating graphene and a THz source into the design. Specifically, we plan to use p-n junction plates composed of silicon carbide, gallium nitride, aluminum nitride or diamond and place them under a graphene sheet to generate an electrical current through an electron-beam-induced effect. The LENB materials, namely hydrogen and carbon, are expected to have weak interactions assuming that protons are neutralized by electron capture prior to undergoing fusion [1][2]. Therefore, we expect to observe beta decay processes that emit electrons through proton-proton chain reactions in plasmons excited by THz irradiation on the surface of graphene. At low energies, neutralized protons are expected to undergo neutron-neutron fusion more frequently, considering the following reaction: $n + n \rightarrow d + e^- + \bar{\nu}_e$. The maximum energy of the outgoing electron is estimated to be 3.52 MeV [3]. In addition, proton captures during the proton-proton chain reaction are more likely to result in neutron captures. At this stage, a schematic of the experimental setup is shown and the device is still in the planning stages, but the basic design is similar to that of a common LENR device [4], except that it produces electricity.

Keywords: LENR, LENB, H_2 gas, graphene, THz, plasmon, electron capture, neutron capture, SiC, GaN, AlN, Diamond

1. Introduction

Since two electrochemists, Fleischmann and Pons, reported on their electrolysis experiment with palladium and deuterium generating nuclear energy in the form of heat in 1989 [5], research on low-energy nuclear reactions (LENR) has been conducted by numerous experts worldwide. Although LENRs have not gained widespread attention in the scientific community, there have been significant developments in recent years that indicate their potential to meet our energy demand. In 2022, the US Department of Energy began funding LENR projects as part of its Exploratory Topics program. Several academic institutions that have been recipients of the available funding are now conducting LENR research [6].

Our paper challenges the current understanding of the developmental stages of LENR, particularly in regard to quantitative reproducibility and theoretical foundations. As such, we focus on developing a hypothesis-driven experiment that can be used to guide the design of a low-energy nuclear battery (LENB). Our ultimate goal is to determine the most efficient method for directly extracting electrical energy from LENRs.

2. Design of the LENB

LENBs represent a new type of battery technology that uses nuclear fusion reactions to generate power. Unlike traditional nuclear reactors, which generate heat, the LENB extracts electricity directly from the fusion reaction using hydrogen gas as a fuel.

The design of LENB is illustrated in Fig. 1. To enhance the LENB performance, we use graphene sheets and p-n junctions composed of silicon carbide, gallium nitride, aluminum nitride or diamond, as well as a THz source operating at approximately 1–10 THz. By miniaturizing and simplifying these essential components for operation on the nanoscale, we can improve device efficiency while ensuring greater safety.

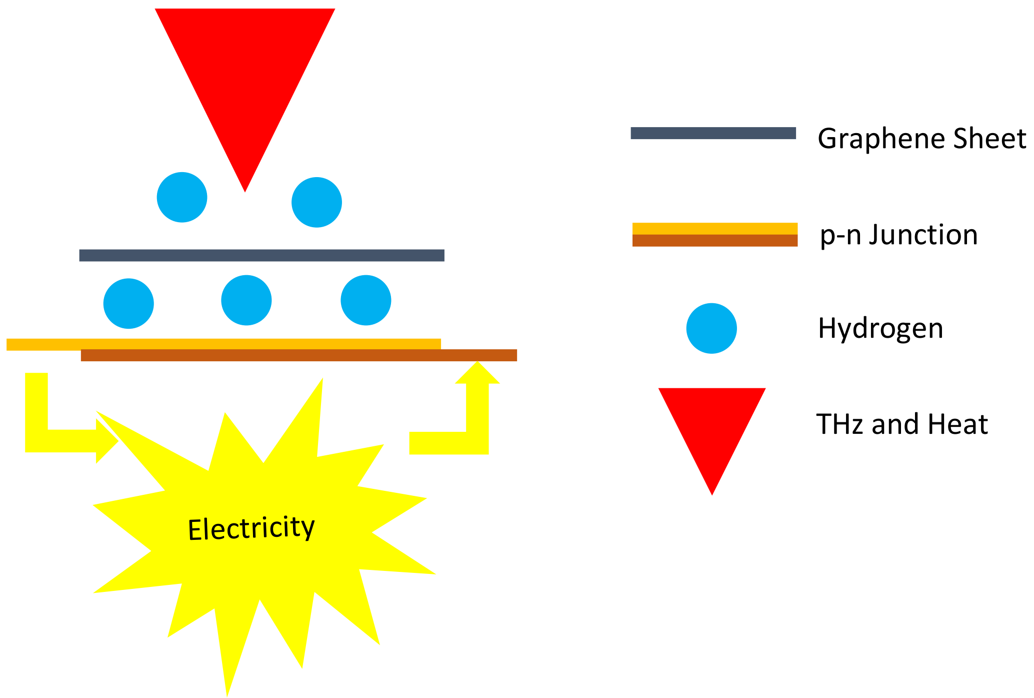

Fig 1. Illustration of the LENB design

3. Experimental Setup and Plan

A schematic of the experimental setup is shown in Fig. 2. Our initial objective in the experiments is to determine whether the reaction generates sufficient electrical power. Before beginning our experiment, we do not perform any pretreatment of the LENB core, which comprises the graphene and the p-n junction. Instead, we expose it to vacuum conditions while simultaneously introducing the gas. The graphene surface is the reaction site of the LENB, which allows for the evaluation of the reaction performance primarily through electrical output rather than thermal or byproduct formation.

We then manipulate three critical factors: the core temperature, the THz frequency, and the gas pressure. The core temperature can be set lower than typical values for LENRs, which are estimated to be around 100–300 °C. This is because the THz radiation peak for different materials commonly occurs within this range. The p-n junction ideally breaks down above certain temperatures to function as a circuit breaker within the primary energy loop, safeguarding the entire device, particularly during the experimental stage. It is necessary to observe a small amount of current in response to plasma excitation due to THz radiation in the absence of any gases; this is considered the reference state. In addition, before conducting any experiments involving gases, it is crucial to meticulously set up the experimental apparatus to optimize the reaction site. This may entail adjusting several components of the device, such as the THz frequency or the gap between the graphene and p-n junction, can impact the plasmon's Fermi velocity, charge density, and resistance of the p-n junction against electron through beta decay. In addition to establishing the optimal conditions, including the core temperature and pressure, for the desired LENR, as described in Section 6.

After preparation, gases can be loaded into the chamber. We believe there is a proportional relationship between gas pressure and electric generation, considering the simple reaction rate. However, as the reaction site has not been studied in sufficient detail, we must exercise caution when increasing the gas pressure and conduct the experiments gradually.

To gain a deeper understanding of LENRs, we plan to conduct experiments using microscale materials. By exciting plasmons on graphene sheets using THz radiation, we can observe a static pattern on the nanoscale. At this scale, these particles exhibit a behavior that is more similar to classical particles, making it easier to study their properties.

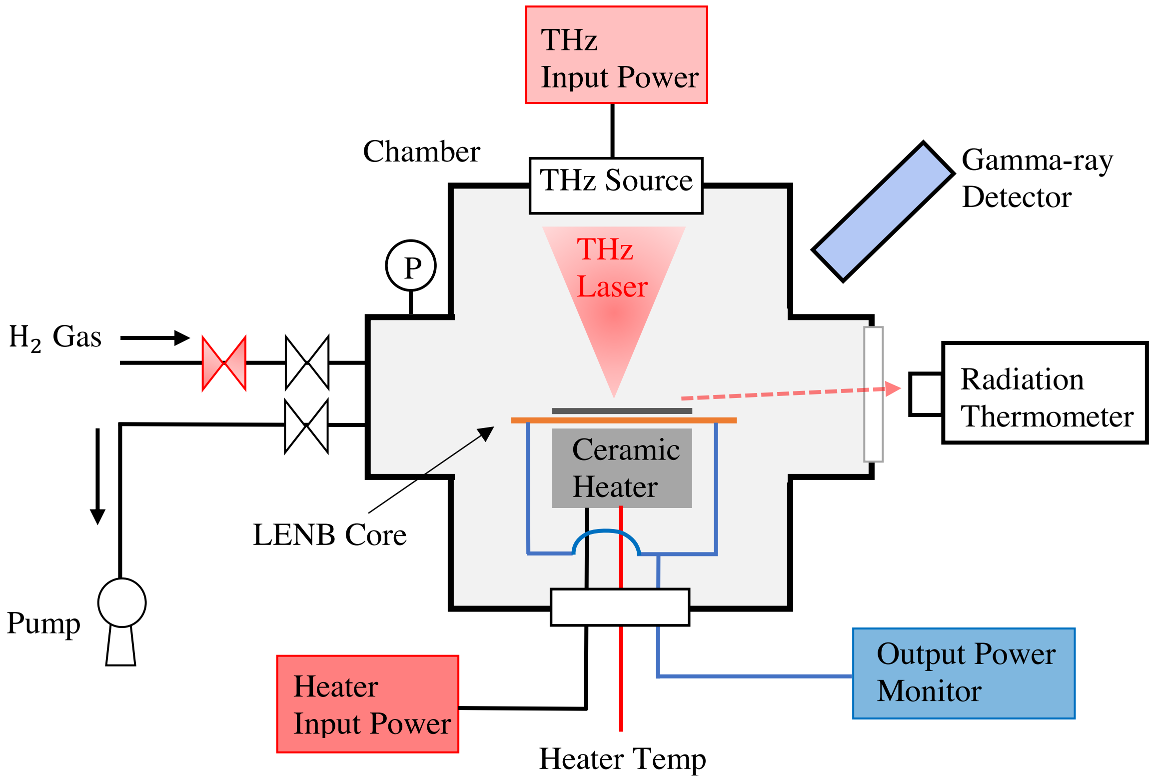

Fig. 2. Schematic of the experimental setup

4. Theoretical Assumptions

Here, we discuss the theoretical assumptions related to LENRs. In the first stage, THz irradiation creates plasmons on the surface of the graphene. As a result, hydrogen atoms are condensed within these plasmons. In the plasmons, protons capture electrons and turn into neutrons. Then, these ultra-low momentum neutrons fuse with protons or with each other. As a result of this process, we assume that one of the neutrons emits an electron through beta decay. The emission of electrons generates electricity on the p-n junction via an electron-beam-induced effect.

In addition, a low-energy proton-proton (LEPP) chain reaction may occur. The LEPP chain reaction is a significant and desirable reaction that occurs on the graphene surface. This reaction process involves the following four steps.

1) Electron capture: $\mathrm{p} + \mathrm{e}^- \rightarrow \mathrm{n} + \nu_\mathrm{e}$
2) Deuterium production: $\mathrm{p} + \mathrm{n} \rightarrow \mathrm{d} + \nu_\mathrm{e}; \mathrm{n} + \mathrm{n} = \mathrm{d} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$
3) Helium-3 production: $\mathrm{d} + \mathrm{n} \rightarrow {}^3\mathrm{He} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$
4) Helium-4 production: ${}^3\mathrm{He} + \mathrm{n} \rightarrow {}^4\mathrm{He} + \nu_\mathrm{e}$

In the first step, protons undergo electron capture. Then, the second and third steps lead to neutron capture through beta decay. This process differs from the proton-proton chain reaction that occurs in hot fusion.

The mass deficit that is observed in the latter three steps can be explained by the conversion of that mass into massless particles known as gravitons [7]. These particles are believed to carry kinetic energy, which they can then transfer to particles with mass through collisions. When gravitons collide with charged particles, they can emit electromagnetic radiation such as gamma rays. This may explain why we do not observe high levels of gamma-ray emission in the low-energy fields associated with LENRs. We can also consider that the heat generation in LENRs is due to fundamental processes involving electron scattering through interactions with gravitons, which are emitted during the mass-energy conversion of nuclear binding energy.

In order to generate electricity through electron scattering as well as beta decay, it may be necessary to lower the core temperature while ensuring that the energy remains at a sufficient level to trigger LENRs. Such a decrease in temperature could potentially limit the conversion of electron energy into both excess heat and light.

5. Two Possibilities of the Plasmons with Low-Energy Protons

The key reaction process in the LENB is electron capture, as it triggers LENRs. Plasmons can interact with protons in two ways: through the stopping power or by capturing electrons.

1) Stopping Power

The most likely interaction is the stopping power. Low-energy protons on the surface of plasmonic graphene can be trapped by an electron flow in one direction, appearing as ionized protons moving rapidly within electron clouds. As a consequence, the protons adopt a lower energy state, exhibiting similar behavior to ionized particles. In weaker plasmons, protons can temporarily exchange potential energy with the free electrons as they pass through the range where the K-orbit electron resides. In more excited plasmons, protons share potential energy with all surrounding free electrons within a wider range, equivalent to a single electron potential in total. The kinetic energy of electrons that have been scattered by protons because of their stopping power can increase through repeated interactions with additional protons. As a result, these free electrons may gain kinetic energy to undergo electron capture.

2) Electron Capture

The other interaction is electron capture, which occurs when electrons flow in the correct direction toward the protons within the range where they can fuse with them. This process leads to LENRs, as discussed in the previous section.

According to Coulomb's inverse-square law or its relativistic perspective, it is possible to achieve an infinite energy density near protons by moving electrons closer to them. This phenomenon is also observed in the gravitational field around black holes, where the strength of the field becomes infinite as one approaches the event horizon. The graviton model [7] presented in Section 4 offers a means to evade the issue of infinite energy. By employing an inverse potential, we can make the maximum energy density finite. Therefore, the mass difference between neutrons and protons can be considered as the sum of the electron mass and the nuclear binding energy at the maximum energy density. If the energy of the captured electrons exceeds this value, then energy will be released in the form of emitted particles.

6. Computational Approach for Finding Optimized Setup

Large-scale simulations reduce the need for trial and error in actual experiments. By performing simulations, it is possible to design a precise experimental setup for LENBs. In this section, we discuss two computational approaches that are crucial for initiating LENRs.

First, it is necessary to determine the electron capture process in plasmons. To simplify the problem, we consider excited electrons in lattice positions within a 2D or 3D framework. Next, we launch a single proton toward the flame from different angles while varying its relative velocity, electron density, and energy state. Thus, we can optimize the core temperature and gas pressure required for electron capture. In some cases, it may be necessary to reduce these parameters to enable protons to condense into plasmons.

Second, we must develop the THz laser setup for generating plasmons on the graphene surface. Based on our initial calculations, we can determine the optimal THz frequency and examine potential device specifications. This involves considering factors such as lens mounting, the design of the multi-layer LENB core, and any other relevant factors that were discussed in Section 3.

It is also necessary to compute more complex events, such as LEPP chain reactions. To accomplish this, we need to use experimental data to accurately evaluate the processes. It is possible that we may need to invest additional energy to initiate LENRs through some method. Moreover, it may be possible that LENRs do not continuously occur during THz radiation, as LEPP chain reactions can interrupt electron captures by fracturing plasmons on graphene surface. In this scenario, we propose using multiple LENB cores and THz lasers to activate LENRs in a way that is similar to how multiple engine cylinders work. This method should allow for stable, continuous electrical output from LENBs. Finally, we can optimize the battery design.

7. Concluding Remarks

Despite the long-held belief that LENRs are not viable, significant progress has been made in experimental research in recent years, leading many experts and enthusiasts to question whether this technology can ultimately sustain our modern lifestyle and provide hope for future generations. The insights presented in this work may contribute to the further development of LENRs as a viable energy source.

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