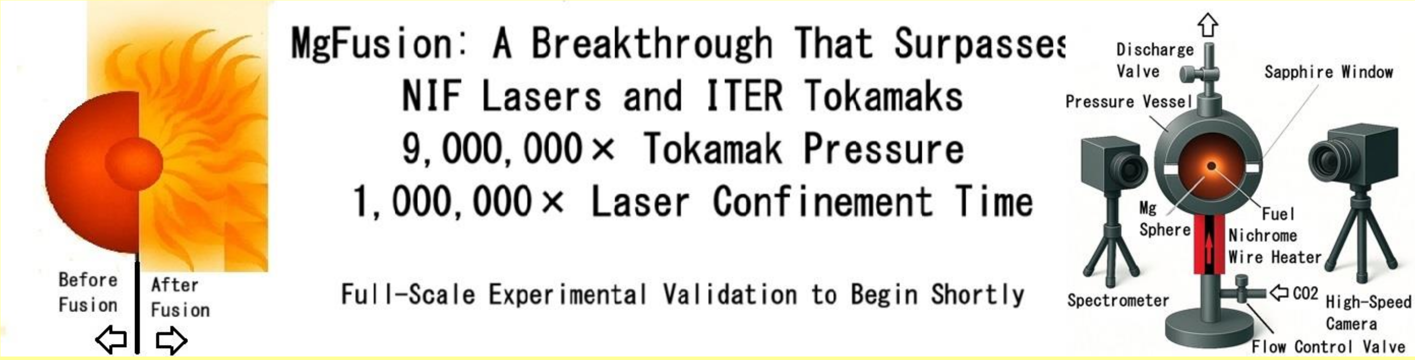

Mg Sphere

1.Introduction

Magnesium Shell Fusion (hereafter MgFusion) is a new concept of inertial confinement fusion in which the detonation of magnesium–carbon-dioxide (Mg–CO_2) reactions compresses and heats fusion fuel inside a small magnesium shell.A peer-reviewed paper on MgFusion was submitted to the Power Division of the American Society of Mechanical Engineers (ASME-POWER), accepted in April 2024, and presented in Washington, D.C. in September 2024. The paper showed, through analysis, that the detonation energy and timescale of the Mg–CO_2 reaction can compress and heat the fuel sufficiently to satisfy the Lawson criterion and achieve fusion ignition.

At that time, however, the detailed mechanism from Mg–CO_2 detonation to actual fusion ignition was not yet fully understood. Over the following year, we studied this mechanism and clarified that a detonation cycle of magnesium combustion repeatedly compresses and heats the fuel, eventually leading to fusion. We also elucidated the post-fusion cooling mechanism, showing that in this process a large amount of CO_2—the main driver of global warming—can be converted into valuable resources. This indicates that MgFusion can overcome key challenges of conventional fusion reactors and supports a realistic conceptual design for fusion power plants.

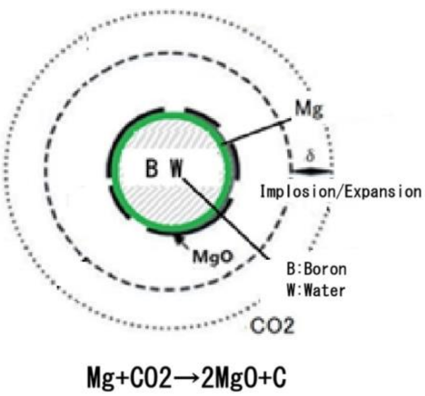

Figure 1. Magnesium spherical shell (Mg shell).

2. Structure of the Magnesium Shell

Figure 1. Magnesium spherical shell (Mg shell).

A magnesium spherical shell of approximately 10 mm in diameter is used. The inner cavity, about 2 mm in diameter, is filled with boron–water (B–W fuel). The outer surface is coated with magnesium oxide (MgO) to prevent premature ignition during handling (Fig. 1).

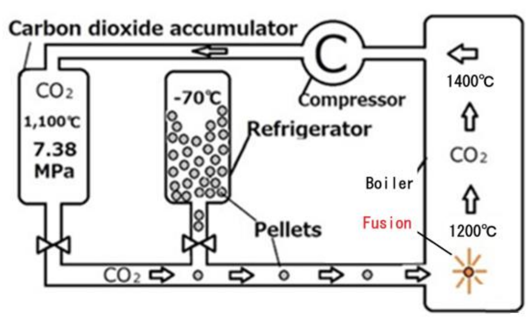

Figure 2. Burner system for injecting Mg shells into the 1200 °C CO_2 boiler.

3. Fusion Process of MgFusion

① Heating and Ignition

When the Mg shell is dropped into a 1200 °C CO_2 boiler using a burner system, the MgO coating breaks, and the outer Mg layer begins reacting explosively with CO_2 (Fig. 2).

② Fuel Heating and Proton Production

Shock waves generated by the detonation penetrate the shell, causing Mg to react with water, generating hydrogen, which ionizes into protons (p) at high temperatures.

③ Detonation and Plasma Formation

When the shell temperature exceeds 10,000 °C, Mg–CO_2 detonation intensifies. At roughly 15,000 °C, magnesium becomes plasma, temporarily halting detonation.

④ Detonation Cycle (Multi-Stage Shock Heating)

As the shell expands and cools, detonation restarts. This detonation → halt → re-detonation sequence repeats, producing a highly efficient multi-cycle shock heating mechanism.

⑤ Fusion Ignition

After approximately 11 detonation cycles over several microseconds, the B–p fuel reaches temperatures exceeding 1×10^9 °C, allowing fusion ignition.

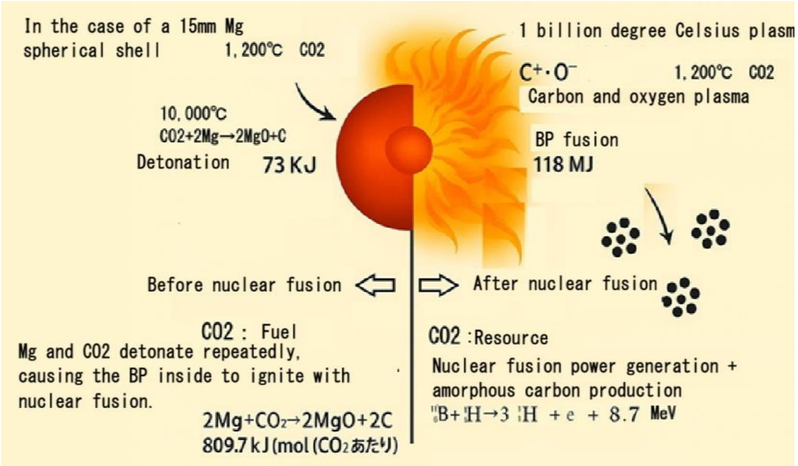

Figure 3. Role of carbon dioxide before and after fusion.

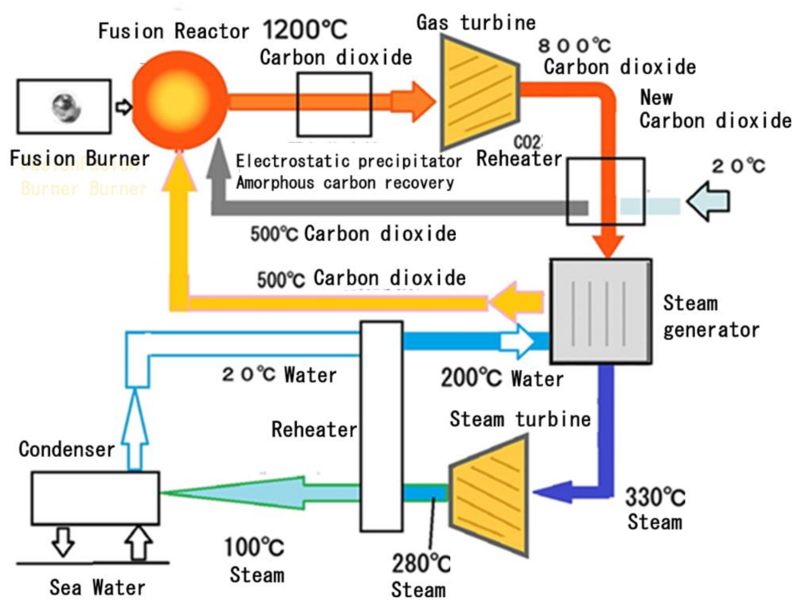

Figure 4. Magnesium shell fusion combined-cycle power plant (MgFusion).

4. Role of CO_2 Before and After Fusion

(1) Before Fusion – CO_2 acts as a fuel

Before fusion, CO_2 itself functions as a chemical fuel. Mg and CO_2 react repeatedly, and the Mg–CO_2 detonation uses CO_2 as the reactant that releases energy and detonation pressure, which in turn compresses and heats the B–p fuel.(Fig.3)

(2) After Fusion – CO_2 acts as a coolant and resource generator

After fusion, CO_2 primarily functions as a coolant. Fusion-generated helium (~20 billion °C at birth) heats the surrounding CO_2 so intensely that it plasma-dissociates into carbon and oxygen plasma. Rapid quenching then produces amorphous carbon, a valuable industrial material that can be recovered. In this post-fusion phase, CO_2 serves not only as a high-temperature coolant, but also as a carbon-recycling material source.(Fig.3)

5. High-Efficiency Combined-Cycle Fusion Power Generation

A MgFusion plant replaces the gas combustor of an LNG combined-cycle power plant with a fusion–detonation boiler. LNG combined-cycle plants (e.g., 6,000 MW class in Dubai) reach 60% efficiency using 1000 °C gas plus 800 °C steam. MgFusion circulates 1200 °C CO_2 without exhaust losses. The theoretical thermal efficiency is about 80%, and a practical efficiency of roughly 70% is expected after accounting for amorphous-carbon extraction and other losses.(Fig.4)

6. Solving Global Warming and High-Temperature Reactor Challenges

A MgFusion plant consumes and permanently fixes approximately 2.5 times more CO_2 than a coal-fired power plant of the same output. Fusion-born helium is absorbed by CO_2 plasma, and CO_2 cools reactor walls to ≤1400 °C, allowing the use of existing high-temperature materials. Meanwhile, amorphous carbon is collected as a high-value material. Thus, CO_2 recycling and fusion power generation are achieved simultaneously.

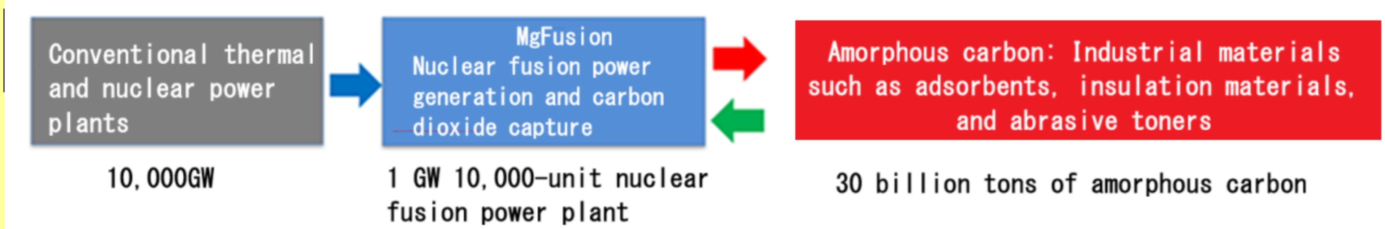

Figure 5. Carbon utilization in MgFusion-based power generation.

7. MgFusion Compared with Tokamak Fusion (ITER) and Laser Fusion

(1) Confinement Pressure Comparison: 10-mm Mg Shell vs. ITER Tokamak

The ITER tokamak generates a maximum magnetic field of approximately 12 T using superconducting coils.
The corresponding magnetic pressure is only 5.5×10^{7} Pa (55 MPa = 0.055 GPa).
Given the expected plasma beta of about 0.5%, the *effective* confining pressure is merely 0.28 MPa.
Although ITER claims to satisfy the Lawson criterion for DT fuel, the severe bremsstrahlung losses **make** DT ignition itself marginal—and boron–proton (Bp) fusion is essentially impossible under such conditions.

MgFusion Pressure Estimate
A 10-mm magnesium sphere with a 2-mm inner cavity contains about 0.90 g of Mg.Its reaction with CO_2 releases ~15 kJ of energy.
If roughly half (~7.5 kJ) heats the CO_2 in the 2-mm cavity, the internal pressure instantly reaches:
→ 5×10^{11} Pa (500 GPa)
→ ~9,000× ITER's magnetic pressure
With continued detonation and multi-stage shock compression, the inner radius contracts from 1 mm to 0.1 mm (volume ×1/1000), increasing the pressure to:
→ 5×10^{14} Pa (500 TPa)
→ ~9,000,000× ITER's confinement pressure
Thus, MgFusion achieves million-fold higher pressure than any magnetic confinement system.

(2) Confinement Time Comparison:
At the National Ignition Facility (NIF), many high-power lasers compress a fuel capsule, but the high-density state 10-mm Mg Shell vs. NIFlasts only hundreds of picoseconds to about 1 nanosecond (~10^{-9} s).
The fuel is sensitive to illumination asymmetry and Rayleigh–Taylor instabilities, and even in NIF's ignition shot only four shock stages were achieved, with an extremely short stagnation time.

In MgFusion, once the Mg shell is injected into 1200 °C CO_2, it undergoes detonation cycles of 0.2 μs.(Fig.6)
If about 10,000 cycles occur before collapse, the effective confinement time is on the order of 10^{-3} s (milliseconds):
NIF: ~10^{-9} s **MgFusion: ~10^{-3} s**
Thus, MgFusion offers a confinement time 10^{6} times longer, giving a one-million-fold advantage in the τ part of the Lawson parameter nτ.

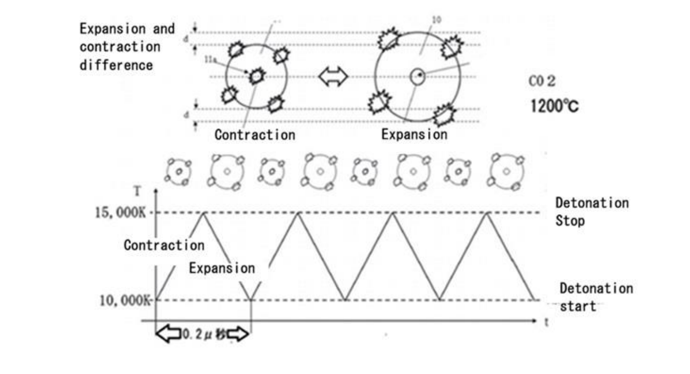

Figure 6. Detonation Cycle of the Magnesium Shell

(3) Fusion Ignition Conditions
(i) Lawson Criterion for Bp Fusion
The ignition requirement for Bp fusion is:
$n\tau T \geq 10^{17}$**keV\cdotps/cm^{3}**

Assuming:

- **Density: $n = 1.5\times10^{23}\,\mathrm{cm}^{-3}$**
- **Confinement time: $\tau = 2\times10^{-3}$ s**
- **Temperature: $T = 100$ keV**

$$n\tau T = 3\times10^{22}$$

→ More than 100,000× the Lawson requirement

(ii) Achievable Temperature
For Bp fusion, ignition requires temperatures exceeding 1×10^{9} °C.
Example:

- **At 5×10^{8} °C, sound speed ≈ 1,930 km/s**
- **Shock speed ≈ 4,826 km/s (Mach ≈ 2.5)**
- **Resulting temperature ratio ≈ 2.8**
- **Compression ratio ≈ 1000**

The initial temperature is 10,000 °C, and each shock cycle increases temperature by ×2.8, then after 11 repeated shocks:

$$10^{4}\times2.8^{11}\approx1.1\times10^{8}\ ^{\circ}\mathrm{C}$$

7. Overcoming the Four Fundamental Limitations of Conventional Fusion Reactors

① **Extreme confinement pressure:**
Detonation of the Mg–CO_2 reaction generates **500 GPa–500 TPa**, up to **9,000,000×** the confinement pressure of ITER.

② **Millisecond-scale confinement time:**
MgFusion achieves an effective confinement time of **~10^{-3} s**, about **1,000,000×** longer than NIF's nanosecond-scale confinement.

③ **No need for ultra-high-temperature first walls:**
Fusion heat is absorbed and cooled by circulating CO_2, keeping reactor wall temperatures **below ~1400 °C**, so exotic first-wall materials are unnecessary.

④ **Neutron-free, radiation-free fusion pathway:**
The large ignition margin in pressure and time enables **boron–proton (B–p) fusion**, with **no neutrons and no radioactive by-products**.

8. "Scarecrow-Type" Experimental System

To experimentally verify MgFusion, we have completed the design and cost estimation of the **Scarecrow-Type Fusion Experiment System**. The apparatus is patent-pending and requires only **one-millionth the cost** of tokamak or laser fusion facilities.

- Fabrication period: ~3 months
- Test campaign: ~3 months
- Phase-1 budget: **<100 million JPY**

Experiment Phases

1. **Mg Shell Combustion Test**
– Measure Mg–CO_2 heating and shock propagation.
2. **Mg Shell Fusion Test**
– Introduce DT water or B–W fuel and verify multi-cycle detonation-driven ignition.

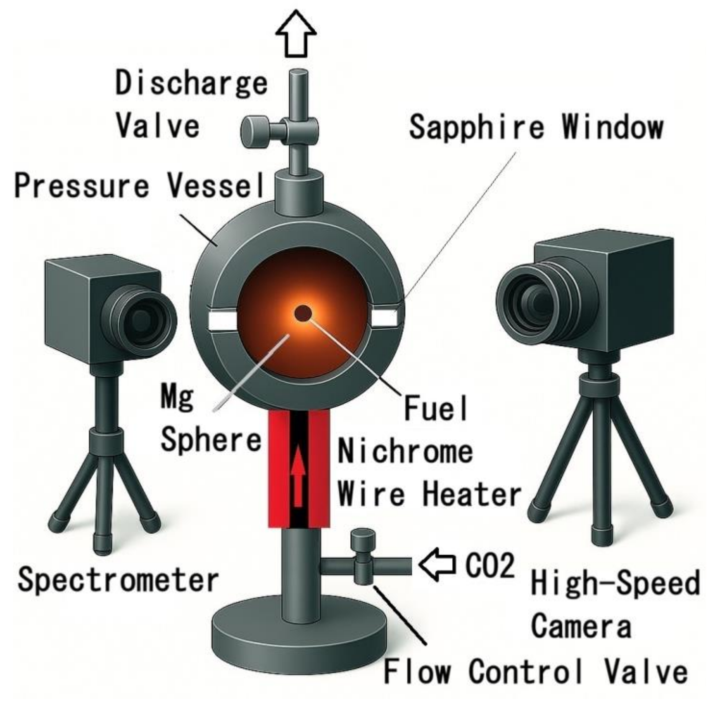

Figure 7. Scarecrow-Type MgFusion Experimental Apparatus

9. International Joint Development

MgFusion patents have been filed domestically and internationally. We aim to promote global co-development for both fusion power and CO_2-resource recovery. Negotiations have already begun with partners in Japan, China, India, and South Korea. MgFusion Inc. CEO Haruo Morishige retains golden shares to ensure strategic control and protect the technology.

Participation Opportunities

- Strategic investors
- Electric utilities
- Heavy-industry manufacturers
- Materials companies
- Financial institutions
- Individual supporters (via annual seminar membership)

Technology Offering

- Licensing based on a comprehensive PCT patent portfolio
- Priority access to MgFusion plant development
- Participation in CO_2-resource recycling businesses

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