

Advanced Atomic Energy Research Section

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1. Introduction

Main objective of our research division is to realize advanced energy systems for the sustainable development under global environmental constraints. We have shown a Zero-emission energy scenario based on fusion energy with biomass-based recycling system where biomass waste is converted into liquid fuel or hydrogen. And further we now propose an innovative Negative emission scenario to isolate CO₂ in the atmosphere by a carbonization process. Our research section focuses on development of hydrogen isotopes fuel circulation system, breeding blankets, fusion material R&D, feasibility study for fusion-biomass hybrid power system, conversion of biomass waste, and fusion neutron generation/measurement. The following are the main research achievements in the fiscal year of 2024.

- Accomplishment of the highest efficiency for fusion fuel extraction from lead lithium eutectic alloy using the droplet system in the fusion study field.
- Hydrogen solubility investigation for new liquid breeder Li-Pb-Na.
- Corrosion study of fusion reactor materials in supercritical carbon dioxide
- Syngas production from biomass using microwave reactor.

2. Fusion fuel (hydrogen isotope) recovery system development from liquid lead lithium droplets

Lead lithium eutectic alloy (Pb-17at%Li, Pb-Li) is a promising liquid material for the fuel (hydrogen isotope) breeding on a fusion reactor. Efficient recovery of the bred fuel is a key viable issue of liquid blanket.

We are studying the recovery method from liquid Pb-Li droplets in a vacuum, named as vacuum sieve tray (VST). This fiscal year, on a collaboration work with National Institute for Fusion Science (NIFS), we challenged a further efficiency enhancement by the tandem extraction method. As shown in Fig. 1, we obtained the efficiencies of between 0.8 and 0.9 [1]. The results exceeded the pre-estimated values of between 0.6 and 0.8. The turbulent flow at the nozzle is considered a probable contributory factor. Previously, under turbulent region of the nozzle jet, it is anticipated to disperse and droplets formation is unattainable. These results are expected to open the new design window for the liquid blanket system. We plan to proceed further detail study under turbulent region.

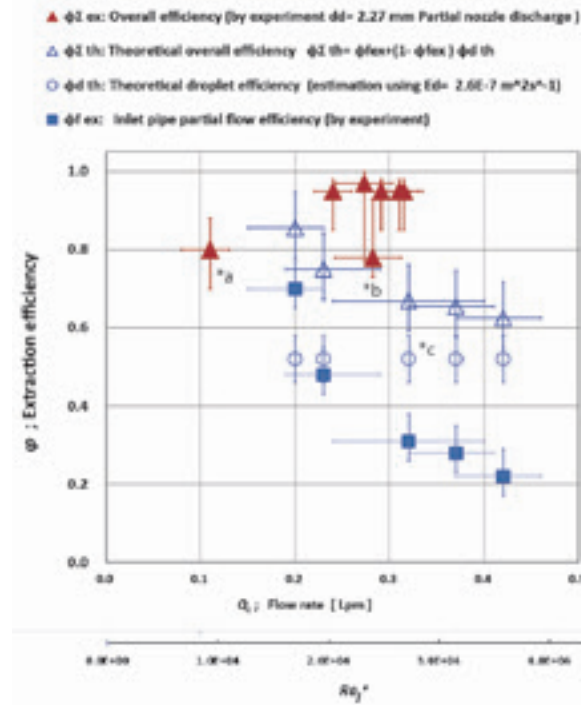


Fig.1 The obtained extraction efficiencies, marked as $\blacktriangle$, as a function of the liquid flow rate [1]. The obtained overall efficiencies exceeded the pre-estimated value marked as $\triangle$. The turbulent flow at the nozzle jet is considered the prob-

3. Hydrogen solubility and tritium breeding ratio of advanced liquid breeder Li-Pb-Na

Lead lithium eutectic alloy (Pb-17at%Li, Pb-Li) has a low hydrogen solubility, which poses a problem for tritium leakage.

We are focusing on Li-Pb-Na (Pb-19at%Li - 5at%Na, Li₁₉Na₅Pb₇₆ and Pb-15at%Li-35at%Na) liquid alloy to reduce the mass density and increase hydrogen solubility relative to Pb-Li. Fig. 2 shows the temperature dependence on the hydrogen solubility of the liquid metal materials. The hydrogen solubilities of Li₁₉Na₅Pb₇₆ and Li₁₅Na₃₅Pb₅₀ were similar, and higher than that of Pb-Li. Furthermore, the mass density measured by Archimedes' method was reduced by 30% when 35at% Na was used. On the other hand, the tritium breeding ratio (TBR) was calculated and the TBR was lower than 1.0 when Li₁₅Na₃₅Pb₅₀ was used. The liquid blanket should have a TBR more than 1.0, and adding too much Na was found to be inappropriate. The TBR of Li₁₉Na₅Pb₇₆ and Pb-Li was similar, indicating that Li₁₉Na₅Pb₇₆ has a higher hydrogen

solubility than Pb-Li and reduces the pump load. We continue to develop liquid metal materials with high hydrogen solubility, low mass density, and high TBR.

4. Corrosion of Fusion Reactor Structural Materials by Supercritical Carbon Dioxide

Recently, supercritical carbon dioxide has attracted attention as a breeder material that can be easily separated from tritium, does not cause MHD pressure drop, and can be used for driving turbine directly. On the other hand, the corrosion behavior of supercritical carbon dioxide on F82H has not been researched sufficiently.

We are researching corrosion behavior of structural materials in response to supercritical carbon dioxide and coatings on structural materials for corrosion resistance, as collaboration research with the Chemical Reaction Complex Processes Research Section in IAE (Prof. Nohira lab.) and NIFS. Corrosion of F82H in a supercritical CO₂ 25 MPa, 550 °C atmosphere for 500 hours resulted in the formation of magnetite and iron-chromium oxide layers on the F82H surface. Ni was coated by electrodepositing on F82H (F82H+Ni) to prevent these oxidations. F82H+Ni cor-

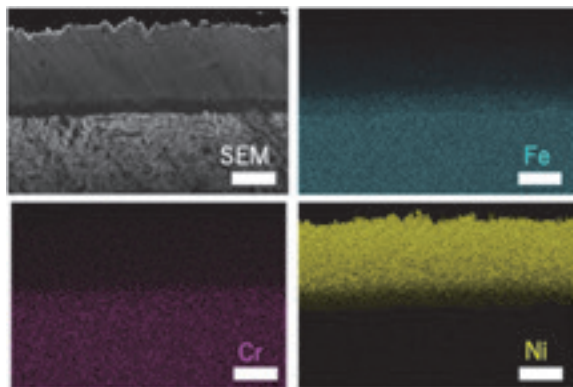


Fig.3 Cross-sectional SE image and elemental mapping of F82H+Ni after 500h test (scale bar = 30µm)

roded under the same conditions showed that oxidation was prevented, and that the Ni coating imparts corrosion resistance (as shown in Fig. 3). We continue to develop advanced Ni and W coated structural materials for F82H and other structural materials such as V.

4. Fusion-biomass hybrid power system

We propose to apply the enormous energy from fusion power generation to the conversion of biomass resources. Fusion power generation produces enormous amounts of electrical and heat energy from condensers and other equipment. We are studying microwave heating of biomass in a steam atmosphere, using electrical energy for microwave oscillation and heat energy for steam generation. While this method is expected to use both electrical and heat energy from fusion effectively, the effects of steam addition and

microwave heating have not been sufficiently investigated. To investigate the effect of steam addition, biomass mixed with a susceptor was heated by microwave at 800°C with and without steam.

The results showed that steam addition induces a water gas shift reaction, leading to hydrogen-rich products (Fig. 4) [2]. It was also suggested that the combination of microwave heating and steam reduces the formation of secondary char that can cause pipe blockage

(Fig.5). In addition, a techno-economic assessment of the possible application of fusion systems to biomass conversion is conducted to examine the feasibility of a biomass-fusion hybrid system.

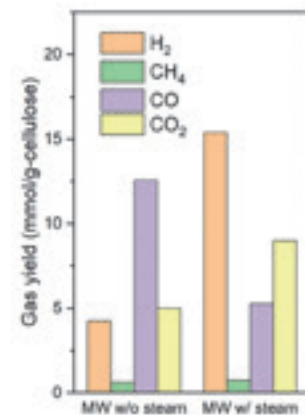


Fig.4 Microwave gas generation at 800 °C with and without steam

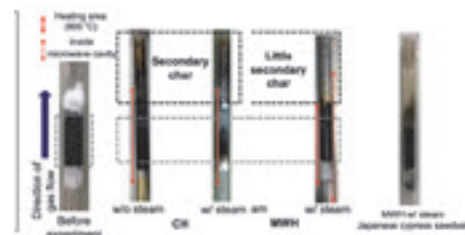


Fig.5 The appearance of the reaction vessels before and after experiments at 800°C.

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Collaboration Works

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八木重郎, 核融合科学研究所・一般共同研究, 横断的研究のための COE 共同研究プラットフォーム・Oroshhi-2 の利用検討会

Financial Support

1. Grant-in-Aid for Scientific Research

八木重郎, 基盤研究(B), 機能性被覆の劣化診断手法と修復技術の開発 (分担金)

八木重郎, 基盤研究(B), 高強度中性子環境における電気絶縁被覆機能材料の反跳原子による特性変化 (分担金)

伊藤諒, 特別研究員奨励費, 液体金属と溶融塩を用いた電気化学的手法によるリチウム 6 同位体濃縮技術の開発

2. Others

八木重郎, 京都フュージョニアリング (株), 核融合炉内機器及び付属システムの開発研究

八木重郎, 量子科学技術研究開発機構, 固体増殖材による低放射化フェライト鋼の腐食と機械的強度への影響評価

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