Oral | Applications: Motors and others

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[O6] Applications

Session Chair: Dr. Yusuke Hirayama(National Institute of Advanced Industrial Science and Technology)

Invited

11:35 AM - 11:55 AM JST | 2:35 AM - 2:55 AM UTC

[O6-4] Development of an active magnetic refrigerator for hydrogen liquefaction

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In Japan, hydrogen has been recognized as one of the key elements in the Green Growth Strategy formulated in December 2020 by the Ministry of Economy, Trade, and Industry, in response to the Carbon Neutral Declaration. The strategy aims to achieve a maximum hydrogen demand of 3 million tons by 2030 and 20 million tons by 2050, while also reducing the current hydrogen supply price from 100 yen/m^3 to 30 yen/m^3 by 2030 and to 20 yen/m^3 or less by 2050.

To make hydrogen usable as an energy source for consumers, it is necessary to convert it into a compact and manageable form for distribution. Various forms of hydrogen, such as liquid hydrogen, ammonia, and methylcyclohexane, have been considered, and ongoing research and development are focused on overcoming technical challenges, considering the advantages and disadvantages of each option. Among these forms, liquid hydrogen offers the advantage of significantly reducing the volume of hydrogen gas to 1/800th, but its higher cost compared to other forms has been a drawback. To liquefy hydrogen, hydrogen gas needs to be cooled to cryogenic temperatures of around 20 K at a pressure of 1 atmosphere, which requires a considerable amount of electricity by conventional gas refrigeration.

One method that has the potential to greatly enhance liquefaction efficiency and reduce amount of electricity is magnetic refrigeration. Magnetic refrigeration is a refrigeration method based on the "magnetocaloric effect," which generates temperature changes by ordering or disordering the magnetic moment (spin entropy) of magnetic refrigerants by changing the magnetic fields. Magnetic refrigeration can theoretically achieve liquefaction efficiencies of 50% or more, which is about twice that of the conventional gas expansion refrigerators.

This talk will introduce Active Magnetic Refrigerator (AMR) for hydrogen liquefaction being developed under the Japan Science and Technology Agency (JST) Mirai Project.[1)] The JST Mirai project has two goals: POC1 (Proof of Concept 1) and POC2. In POC1, efficient hydrogen liquefaction is performed, while POC2 involves the efficient re-condensation of liquid hydrogen. POC1 requires a relatively large amount of hydrogen, which necessitates significant refrigeration capacity. For this reason, a 5T magnetic field is necessary for magnetic refrigeration, and therefore a superconducting magnet is used. On the other

hand, the re-condensation of liquid hydrogen in POC2 does not require as much capacity as POC1, allowing the use of permanent magnets to drive magnetic refrigeration.
In this talk, I will first introduce the AMR (Active Magnetic Regenerator) system used for hydrogen liquefaction in POC1 and report on the world's first hydrogen liquefaction experiment using AMR. Then, I will describe the magnetic refrigeration system using permanent magnets implemented in POC2 and report on the development status of the newly developed permanent magnets at NIMS for this JST Mirai project[2)].

Reference
1) Koji Kamiya *et al*. Appl. Phys. Express 15 (2022) 053001
2) X. Tang, J. Lai, H. Sepehri-Amin *et al.* Scripta Mater. 194 (2021) 113648.