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Fundamental study of tank with MgB_2 level sensor for transportation of liquid hydrogen

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Hydrogen is attracting attention as an alternative energy source to fossil fuels and nuclear power. In the storage and transport of large quantities of hydrogen by sea, liquid hydrogen (LH_2) is very effective because its density is about 800 times that of gaseous hydrogen (273 K, 1 atm). To ensure the safety of the marine transportation of LH_2, its behavior in a tank must be elucidated using a highly precise level gage because the sloshing phenomenon inside the tank becomes a problem during the transportation. We are currently developing an external-heating-type superconducting magnesium diboride (MgB_2) level sensor for an LH_2 tank [1] [2]. We previously reported the thermal response of the MgB_2 level sensor [3]. However, the measurement current dependence of the level-detecting characteristics of the sensor for LH_2 under a static condition has not yet been clarified. We performed an experiment on board of a training ship to evaluate the measurement system. The aim of this study is to elucidate the measurement current dependence of the level-detecting characteristics of the MgB_2 level sensor for LH_2 under a static condition using the measurement system on board of the training ship.

External-heating-type MgB_2 level sensor

The MgB_2 wire used in this experiment was 0.32 mm in diameter, had a total length of 200 mm, and was reinforced by a CuNi (7:3) sheath. It was fabricated by an in situ method based on the powder-in-tube method. A manganin wire of 0.2 mm diameter was wound spirally around the MgB_2 wire with a pitch of 2 mm for use as an external heater. To reduce the critical temperature T_c of the wire, 10% SiC was added as an impurity to the MgB_2 core. The heat treatment temperature was 873.15 K and T_c was 32 K

Experimental apparatus and experimental method

The measurement system consists of a cryostat, a MgB_2 sensor, a current source for the sensor, a power supply for the heater, and a nanovoltmeter as shown in Fig. 1. Figure 2 shows the setup of the experimental apparatus on the training ship. Figure 3 shows a photograph of the experimental apparatus. Figure 4 shows a photograph of the training ship “Fukaemaru”.

We experimentally investigated the level-detecting characteristics of the MgB_2 level sensor by determining the relationship between the sensor output voltage and the liquid level at atmospheric pressure as a parameter of the measurement current at heater inputs of 3 W and 6 W while the liquid level was decreased from 140 mm to 0 mm. The measurement current was varied between 10 mA and 100 mA in intervals of 10 mA.

Furthermore, we examined the effect of self-heating caused by the measurement current by determining the relationship between the sensor output voltage and the measurement current at atmospheric pressure as parameters of the heater input with liquid levels of 0 mm and 80 mm. The output voltage of the sensor was measured by a four-wire technique in these experiments.

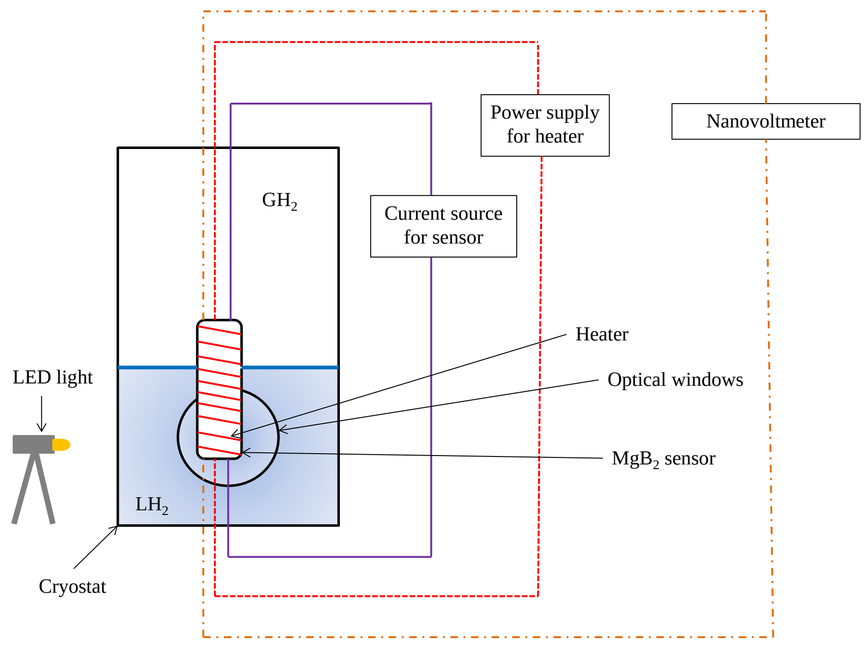

Fig. 1 Measurement system.

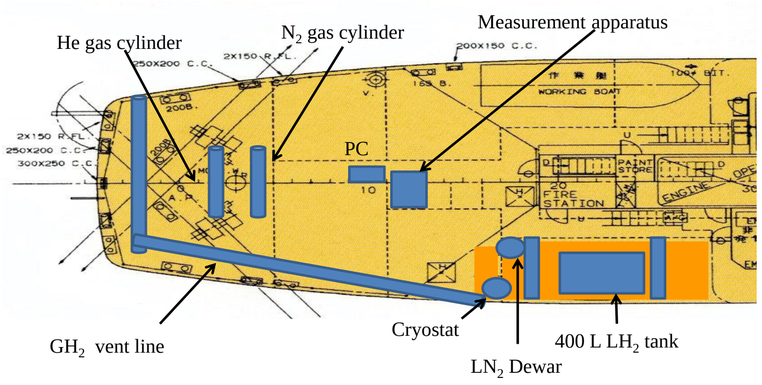

Fig. 2 Setup of experimental apparatus.

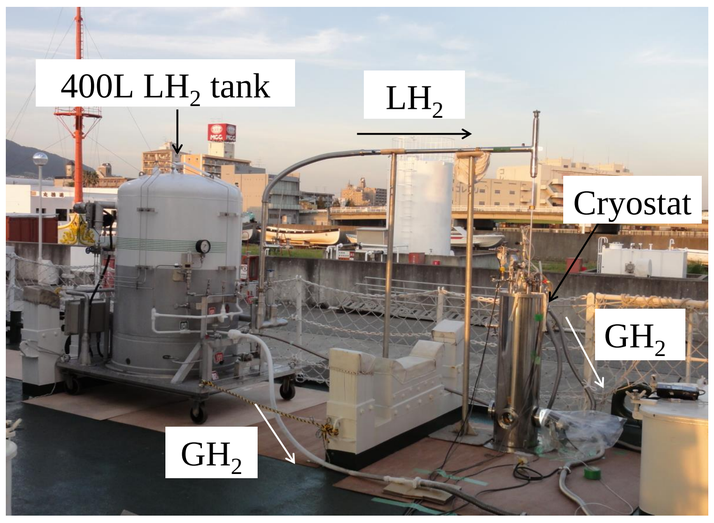

Fig. 3 Photograph of experimental apparatus.

Fig. 4 Photograph of training ship “Fukaemaru”.

Experimental results

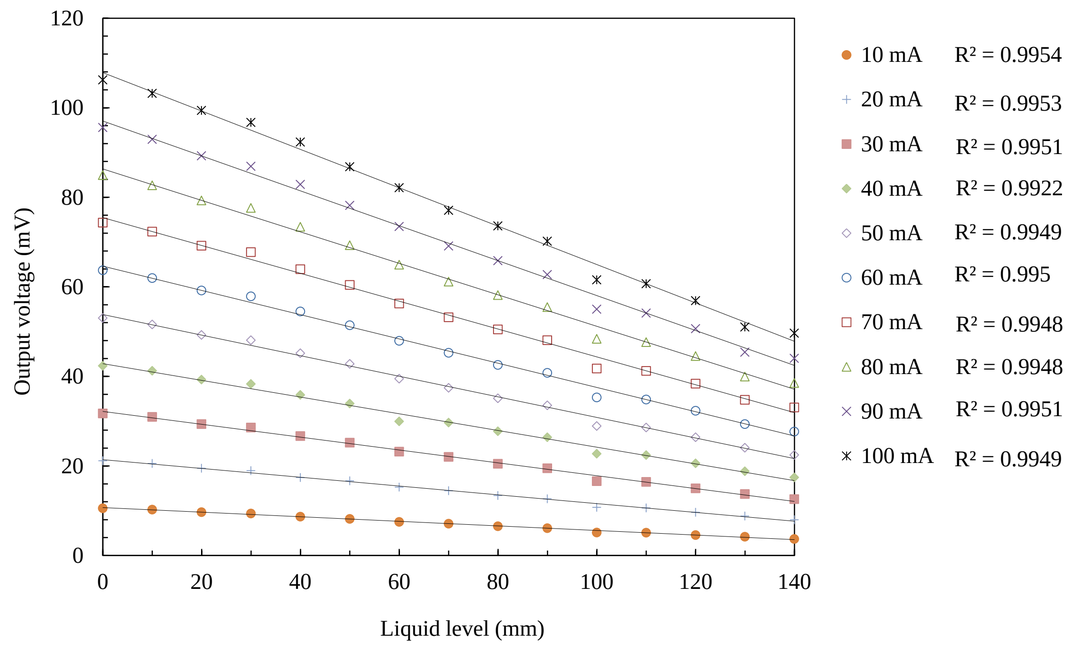

Fig. 5 Level-detecting characteristics of the MgB_2 level sensor as a parameter of the measurement current at a heater input of 3 W.

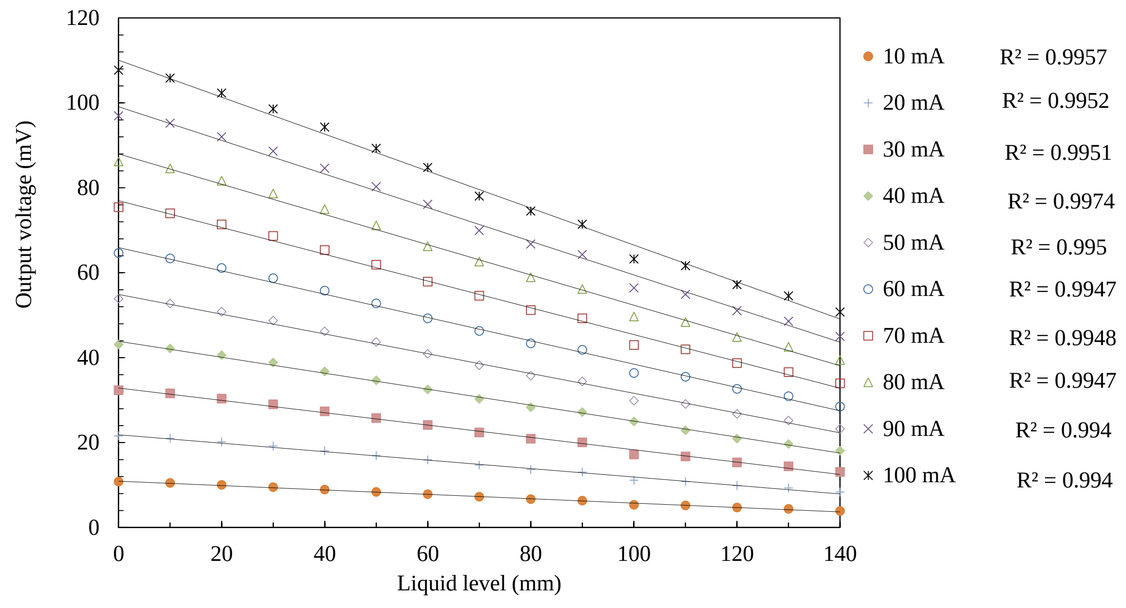

Fig. 6 Level-detecting characteristics of the MgB_2 level sensor as a parameter of the measurement current at a heater input of 6 W.

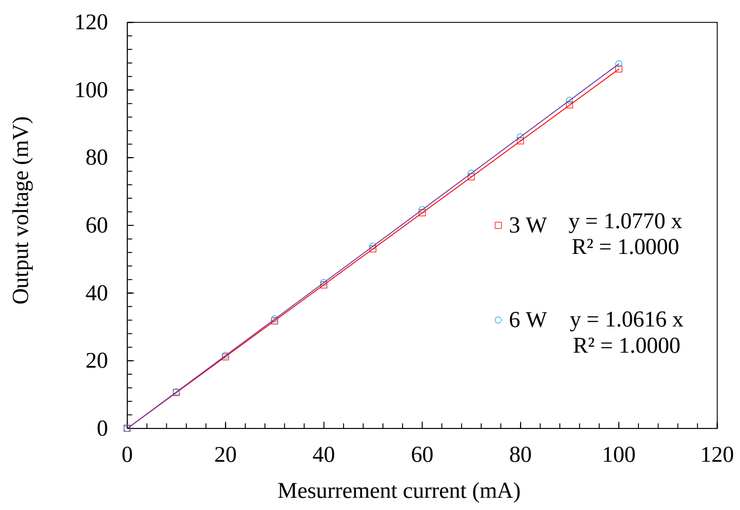

Fig. 7 Effect of self-heating caused by the measurement current at a liquid level of 0 mm.

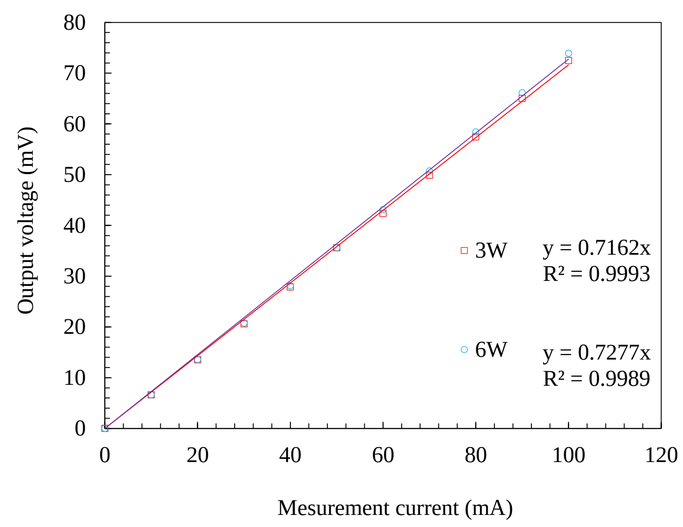

Fig. 8 Effect of self-heating caused by the measurement current at a liquid level of 80 mm.

Figure 5 shows the level-detecting characteristics of the MgB_2 level sensor as a parameter of the measurement current at a heater input of 3 W. The linear correlation coefficient was 0.99 or more, indicating high linearity, regardless of the measurement current. Figure 6 shows the level-detecting characteristics at a heater input of 6 W. This figure shows a similar tendency to Fig. 5; the linear correlation coefficient was 0.99 or more. Therefore, the level-detecting characteristic of the MgB_2 level sensor was independent of the measurement current.

Figure 7 shows the effect of self-heating caused by the measurement current on the level-detecting characteristics of the MgB_2 level sensor at a liquid level of 0 mm. The linear correlation coefficient was 0.99 or more for both heater inputs. Figure 8 shows the effect of self-heating caused by the measurement current at a liquid level of 80 mm. The linear correlation coefficient was 0.99 or more for both heater inputs.

Thus, the performance of the MgB_2 level sensor is unaffected by self-heating caused by the measurement current and detects the liquid level precisely even if the measurement current increases. It was found that a measurement current of up to 100 mA can be used.

CONCLUSION

We clarified the measurement current dependence of the level-detecting characteristics of our MgB_2 level sensor for LH_2. The linear correlation coefficient was 0.99 or more, indicating high linearity, regardless of the measurement current at heater inputs of 3 W and 6 W. Moreover, there was no effect of self-heating by the measurement current and a measurement current of up to 100 mA can be used.

We plan to elucidate the sloshing phenomenon inside the tank during the marine transportation with several longer MgB_2 level sensors.

Acknowledgements

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References

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