Fundamental study of tank with MgB\textsubscript{2} level sensor for transportation of liquid hydrogen

MgB\textsubscript{2} is fabricated using sintering. The MgB\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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.
Experimental results

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, 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.

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

This work was supported in part by a Grant-in-Aid for Scientific Research, JSPS KAKENHI Grant Number 24246143.

References