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Thermal Storage Project に向けた Fe-Cu 合金融体の表面張力測定

Surface Tension Measurement of Liquid Fe-Cu for Thermal Storage Project

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1. Introduction

Fe–Cu binary alloy shows a metastable miscibility gap in a wide composition range when the melt is undercooled below liquidus temperature. If the undercooled melt separates to form small droplet of Cu-rich phase in the matrix of Fe-rich phase at the immiscible liquid region followed by a frozen of the demixed microstructure at room temperature, it has a potential to be used as a new high-performance thermal storage material utilizing a latent heat of liquid–solid phase transformation of Cu-rich phase inside the outer supporting material of Fe-rich phase. Accurate measurement of thermophysical properties of molten Cu–Fe alloys is planned on Japanese science module for the International Space station (ISS), KIBO, as a part of ELF-Thermal Storage project[1)]. Accurate thermophysical properties date is crucial to control the microstructure of Fe–Cu alloys.

In the present study, we investigated the effect of changes in the sample composition due to evaporation at high temperature on the surface tension of molten Fe–Cu alloy by using the electromagnetic levitation (EML) on the ground as a preliminary study for the ELF-Thermal Storage project[1] at the KIBO, because one of the components in the alloy may preferentially lost during the measurement. Furthermore, the influence of oxygen partial pressure, P_{O_2}, on the surface tension was confirmed because oxygen is one of the strongest surfactants for molten metallic melt.

2. Experimental Procedure

A cube of high purity iron with a nominal composition of 99.99 mass% was electromagnetically levitated with a cube of copper with a nominal composition of 99.99 mass% simultaneously and then uniformly melted under a flowing of Ar–He and Ar–He-0.5 vol.%H_2 gases. After the indicated values of sample temperature and oxygen partial pressure of the atmospheric gas, measured by pyrometer and zirconia oxygen sensor, became constant, the oscillation behavior of the droplet was monitored from above at 500 fps for 16 s using a high-speed video camera. The frequencies of the surface oscillations and those of the center of gravity were analyzed from the HSV images using fast Fourier transformation. The surface tension of the droplet was calculated from these frequencies using the Rayleigh[2] equation and the Cummings and Blackburn[3] calibration. The sample composition was analyzed by inductively coupled plasma (ICP).

3. Results and discussion

Figure 1 shows the surface tension of molten Fe–Cu alloys measured by EML. Even though an initial copper composition of the sample was 10 at%(▲), it decreased with elevating the temperature due to the evaporation under Ar–He-0.5 vol.%H_2 gas. As a result, the surface tension of molten sample shows almost the same value regardless of temperature, as shown by a green line. When the copper composition after the measurement was controlled to be 10 at% even at high temperature by adjusting the initial composition and maintained period (●), the surface tension was decreased with elevating temperature as shown by a blue solid line.

Although the P_{O_2} was increased to 10^{-2} Pa under Ar–He gas (◆), the surface tension of molten sample showed almost the same as that measured at P_{O_2} < 10^{-10} Pa under Ar–He-0.5 vol.%H_2 gas, when the copper content in the sample was 10at% after the measurement. It was reported that the surface tension of molten copper is not affected by oxygen adsorption under Ar–He gas at P_{O_2} of 10^{-2} Pa [4]. The surface tension of molten Fe–10at%Cu alloy was clearly lower than the averaged surface tension calculated from the surface tension of liquid iron and copper shown by a bule dotted line, suggesting a surface segregation of copper. Therefore, surface tension of molten Fe–Cu alloy would not be affected by oxygen adsorption under Ar–He gas at P_{O_2} of 10^{-2} Pa.

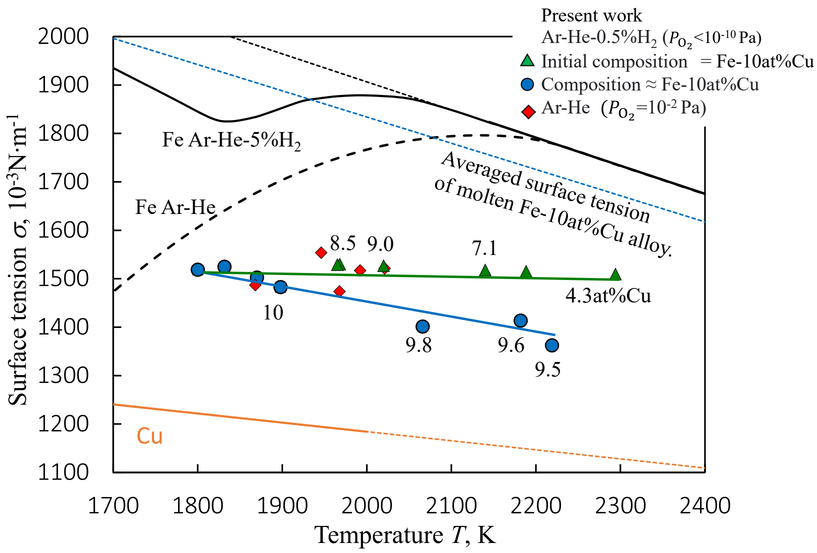

Figure 1. Surface tension of molten Fe–Cu alloys along with literature data of surface tension of liquid iron [5] and copper [4]. The numbers near the plot indicate a copper content in the sample after measurement.

4. Summary

The surface tension of Fe–Cu alloy was measured by oscillating droplet method using the EML. The surface tension of molten Fe–10at%Cu decreased with elevating temperature at P_{O_2}<10^{-10} Pa under Ar–He-0.5vol.%H_2 gas. However, the decrease in the copper content due to the evaporation at high temperature increased the surface tension. Even though the P_{O_2} was increased to 10^{-2} Pa under Ar–He gas, it did not affect the surface tension of the molten when the copper content was 10at% after the measurement.

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References

1) H.Kobatake (2021), Design of Thermal storage material from the aspect of nucleation and their thermophysical properties, https://humans-in-space.jaxa.jp/kibouser/subject/science/73004.html (accessed 2022-07-22)
2) Load Rayleigh Proceeding of The Royal Society of London 29, (1879),71.
3) D. L Cummings, and D. A. Blackburn: J. Fluid. Mech., 224. (1991),395.
4) Y. Takei, S. Ozawa, and M. Nishimura, Thermophysical Properties, Nov.22-24 (2014)
5) S. Ozawa, S. Takahashi, H. Fukuyama, and M. Watanabe. Journal of Physics: Conference Series 327 (2011)