**P16**

# 電磁浮遊法を用いた Fe-Cu 融体の表面張力測定

# Surface Tension Measurement of Liquid Fe-Cu Alloys by Electromagnetic Levitation

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## 1. Introduction

Fe-Cu binary system is known to be characterized by a metastable miscibility gap in a wide composition range at high temperature when it is undercooled below the binodal line. The undercooled melt with hyper-monotectic compositions separates to form small droplets of one liquid phase (dispersed phase) in the matrix of the other liquid phase (continuous phase) at the immiscible liquid region followed by a frozen of the demixed microstructure at room temperature. If small particles of Cu-rich phase are dispersed in the matrix of Fe-rich phase, 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, expecting high thermal storage density, fast thermal exchange rate, high efficiency use at high temperature and so on. The important factors to control the behaviors of dispersed and continuous phases, including their replacement, shape, numbers of droplets and so on, are the surface tension, interfacial tension, and viscosity of the liquid phases as well as the sample composition.

In the present study, Fe-Cu alloys were melted and solidified under levitated state by using electromagnetic levitation (EML) furnace. The temperature profile of the heating and cooling process and microstructure were investigated to obtain a basic data of the liquid separation of the alloy. Furthermore, we measured the surface tension of liquid Fe-Cu alloys.

## 2. Experimental Procedure

One each of cubic copper and iron with the nominal composition of 99.99 mass % was placed on a quartz holder positioned in the electromagnetic levitation coil. These two cubic were electromagnetically levitated at the same time and then melted under the flow condition Ar-He gas mixture (2L/min) with the oxygen partial pressure of $10^{-7}$ Pa. The temperature of the levitated sample was controlled by changing the partial pressures of argon and helium gases together with using a monochromatic pyrometer. The oscillation behavior of the droplet was monitored from above using a high-speed camera at 500 fps for 16 sec. The frequencies of the surface oscillations of the $m = 0, \pm1$, and $\pm2$ for the $l = 2$ mode, and those of the center of gravity (oscillations of the $m = 0$, and $\pm1$ for the $l = 1$ mode) were analyzed from time-sequential data of the HSV images through fast Fourier transformation (FFT). The surface tension of the liquid Fe-Cu alloys was calculated from the frequencies using the Rayleigh equation [1)] and the Cummings and Blackburn calibration [2)].

## 3. Results and discussion

For the measurement of thermophysical properties of liquid Fe-Cu alloys such as the surface tension and interfacial tension, it is indispensable to know the state of the liquid whether it is undercooled single-liquid phase or mixture of separated liquid phases. It was measured the temperature profile of sample during the melting and solidification as one of the ways to investigate it. One example of the results for Fe-50at%Cu alloy is shown in fig. 1, at which the setting emissivity of the pyrometer was selected that the inflection point (A) due to increase in the temperature gradient when the sample was completely melted to be corresponded to liquidus temperature. The temperature profile of the cooling stage shows two inflection points (B and C) before recalescence (D) induced by a crystallization of some solid phase followed by a short plateau (d). Although the inflection point of B is detected at almost the same as the liquidus temperature observed at the heating stage, it is difficult to distinguish it whether it corresponds to formation of primary phase or separation of liquids because the reported binodal line is very closed to the liquidus temperature. The inflection point of C does not correspond to any of the phase transformation temperature described in the equilibrium phase diagram as is the cases of the recalescence and plateau. It would be attributed to a variation of the emissivity of the sample induced by the liquid separation during cooling the sample.

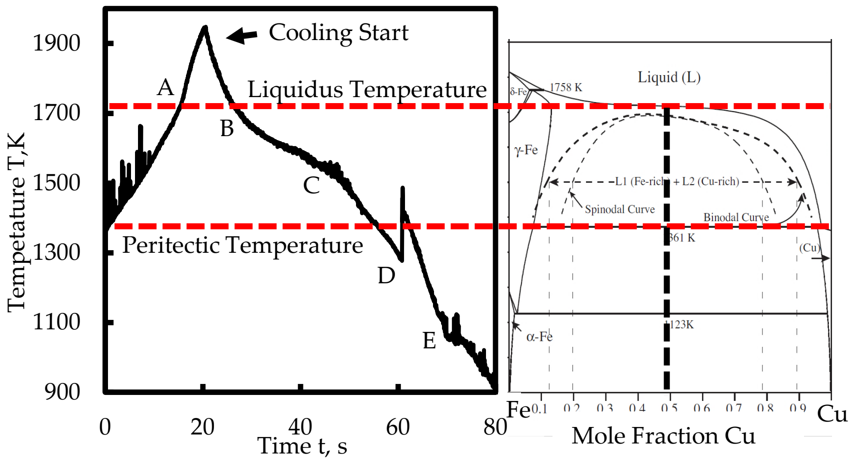


**Fig.1** Temperature profile of electromagnetically levitated Fe-50at%Cu alloy sample and Fe-Cu state diagram3).

Since it is difficult to measure the surface tension of liquid Fe-Cu alloys after liquid separation, the surface tension measurement was carried out at high temperature showing single liquid phase. The surface tension of the liquid alloys at low temperature used to consider the behavior of dispersed and continuous liquids can be expected from the temperature dependence measured at high temperature. Figure 2 shows the temperature dependence of the surface tension of liquid Fe-50at%Cu alloy. The surface tension of liquid Fe-50at%Cu alloys decreased with increasing temperature. The temperature dependence of the surface tension is almost the same as that of liquid copper, suggesting that the surface of liquid alloys is almost covered by copper.

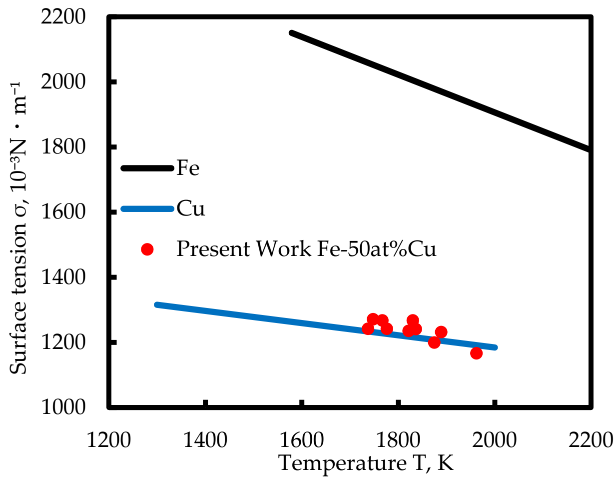


**Fig.2** Temperature dependence of surface tension of liquid Fe-50at%Cu alloy.

## 4. Summary

Fe-Cu alloys were melted and then solidified under containerless state using EML. As a result, it was difficult to measure the phase transformation temperature such as liquid separation by using a pyrometer because of the variation of emissivity of the sample during cooling the sample. it was found that surface tension of liquid Fe-50%Cu alloy is almost the same as that of liquid copper.


## Acknowledgement

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## References


1). Load Rayleigh Proceeding of The Royal Society of London 29, (1879),71.

2). D. L Cummings, and D. A. Blackburn: J. Fluid. Mech., 224. (1991),395.

3). R.P. Shi, C.P. Wang : Acta Materialia 61 (2013) 1229–1243.