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Effect of oxygen on the impurity removal and interfacial phenomena between liquid slag and liquid metal in recycling process

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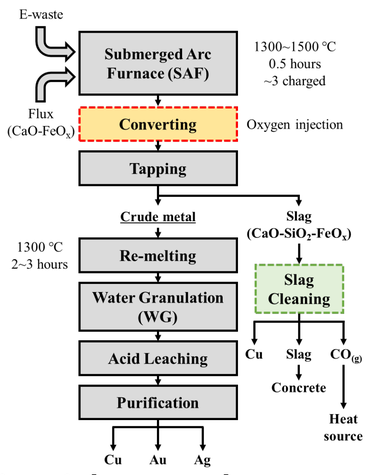
Abstract

In order to understand the effect of oxygen injection on the valuable metal recovery from liquid metal which was obtained from the obsolete copper-based Printed Circuit Board (PCB), a series of high-temperature experiments were conducted using a high-frequency induction furnace at 1673 K. The PCB was melted along with $CaO\text{-}SiO_2$ based pre-fused slag, and oxygen gas was injected in two modes (bottom blowing or top blowing). The change of chemical compositions of the alloy and the slag were analysed using ICP-AES, and the associated interfacial morphology was observed using FE-SEM. As oxygen was injected into the molten alloy, the impurities in the liquid metal were removed. At the same time, the oxygen lowered the interfacial tension between liquid slag and liquid metal which induced metal loss noticeably, thereby increasing Cu loss into the slag phase. Oxygen-blowing conditions should be controlled carefully, depending on the content of impurities in the liquid metal.

1 Introduction

● Converting in recycling process

- Oxygen blowing (converting) is usually applied to remove impurities in molten crude metal.
- In recycling process for valuable element sources, consideration for recovery rate of metal is necessary.
- Because of oxygen blowing, some of metal droplets formed in the slag phase which lowers recovery rate.

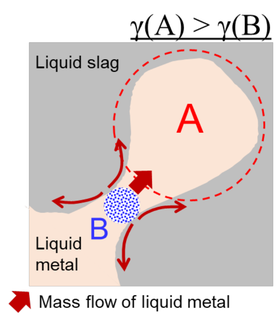


● Effect of oxygen on the property of liquid metal

- Oxygen is known as surface active element of liquid metal, which lowers surface tension of liquid metal.
- Impact of oxygen potential on surface tension of liquid metal can be estimated using Belton's equation.
- In the converting process, oxygen can be accumulated because of excessive oxygen blowing into the liquid metal.

$$\sigma_m = \sigma^o - RT\Gamma_{sat}\cdot\ln(1+K_O a_O)$$

$$\Gamma_{sat} = \frac{1}{-RT}\left(\frac{\delta a_m}{\delta \ln a_O}\right)_{const.}$$



● Interfacial phenomena of liquid metal

- Difference of oxygen potential in a liquid phase induces interfacial flow known as Marangoni flow which induces entrapment of the metallic droplets at the liquid slag/metal interface.

● Aim of research

- *In-situ* observation of impurity removal process during oxygen blowing.
- Investigation for impact of oxygen on droplet formation in recycling process.

2 Experiment

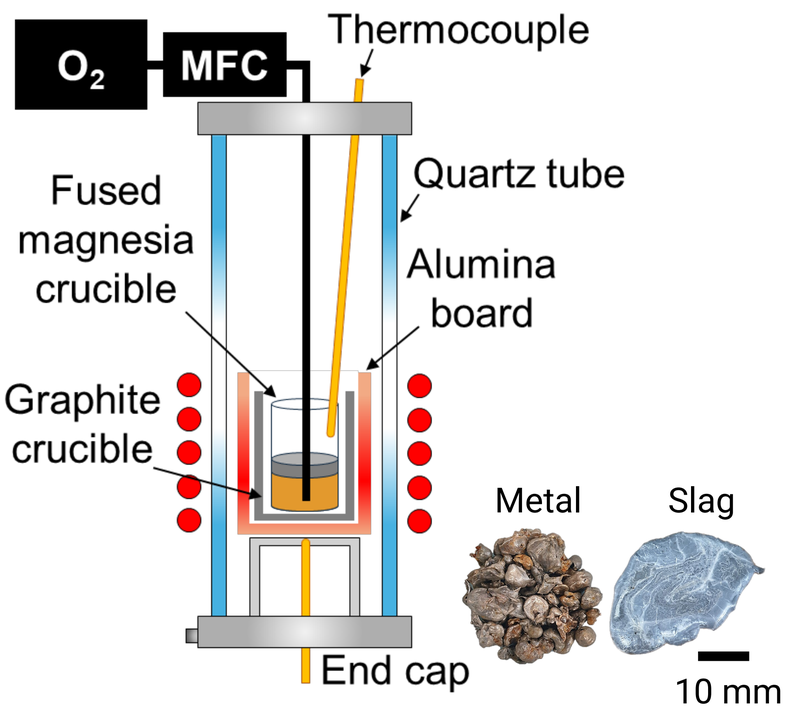
Experimental condition	
Temperature	1673 K
Reaction time	60 min
O_2 flow rate	0.5 L·min^{-1}

Metal	wt%
Cu	Norm.
Fe	10
Si	0.4
O	< 0.003

CASM slag	wt%
CaO	34.65
Al_2O_3	19.20
SiO_2	34.65
MgO	11.50

CSM slag	wt%
CaO	41.20
SiO_2	41.20
MgO	17.60

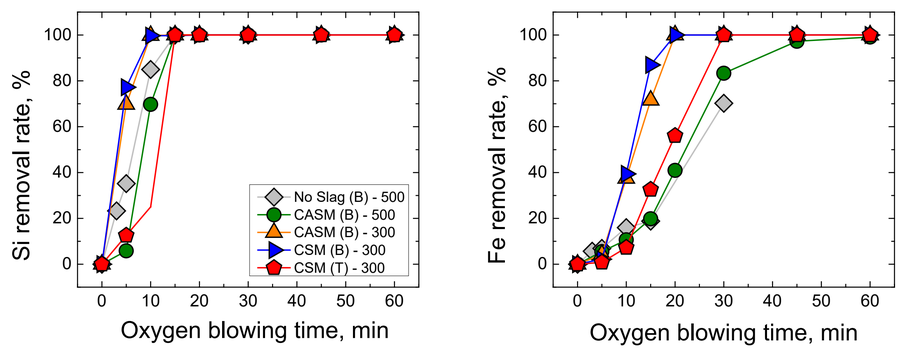
- High frequency induction furnace was used.
- After melting of metal, synthetic slag chips were added using glass tube.
- Oxygen blowing lance was made by alumina.



3 Results and discussion

● Impurity removal regime

- At initial stage, injected oxygen was used to remove impurities in liquid metal. The impurity removal sequence was reasonable.

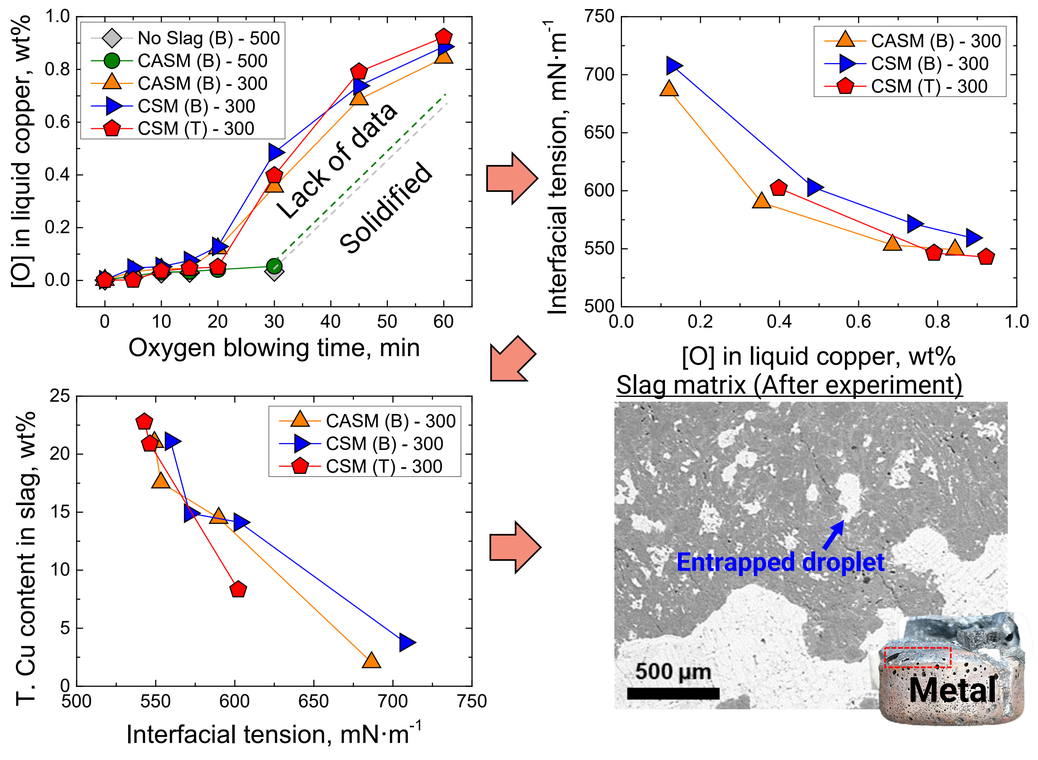


$$[Si]_{Cu} + O_{2(g)} = (SiO_2),\ \Delta G^\circ = -884{,}110 + 232.1T\ (J\cdot mol^{-1})$$

$$[Fe]_{Cu} + \tfrac{1}{2}O_{2(g)} = (FeO),\ \Delta G^\circ = -295{,}000 + 92.5T\ (J\cdot mol^{-1})$$

● Oxygen accumulation regime

- After impurity removal, excessive oxygen accumulated in the liquid copper.
- Oxygen lowered the surface tension of liquid copper, and interfacial tension.
- Significant amount of copper droplet formed in the slag phase.



4 Conclusions

1. At the beginning of the reaction, oxygen was used to remove impurities.
2. After removing impurities, continuous oxygen blowing lowered the surface tension of the liquid metal.
3. Because of lowered surface tension of the liquid metal, the liquid slag/metal interfacial tension was greatly reduced, resulting in metal loss in the form of metal droplets at the liquid slag/metal interface.

References

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