Wetting of Ceramics by Molten Metals

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1. Introduction

The wetting of ceramics by liquid metals is one of the most important processes in the fabricating of metal matrix composites and also in melting and casting of metals, bonding of ceramics to metals, etc. Most of the wetting systems between ceramics and metals are accompanied by interfacial reactions[1]. These interfacial reactions make the wetting phenomena so complicated[1)~3)] that some papers have misinterpreted the nature of the wetting process. So we would like to discuss wetting phenomena from the stand point in fabricating MMC.

2. Measurement of wetting with Meniscograph and Sessile Drop Method

Young proposed treating the contact angle of a liquid as the dynamical equilibrium of a drop resting on a plane solid surface under the balance of three interfacial energies, which is known as the Sessile Drop Method and the Wilhelmy Method or Meniscograph(Fig.1).

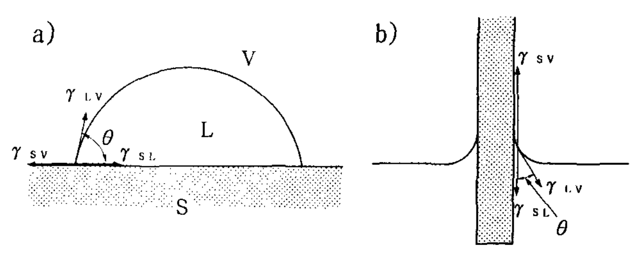

Fig.1 Relationship between contact angle and three interfacial energies. a) Sessile Drop Method. b) Meniscograph.

The equations for the force acting on the specimen are as follows;

$$\cos\theta = (\gamma_{sv} - \gamma_{sl})/\gamma_{lv} \quad \text{------} \quad 1)$$

$$\sin\theta = 1 - \rho g h^2/2\gamma_{lv} = 1 - (h/a)^2 \quad \text{------} \quad 2)$$

where, γ_{lv} is the surface tension of the liquid, γ_{sv} is the surface energy of solid, γ_{sl} is the interfacial energy between solid and liquid and h is the height of the meniscus.

The wetting change over a short time interval is easily obtained from the continuous measurement with Meniscograph. This is the main reason for adopting the Meniscograph for the assessment of the wetting in this investigation. Next we would like to introduce the results of the wetting between graphite and aluminum with Meniscograph.

3. Wetting of graphite (Gr) by Al and Al-Si[3)]

These experiments were carried out with the Meniscograph apparatus previously described[2)] . The experimental conditions were as follows: atmosphere, purified He+3 volume% H_2 (1.05 atm) ; depth of immersion, 10 mm and speed of immersion, 30 mm/ s . The experiments were conducted using 99.99 mass% Al, 99.999 mass% Si and Gr≧99.7 mass% C.

Fig.2 show the wetting curves of Gr by 99.99 mass% Al on a normal time scale and a logarithmic time scale. As can be seen from Fig.2 , the result clearly indicates that there are three phases, namely

Ⅰ : the wetting phase,

Ⅱ : the quasi-equilibrium phase

Ⅲ : the interfacial reaction phase.

But in this experiments, we could not find equilibrium phase.

Ⅳ : the equilibrium phase.

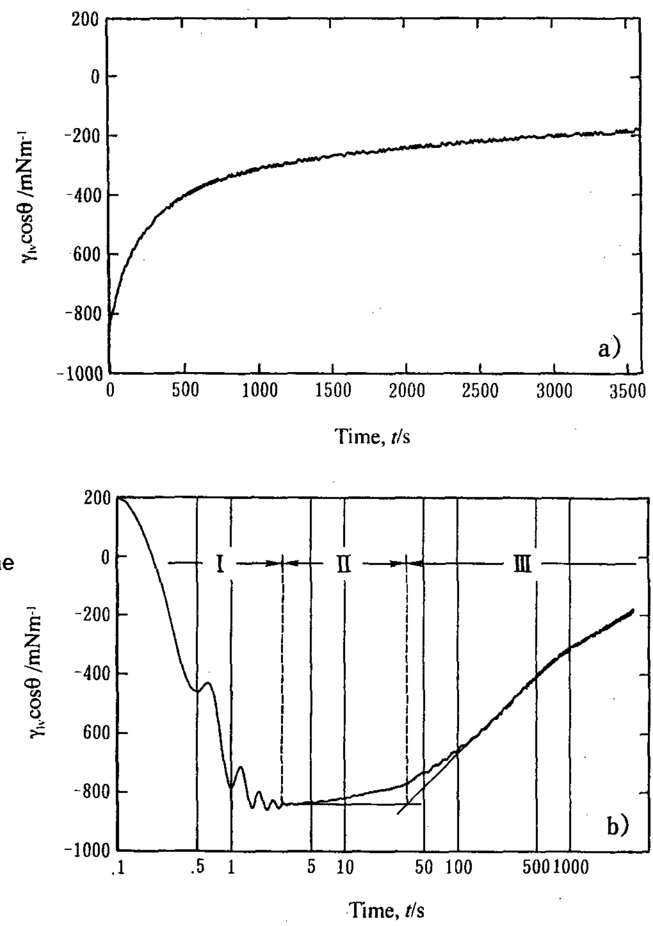

Fig.2 Wetting curves of graphite by Al (1273K). a) Linear time scale.
b) Logarithmic time scale.

The reaction product was analyzed with EPMA and microdiffractometery and the formation of Al_4C_3 was confirmed. In this figure, the value of $\gamma_{lv}\cos\theta$ during the first tens seconds is nearly equal to γ_{lv} of the liquid Al, indicating that $\theta \fallingdotseq 180°$.

The Si contents of aluminium alloys were varied in the experiments (Fig.3). Fig.3 revealed that the speed of wetting in the interfacial reaction phase (interfacial reaction wetting speed) is influenced with the Si contents and that a critical value must exist between 10 mass% and 20 mass%.

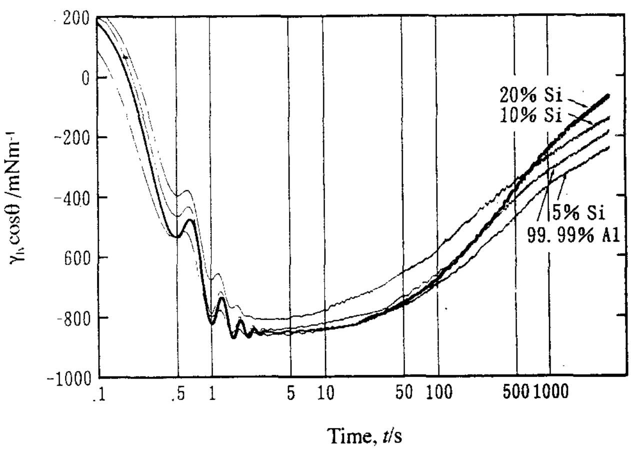

Fig.3 Wetting curves of Gr by Al and Al-Si alloys (1273K)

The reaction products were mainly Al_4C_3 which was confirmed with EPMA and X-ray diffraction, and SiC was observed only in case of 20 mass% Si. These phenomena must be dependent on the activity of Si in liquid the aluminium. The stability of the two reaction products is considered to be represented by the following : $Al_4C_3(s) + 3Si(l) = 3SiC(s) + 4Al(l)$

It was confirmed by the thermochemical calculation that SiC will be stable in aluminium alloys containing more than 13 mass% of Si at 1273K. These results show that the speed of wetting within the third phase depends on the nature of the chemical reactions.

4. Summary

In all the experimental results for Gr/Al and Al-Si alloys, similar wetting curves with time are obtained. Analysis of the overall results indicates the following results:

1) Wetting speed in phase I is the most important value for soldering, joining, casting, plating and fabricating of MMC, etc. And as for the measurement, Meniscograph is appropriate

2) The contact angle in phase II should be adopted as a measure of wettability of the original system, S_0/L_0.

3) Wetting speed in phase III and the contact angle in phase IV depend on interfacial reaction products.

5. References

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3)H.Nakae,K.Yamamoto and K.Sato ; J. Japan Inst. Metals, 54(1990),839