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Wetting and Reaction Characteristics of Al₂O₃/SiC Composite Refractories by Molten Aluminum and Aluminum Alloy

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The reactive wetting behavior in molten aluminum and Al alloy was investigated by the sessile drop method for three alumina-silicon carbide composites, namely TC, TQ, and MC. The initial contact angle for all the three refractory substrates was obtuse in spite of a gradual decrease with time in the first hour of the experiment. TC showed a higher contact angle than TQ and MC. The difference in wetting properties among these refractories is attributed to their compositional and micro-structural variations. The effects of magnesium in the molten Al alloy on the wetting kinetics and the reaction with the refractory substrates are also discussed.

Introduction

There is a greatly increased interest in reducing the corrosion of refractory materials in the metallurgical processing industries. The refractory erosion and corrosion products can be sources of nonmetallic inclusions and contamination of aluminum, which leads to energy

*Xingbo.liu@mail.wvu.edu © 2007 The American Ceramic Society and production losses. One of the approaches adopted to minimize the corrosion is to reduce the metal-ceramic contact surface by reducing the wettability between the ceramic and liquid metal. Many studies were performed to investigate the molten aluminum (Al) penetration in various ceramic materials.¹ The majority of these studies addressed the penetration of SiO₂ substrates by molten Al.^{2–7} Specific reports of exposure of SiC base plates to molten Al were found.⁸ Various crystal configurations of SiC were tested on wetting with molten Al in order to study the crystal plane directional effects on the contact angle.⁹ Additionally, research regarding the wetting properties of molten Al on polycrystalline TiO₂ substrates¹⁰ and the wettability of TiC by molten Al has been reported.¹¹ Wetting SiC by molten aluminum alloys was also studied in the field of silicon carbide-reinforced aluminum matrix composites.^{12,13} Most of the past effort on this topic was to improve the wetting of SiC by aluminum on modifying the aluminum with surface active alloying elements and/ or the SiC by surface coating.¹⁴

For the interaction of SiO₂ substrates with molten Al, a linear dependence of the reaction-layer thickness and composition with time was found.^{2,6} In addition, the wetting behavior was dependent on the formation of a reaction zone by redox reactions and consisted of three different regions with varying chemistries, dependent on the interdiffusion of Si²⁺, Al⁺, Al²⁺, and Al^{3+,3} During a reaction, it was found that Si is released into the liquid metal and diffuses toward the Al source.⁵ This reaction was found to occur in up to five separate steps.⁷

On the other hand, the penetration of silica refractories by molten Al at 700-1000°C was studied by Brondyke using both traditional cup testing and immersion testing.⁴ All tested commercial alumina-silica refractories, used for aluminum melting applications, were found to be wetted and subsequently penetrated on exposure to molten Al. The results indicated that the problems associated with alumina-silica refractories resulted from the penetration of molten Al, side-wall build-up, and formation of corundum and metallic silicon due to the metal reaction of Al with the Si and Si-bearing constituents. Subsequently, there was an increase in the volume of the penetrated product, which would lead to generation of tensile stress due to aluminum oxide build-up caused by oxidized aluminum and its alloy components around the metal line. The presence of tensile stress would ultimately cause cracking in the refractories. In addition, dissolution of Si occurred in the molten Al, with the penetration rate controlled by diffusion of Al and Si through the aluminum oxide.

Regarding the wetting of Al_2O_3 by Al alloys, it has been found that the contact angles between the Al_2O_3 substrate and molten pure Al decrease with time and reach 82° after 4500 s at 1300°C.¹⁵ In addition, adding La and Y in the molten Al can reduce the contact angle to 57° and 69°. It was also found that Cu (up to 33%) and Ni (up to 6%) in molten Al have no effect on the wetting characteristics of Al_2O_3 .¹⁶ In this work, the wettability and corrosion of different compositions of SiC-Al₂O₃-Al-Si composite refractory materials by liquid Al/Al-Mg systems were investigated. Wetting was studied by the sessile drop method, while corrosion was studied through the characterization of the solid-liquid interfaces using spectroscopic methods. From results of this testing, the wetting and corrosion mechanisms are examined.

Experimental Procedure

Materials

Three composite refractory materials studied, which were supplied by Fireline TCON Inc., (Youngstown, OH) contained a continuous microscopic network of interpenetrating microscopic-scale ceramic and metallic phases. The presence of metallic phases provides a significant improvement in toughness and damage tolerance, while the ceramic phases would lead to high hardness and improved performance at elevated temperatures. The compositions of these materials are listed in Table I. The microstructures of these three composite refractories are shown in Fig. 1.

The TCON materials evaluated in the present study are produced utilizing the displacement reactions in the following equation:

$$\begin{array}{ll} 3\text{SiO}_2 + 4\text{Al} \rightarrow 2\text{Al}_2\text{O}_3 + 3\text{Si} & (\text{base reaction}) \\ 3\text{SiO}_2 + (\text{phases}) + 4\text{Al} \rightarrow & \\ 2\text{Al}_2\text{O}_3 + (\text{phases}) + 3\text{Si}^* & \\ (\text{*Si retained in the final product is} < 5\%) & \\ & (1) \end{array}$$

Owing to volumetric contractions caused by loss of silica and formation of alumina, void spaces created as the reactions proceed (starting from the outside surfaces) would be completely filled with Al metal. The silicon by-product subsequently dissolves into molten Al, with the resulting composite containing 70 wt% (63 vol%)

Table I. Refractory Substrate Compositions

Composition (wt. %)	МС	ТС	ΤQ	
Silicon Carbide	54	50	/	
Aluminum Oxide	38	35	70	
Aluminum/Silicon	8	15	30	



Fig. 1. Microstructure of refractory materials (a) MC, (b) TC, and (c) TQ.

 Al_2O_3 and 30 wt% (37 vol%) aluminum-silicon alloy. The process of transforming a silica pre-form into a TCON component is efficient, in that there are minimal dimensional changes; the part's shape and size are essentially unchanged as the silica is converted to the alumina-aluminum alloy composite. In addition, silicon carbide particles can be added to the composites to increase the toughness, strength, wear resistance, and thermal shock resistance.

Refractory plates $(12 \text{ mm} \times 12 \text{ mm} \times 3 \text{ mm})$ were used as substrates in subsequent wetting studied. Aluminum pigs (99.99% pure) and aluminum alloy 5083, with the composition given in Table II, were machined down to cubes $(5 \text{ mm} \times 5 \text{ mm} \times 3 \text{ mm})$ for melting during static testing or wire segments of 3 mm diameter that were melted to produce sessile drops during dynamic testing. Experiments were carried out in purified Ar-4% H₂ at 900°C and changes in contact angle between molten Al and refractory substrates were monitored with time using a high-speed CCD camera.

Wetting Tests

Static and dynamic sessile drop methods were used for studying the wettability. According to the static method, which is the most conventional method, a solid cube of Al/Al alloy is placed on the refractory substrate before heating. A modified dynamic method was also used in which a molten Al/Al alloy was dropped on the refractory substrate by a heated delivery device. This

modified method was developed to study the dynamic wetting behavior of the refractory/metal system as this approach has been suggested to be closer to the application conditions.⁷ The apparatus used for both methods of sessile drop experiments is schematically illustrated in Fig. 2. It consisted of a 33 kW horizontal circular infrared furnace, using an evacuating system with a rotary pump and a refilling gas system supplying purified Ar-4%H2. The quartz furnace chamber was enclosed on one end by a copper lid and slide device, which was used to move the experimental assembly inside the chamber. A small-diameter quartz tube was also passed through the copper lid and extended to a location directly above the sample substrate where the tube was bent 90° and its diameter was reduced. This tube was used to contain the Al/Al alloy wire segment during heating and melting, which produced the molten metal drop for the dynamic test. Both sealed end caps of the furnace assembly contained quartz windows, allowing a color CCD camera to monitor the experiments continuously. The resolution of the camera was 640×480 . Three Type-S thermocouples (with ceramic sheath) were inserted into the horizontal quartz test chamber through the copper end plate to monitor the refractory substrate temperature, molten metal drop temperature, and the reaction temperatures, respectively.

Before the experiment, the refractory substrate and the Al/Al alloy cube or wire segment were ultrasonically cleaned in acetone. The substrate was then carefully slid into the center of the horizontal chamber. For the static

Table II. Chemical Composition of Aluminum Alloy 5083

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	7n	
Wt. %	92.4-95.6	0.05-0.25	Max 0.1	Max 0.4	4_4 9	0 4_1	Max 0 4	Mar 0.15		
						0.1-1	IVIAX 0.4	101ax 0.15	Max 0.25	



Fig. 2. The sessile drop unit, schematic sketch.

sessile drop method, a cube of Al/Al alloy was placed on top of the refractory substrate. The sealed chamber was evacuated to a vacuum of 1×10^{-6} Pa and then refilled with the purified Ar-4%H₂ gas. Following evacuation and refilling, the IR quartz chamber was heated to 900°C at a rate of 30°C per minute. The cube of metal was allowed to melt and the wetting behavior between the metal and refractory substrate was observed.

For the dynamic sessile drop method, a wire segment of an Al/Al alloy was placed in the quartz tube used for delivering molten metal to the substrate. This tube was inserted through the copper end plate into the IR chamber. The chamber was evacuated and refilled, in the same manner as for the static test. While the Al segment in the quartz tube was kept in the cold zone, the IR quartz chamber was heated up to 900°C at a rate of 30°C per minute. The furnace was allowed to stabilize for 20 min before the Al segment was slowly moved from the cold zone to the hot zone of the furnace where it was allowed to melt and pass through the vertical portion of the delivery tube as a molten drop onto the refractory test substrate. Similar to the static test method, the entire duration of the experiment was captured and recorded by the camera and VCR, from which the video still frames were extracted and analyzed to determine the contact angle changes with the time.

At the end of each experiment, the substrate was removed from the furnace and prepared for examination by a scanning electron microscope (SEM), energy dispersive spectroscopy (EDS), and electron microprobe. Further data analysis was carried out using axisymmetric-drop-shape-analysis (ADSA) software, by which the contact angle (CA), the drop base diameter (D), and drop height (H) were directly measured from the drop profiles.

Experimental Results

Contact Angle

Contact angle and drop dimensional analysis for a composite refractory (TC) and molten Al system is discussed here as an example of the behavior exhibited by these materials. Figure 3 shows optical micrographs of a molten aluminum drop on the TC substrate during isothermal dwelling at 900°C, illustrating the changes in contact angle and drop geometry with time. The initial contact angle between the TC substrate and liquid Al was an obtuse angle of $\approx 125^{\circ} \pm 1^{\circ}$. This value is similar to the value (120°) reported by Z. Yu for the Al₂O₃-Al system at 900°C.¹⁷ The contact angle was found to decrease gradually to a value of 82° during a hold time



Fig. 3. Wetting progress of a molten Al droplet on a TC substrate at 900°C.

of 65 min. The present experimental results are similar to the Al₂O₃-Al system data reported previously, ^{15,18} in which a steady value of 82° was observed after 40 min at 1000°C. Yet, for the literature, the drop height continued to change with the dwell time until the end of the 120-min experiment, when it reached an angle of 78°. This final state was considered to represent the onset of wetting and the build-up of reaction equilibrium. Differences between the current experimental case and the literature cases are expected to be due to the differences in experimental temperature and substrate chemistries.

Four parameters, namely, contact angle (CA), drop volume (V), drop base diameter (D), and drop height (H), were plotted on a linear time scale revealing the wetting kinetics as shown in Fig. 4. The change in contact angle characterized by the advance of the triple phase reaction (where the solid substrate, liquid metal, and gaseous experimental environment are in contact) was due to the decrease in the drop height and/or the increase in the drop base diameter. The determinant factor was found to switch during the different substages of the wetting process, leading to the maximum of the drop volume achieved after 10 min of contact. The wetting kinetics could be inferred by a combination of the changes in contact angle with those in drop size.^{7,19} After the initial rapid spreading stage (around 10 s), the interfacial front advanced quickly, resulting in the steep slope found in the initial portion of the contact angle plot and until the drop volume reached a maximum. After the initial stage, the decrease in drop height was dominant over the increase in drop base diameter, resulting in a decrease in the overall drop volume. Finally, a steady state was attained at around 65 min, during which CA, V, D, and H remained unchanged.

Figure 5 shows the contact angle plots for the sixtested system, namely three types of composite refrac-

tory substrates wet by two types of molten metal drops. During the 5000-s dwell time, all the values of contact angle were found to be larger than 90 degree. Among these three materials, the TC base material displayed the best wetting-resistance performance among the three TCON substrates, regardless of wetting with either a pure Al or a 5083 AlMg alloy. It was also found that for all the three materials, the contact angles with pure aluminum are always higher than that with the molten 5083Al-Mg alloy, which means Mg addition in the molten Al drop aids the wetting process and interaction with the base materials. This is believed to be the result of formation of Mg silicides and/or carbides at the metal/refractory interface.²⁰ These interfacial chemical reactions play an important role during the course of wetting and thus, are important from the point of view of wettability. More reaction details are discussed in the following sessions. Comparing the wetting behaviors among three TCON substrate materials, TC surpasses the other two in the property of wetting resistance against a molten Al/AlMg alloy, as shown in Fig. 5. TQ and MC are comparable with each other during the

Interfacial Morphology

Following completion of the experiments, polished cross sections of samples were prepared using the standard metallographic procedures. The metal/refractory interface was examined by SEM/EDX and an electron microprobe to determine the chemical elements present and distribution, as shown in Fig. 6.

Interfacial regions for all three types of refractory showed a high concentration of silicon in the Al drop, indicating that the silicon diffused from the refractory substrate into the liquid Al drop during the experiment.







Fig. 5. Variations in contact angle of three types of refractory substrates with a liquid Al/Al alloy during dwelling at 900°C.

It is known that the solubility for Si in Al at 900°C is 36 %wt Si.²¹ The observation of Si in the Al alloy drop by SEM meant that the Si content in the drop was higher than its solubility. In addition, low levels of Mn, Cr, and Fe were also detected in the microprobe mapping at both sides of the interface.

During the wetting process, Al was found to penetrate into the porosity of the refractory substrate. The diffused liquid Al joined with the existing residual Al metal present in the composite refractories, inhabiting both the porosity as well as the positions vacated by the diffusing silicon. It was reported from the research of the Al–Si–C ternary system (Fig. 7) that thermodynamically three-phased monovariant equilibrium can be reached by reacting aluminum and SiC at temperatures above 650° C.^{22,23} The equation for such a reaction is

$$4\mathrm{Al}(l) + 3\mathrm{SiC}(s) \rightarrow \mathrm{Al}_4\mathrm{C}_3(s) + 3\mathrm{Si}(s) \qquad (2)$$

For a long time, it has been commonly accepted that SiC was not attacked by aluminum. In fact, it is now established that at the temperatures above the melting point of Al, SiC becomes thermodynamically unstable and an invariant reaction occurs at 650°C and leads to the formation of aluminum carbide Al₄C₃ and silicon according to the above reaction. Silicon formed in this reaction dissolves in unreacted aluminum.²⁴ The formation of Al₄C₃ was observed in BSE photomicrographs and microprobe mapping of the cross section of the molten aluminum 5083 alloy droplets on TC (Fig. 6b) and MC substrates (Fig. 6c), both of which contain SiC particles in the tested substrate materials. In Fig. 6b and c, it is found that along the jagged outlines of SiC particles, Al₄C₃ forms dark crystallites non-uniformly distributed on the surface of the SiC particles. The Al₄C₃ crystallites tend to join together, forming a reaction zone with an average thickness of about $1-2 \,\mu m$. This reaction zone still remains discontinuous and small



Fig. 6. BSE photomicrographs and microprobe mapping of the cross section of the molten aluminum 5083 alloy droplets on (a) TQ, (b) TC, and (c) MC substrates at 900°C for 1 h.



Fig. 7. (a) Al–C–Si phase diagram at temperature of 900°C (1173 K) and (b)Al–Si phase diagram.

notches in which SiC being in close contact with the Al-Si alloy can be observed. The non-uniformity of the Al_4C_3 layer and the well-facetted character of the constituting crystallites are clearly visible in the back-scattered electron micrograph shown in Fig. 6c12.

Figure 8 shows back-scattering images (BSIs) of the TC substrate following wetting by pure molten aluminum and 5083 aluminum-magnesium alloy drops after 2 h at 900°C. Plenty of Si was found scattering in the Al drop from Fig. 8a, confirming that free Si diffused from TC base to pure Al drop because originally molten Al drop did not contain Si. Si diffusion was driven by the concentration gradient of Si in Al, resulting in more Si precipitation at the interface due to the short diffusion distance compared with the regime far away from the interface. This finding is in accordance with the observations that interfacial regions are the preferred position for the element transferring across the interface and into the other phase.^{10,25} Figure 9 shows back-scattering SEM micrographs of molten aluminum-magnesium alloy drops on TQ, TC, and MC substrates after the sessile drop experiments at 900°C for 1 h.

By comparing the wetting behavior of pure aluminum with that of the aluminum alloy, the results showed that the Al alloy exhibited a larger drop base area and lower drop height, thus leading to a smaller contact angle than that obtained for pure Al. This contact angle difference, based on the drop dimension after the wetting tests, suggests that the alloying magnesium promoted the wetting of the refractory with the molten metal drop. When heated up to the testing temperature, magnesium in the molten 5083 alloy readily diffused into the substrate across the interface, leaving the metallic drop without magnesium.



Fig. 8. Back scattering scanning electron photomicrograph of a section of the TC substrate reacted with (a) a molten Al droplet, and (b) a molten Al 5083 alloy droplet, after 2 h at 900°C.

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Fig. 9. BSE photographs of the sections of the molten aluminum 5083 alloy droplets on (a) TQ, (b) TC, and (c) MC substrates at 900°C for 1 h.

Discussions

Wetting Characteristics

The wetting mechanism of the systems studied could be described as follows: in general, the wettability of a solid by a liquid is indicated by the contact angle. The contact angle, θ , between solid, liquid, and gas/vapor is related by the Young–Dupre's equation²⁶ shown in the following equation

$$\cos\theta = \frac{\gamma_{\rm sv} - \gamma_{\rm sl}}{\gamma_{\rm lv}} \tag{3}$$

where γ_{lv} is the surface tension of the liquid metal, γ_{sv} is the surface energy of the solid, and γ_{sl} is the solid/liquid interfacial energy. Based on the above equation, the contact angle, θ , can be decreased by increasing the surface energy of the solid, γ_{sl} , decreasing the solid/liquid interfacial energy, γ_{sl} , or by decreasing the surface tension of the liquid, γ_{lv} . During heating, the silicon is believed to diffuse from the refractory substrate into the molten Al drop. The drop volume will therefore increase because of the silicon diffusion. as indicated by Figs. 4 and 6. As the wetting test goes on, the silicon can reduce the surface tension of molten aluminum, and thus γ_{lv} is decreased¹ by the adsorption of silicon on the interface and surface (see Fig. 6) of the liquid. In the meantime, the solid/liquid interfacial energy, γ_{sl} , can also be decreased due to the enrichment of silicon on the interface. As a result, the contact angle, θ , will be decreased.

Effects of Magnesium in the Alloy on Wetting Behaviors

It is well known that Mg²⁷ enhances the wetting of SiC by molten aluminum. Previous studies have shown

that the addition of a reactive metal, that is, Mg, to the liquid drop accelerates the interaction with the substrate.^{28,29} It has been shown that magnesium additions to aluminum lower molten drop surface tension³⁰ and its work of immersion in SiC.³¹ Consequently, aluminum alloys that are specifically designed for infiltration of SiC beds have invariably contained varying amounts of Mg. Another investigation indicated that one of the main functions of Mg as a surfactant element is to reduce any aluminum oxide that may be present in the interface.³² Although Al₂O₃ is thermodynamically stable in contact with molten Al, when the alloy contains Mg, several reactions that may cause the reduction of Al₂O₃ are possible³³; these include:

$$3Mg(l) + Al_2O_3(s) \rightarrow 3MgO(s) + Al(l)$$

$$\Delta G = -4.256 \text{ kcal } (900^{\circ}\text{C})$$

$$Mg(l) + \frac{4}{3}Al_2O_3(s) \rightarrow MgAl_2O_4(s) + \frac{2}{3}Al(l)$$

$$\Delta G = -7.164 \text{ kcal } (900^{\circ}\text{C})$$

$$Mg_(l) + 2Al(l) + 2O_2 \rightarrow MgAl_2O_4(s)$$

$$\Delta G = -420.19 \text{ kcal } (900^{\circ}\text{C})$$

In the case of TCON refractory materials, which contain SiC, Al_2O_3 , Al, and Si, the magnesium, arising from the molten drop, can diffuse and react with the TCON base according to equation 5. The Gibbs free energy is provided to 3 reactions in Eq. 5, all of which are negative. This means theoretically those reactions could occur under the experimental conditions (900°C). Mg is also capable of forming magnesium aluminum spinel with different stoichiometries. The microchemistry of these reaction products in the interface is important from the point of view of wettability.³⁴ Considering the reaction kinetics under the experimental

conditions in this paper, Mg penetrates into the base materials, reacting with Al₂O₃ by forming MgO crystallites that intimately contact with Al₂O₃ crystallites leftover. This process accelerates the wetting behavior, even if the formation of the MgAl₂O₄ spinel does not necessarily occur. As shown in Table I, the chemical composition of three TCON substrates, Al₂O₃ content of TQ, TC, and MC is 38%, 35%, and 70%, respectively. With the lowest Al₂O₃ percentage, TC shows the best wetting resistance during the sessile drop test, as shown in Fig. 5. In addition, the grain size, distribution, and morphology of Al₂O₃ particles in TCON substrate materials play an important role into its wettability. It is well known that the round-shaped Al₂O₃ particles have less surface area than the angular-shaped Al₂O₃ particles in morphology, leading to less reaction sites in contact with Mg based on the reactions in Eq. 5. Palasamudram and Bahadur reported that the reaction rate increases with increases in particle angularity.³⁵ From Fig. 6, it is clear that TC has Al₂O₃ particles that are not clustered and has a rounded shape, while TQ and MC has Al₂O₃ particles clustered and has an angular shape. Rounded particle reinforcements are preferred in a metal matrix because sharp corners associated with angular particles can act as points of stress concentration where cracks may initiate as mechanical deformation proceeds.³⁶

However, magnesium has a low vapor pressure and is, thus, easily lost from aluminum alloys at an elevated temperature: $AI[Mg] \rightarrow AI + Mg(g)$. The presence of a protective atmosphere (Ar-4%H₂) and its flow helps to remove the Mg vapor from the wetting system. This could explain experimental results wherein no Mg was found from TCON samples after sessile drop tests with an Al-5Mg liquid drop applied.

Effects on Si and Al in the Refractories on the Wetting Behavior

On the other hand, Si was found to have a negative effect on increasing the contact angle. It has also been found that free Si around SiC particles improve the spreading of molten aluminum on the SiC substrate.¹² Moreover, it has been shown that aluminum alloys better wet siliconized SiC substrates than unsiliconized SiC substrates. This can be attributed to a chemical reaction in which both Si and aluminum are active participants.¹³ The regions enriched with free silicon behaved as preferential diffusion paths with the formation of an {A1–Si} solution.¹ This may be explained by referring to

the Al–Si Binary phase diagram shown in Fig. 7. At 900°C, when a drop of liquid Al (indicated by point C) on the phase diagram contacts Si (indicated by point A), wetting occurs readily as the Si from substrate becomes a participant in a reaction that changes its surface composition toward equilibrium (indicated by point B). Simultaneously, the liquid Al becomes a participant in a reaction that changes its composition toward point B. Figure 6 shows the dissolution of silicon from the TCON into an aluminum alloy at the interface. The contribution of the reactions to reactive wetting may be represented mathematically by modifying Young's equation for a non-reacting, steady-state sessile drop to include the contribution of the free energy of the reaction³⁷:

$$\gamma_{\rm sv} - (\gamma_{\rm sl} + \Delta F_{\rm r}) = \gamma_{\rm lv} \cos \theta \tag{5}$$

It was also found that Al additions to TCON substrate had a positive effect in increasing the contact angle by reducing the compositional gradient of Al diffusion from molten drop to TCON base, slowing down the diffusion rate, and thus, resulting in better wetting resistance of the base materials. To rank the wetting performance of three types of TCON materials, a combined consideration should be made of Al, Si, and Al_2O_3 contents in TCON.

Conclusions

Reactive wetting tests were carried out in an Ar-4%H₂ atmosphere using Al and Al-Mg alloys in contact with three types of alumina-SiC composite refractory materials. The interaction resulted in contact angle values that were initially obtuse, but changed to acute angles in most cases. Some wetting and reaction mechanisms were discussed based on the identification of changes of contact angles and drops dimensions as well as the interfacial elemental mappings.

Among the three refractory substrates tested, namely TC, TQ, and MC, it was found that TC showed a higher contact angle values than TQ and MC, which indicated that TC shows better nonwetting performance in a molten Al/Al alloy. The difference in the wetting properties among three types of refractories is attributed to their microstructural and compositional variations.

A strong diffusion of silicon from the substrate into the liquid metal drop was observed and silicon was noted to accumulate on the interface and surface area of the drop. Additionally, Al was found to move into the refractory.

The Mg found in the 5083 alloy apparently promoted the wettability of molten Al on refractory substrates as noted by the observations of changes in the wetting behavior.

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