Chapter 15
Wetting and Joining of Structural Ceramic Components

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ABSTRACT
This chapter summarises the recent studies on the wetting behaviors of ceramics which include carbides, oxides, nitrides, and borides at a wide temperature range and under various atmospheres. Also, their joining experiments, mainly by brazing and reaction joining methods, are reviewed. The typical and fundamental physical, mechanical, and microstructural examinations, such as contact angle, joint strength, and interlayer structure, are also presented.

INTRODUCTION
Successful applications of ceramic materials in many structures and components need some types of ceramic-metal joining. Two main factors derive the need for the development of joining techniques: (1) the difficulty to fabricate large ceramic structures with complex shapes; (2) the requirement of ceramic only in one part of a structure. For the practical applications, it will be necessary to join the ceramic to either another ceramic, or to a metal. The development of feasible joining techniques will facilitate the adaptation of advanced ceramics into complex and multifunctional structures.

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During the joining process, one of the most important underlying issues is related to the wetting properties between ceramic substrate and metal or alloy. For this purpose, in this chapter, we have summarized the wettability between ceramics and metals in recent 10 years, and focused on the frequently used joining methods (brazing, glass joining and melt infiltration joining), and subsequently generalized the common regularities in wetting tests for each material system.

THEORETICAL CONSIDERATIONS

Wetting

Wetting is the ability of a liquid drop to keep contact with a solid surface. The degree of wetting is qualified by a contact angle ($\theta_C$), at which the liquid-vapor interface meets the solid-liquid interface, as shown in Figure 1. The contact angle is governed by the balance between adhesive and cohesive forces and it provides an inverse measure of wettability.

If we denote the solid-vapor interfacial energy as $\gamma_{SG}$ (or surface energy), the solid-liquid interfacial energy as $\gamma_{SL}$ and the liquid-vapor interfacial energy as simply $\gamma_{LG}$ (surface tension), we can use the following equation to describe the equilibrium (known as the Young Equation) (Young 1805):

$$\gamma_{SG} = \gamma_{SL} + \gamma_{LG} \cos \theta_C$$

Generally, a low contact angle ($\theta_C < 90^\circ$) means that wetting of the solid surface is very favorable, and hence the liquid will spread over a large area of the surface. A high contact angle ($\theta_C > 90^\circ$) usually indicates that wetting of the solid surface is unfavorable, and thus the liquid will minimize the contact area with the surface and form a compact drop.

It is important to study the wetting behavior of metal or glass liquids to a ceramic material. For instance, the joining of ceramics to metals by active metal brazing depends on the wetting of the ceramic by the braze filler. In the electronics industry,
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