Wetting and strength in the tin–silver–titanium/sapphire system

The wetting of tin-silver-based alloys on Al₂O₃ has been studied using the sessile-drop configuration. Small additions of Ti decrease the contact angle of Sn-3 wt.% Ag alloys on alumina from 150° to 25°. However, a wide variability in contact angles and spreading rates is observed. The variability is related to the kinetics of Ti dissolution in the alloy and the formation of triple-line ridges. Enhanced spreading is not accompanied by the formation of a continuous reaction layer at the metal/ceramic interface. Furthermore, no reaction product could be detected after tests performed at temperatures below 800°C. The average mechanical strength of metal-ceramic bonds fabricated under parallel conditions ranged between 40–110 MPa. In all cases, fracture of the joints occurred at the metal-ceramic interface. The formation of a discontinuous reaction product decreases the strength of the bonds fabricated at higher temperatures.

Keywords: Sn₃Ag; Wetting; Metal-ceramic joining; Interfaces

1. Introduction

New low-temperature brazing alloys are required in many applications to integrate components that decompose or degrade above threshold temperatures. Traditionally, a key component in the design of brazing alloys for ceramic joining is the addition of reactive elements such as Ti, Cr, Zr, etc., in order to enhance spreading. The improved wetting resulting from the addition of reactive elements is usually associated with the formation of new compounds at the solid/liquid interface. However, it is unproven whether compound formation is actually necessary for enhanced wetting or, mechanistically, how the potential for compound formation translates into the capillary forces that specifically drive spreading of the fluid. Recently, an alternative approach has been proposed that focuses on the adsorption of the reactive element at the solid–liquid interface before the nucleation of the reaction phase as the critical step that reduces the interfacial energy and drives spreading [1].

Tin-silver-based alloys have emerged as a lead-free alternative to the traditional solders used in the microelectronics industry [2–3]. In this work the effect of Ti additions on the wetting and bonding of tin-silver-based alloys to alumina is analyzed. Sn–Ag–Ti alloys are also of theoretical interest. It has been observed that the wetting of Sn-based alloys on ceramics can be greatly enhanced by the addition of titanium, but in our work no reaction products could be detected at the metal-ceramic interface, as is commonly observed in other systems [1]. These observations indicate that spreading to low contact angles can be driven by adsorption at the interface either without a reaction phase, or before one is formed. In situ neutron reflectometry studies of Sn–Ti/alumina interfaces have shown segregation of titanium at the ceramic-metal interface without formation of reaction products at the experimental temperatures [4]. Derby et al. [4] have shown that interfacial oxides of Ti appear at the Ag–Cu–Ti/sapphire interface only after solidification.

The present work focuses on the study of the wetting behavior of Sn–Ag–Ti alloys on sapphire. The spreading of the molten metals at different temperatures has been ana-