

The effect of thin interfacial layer on the mechanical properties of metal/Zerodur heterogeneous bonding

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Heterogeneous bonding between metals and ceramics is of significant relevance to a wide range of applications in the fields of industry, defense, and aerospace. Metal/ceramic bonding can be used in various specific part applications such as vacuum tubes, automotive use of ceramic rotors, and rocket igniter bodies. However, the bonding of ceramic to metal has been challenging mainly due to (1) the low wettability of ceramics, on which the adhesion of molten adhesive bonders is limited and (2) the large difference between the coefficients of thermal expansion (CTE) of the two dissimilar bonded materials, which develops significant mechanical stresses at the interface and potentially leads to mechanical failures.

Vapor-phase deposition is a widely used thin film processing technique in both academic research laboratories and manufacturing industries. Since vapor phase coatings do not require wettability or hydrophobicity, a uniform and strongly adherent layer is deposited over virtually any substrate, including ceramics.

In this presentation, we report on the effect of vapor phase-deposited interfacial metal layers on the mechanical properties of bonding between stainless steel and Zerodur (lithium aluminosilicate-based glass ceramic). Direct-current magnetron sputtering was utilized to deposit various thin interfacial layers containing Ti, Cu, or Sn. In addition, to minimize the unfavorable stress at the bonded interface due to the large CTE difference, a low temperature allow solder, that can be chemically and mechanically activated at temperatures of approximately 200 °C, was used. The solder is made from a composite of Ti-Sn-Ce-In. A custom-built fixture and universal testing machine were used to evaluate the bonding strength in shear, which was monitored *in-situ* with LabView throughout the measurement. The shear strength of the bonding between stainless steel and Zerodur was systematically characterized as a function of interfacial metal and metal processing temperature during sputter depositions. Maximum shear strength of the bonding of 4.36 MPa was obtained with Cu interfacial layers, compared to 3.53 MPa from Sn and 3.42 MPa from Ti adhesion promoting layers. These bonding strengths are significantly higher than those (~0.05 MPa) of contacts without interfacial reactive thin metals. The fracture surface microstructures are presented as well. It was found that the point of failure, when Cu interfacial layers were used, was between the coated Cu film and alloy bonder. This varied from the Sn and Ti interfacial layers where the main point of failure was between the interfacial film and Zerodur interface. The findings of the effect of thin adhesion promoting metal layers and failure behaviors may be of importance to some

metal/ceramic heterogeneous bonding studies that require high bonding strength and low residual stresses at the bonding interface.