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Fracture Analysis of Through-Glass Via (TGV) Interposer Under Thermal Loading Based on the Extended Finite Element Method (XFEM)

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ABSTRACT

To meet the demands of rapidly evolving communication technologies, advanced packaging offers a novel integration scheme for radio frequency (RF) devices with higher integration density and improved electrical performance [1]. Although through-silicon via (TSV) interposers have been extensively adopted in advanced packages, their application in RF device integration is limited due to significant signal loss caused by silicon's conductivity [2]. Therefore, the through-glass via (TGV) interposer is considered a promising candidate to replace the TSV interposer, mainly owing to its lower cost [3] and excellent electrical performance [4,5], particularly for RF applications.

However, the brittle glass interposer is prone to fracture during heating due to high thermal stress induced by the coefficient of thermal expansion (CTE) mismatch between the glass interposer and copper vias. Previous studies have investigated TGV interposer fracture through experimental observations [6] and numerical calculations based on the J-integral using two-dimensional (2D) finite element models [7,8], preliminarily identifying failure modes and proposing optimization guidelines. However, crack evolution behaviors and failure mechanisms during thermal processing are still remained to be elucidated.

In this study, a three-dimensional (3D) finite element model of a representative volume element (RVE) extracted from a TGV interposer was developed and analyzed using ABAQUS. Regions with elevated failure risk were first identified based on the tensile stress distribution, after which the extended finite element method (XFEM) [9,10] was employed to investigate crack initiation and propagation. Owing to model symmetry, XFEM was implemented in two symmetric quarter regions between adjacent vias to balance computational accuracy and efficiency.

The stress distribution indicated peak tensile stresses at both the surface and the center near the copper via, originating primarily from the circumferential stress component and suggesting potential radial cracking. Furthermore, XFEM simulations demonstrated that cracks initiated at the surface adjacent to the copper via, propagated initially toward the interposer center, and subsequently extended toward the neighboring via along the radial plane. Upon reaching the center, the crack exhibited significant growth in the buried region. The simulation eventually captured the development of a pronounced radial crack between adjacent vias. The fracture analysis results showed excellent agreement with published experimental data, revealing that crack initiation and propagation during heating are predominantly governed by the circumferential stress distribution.

KEYWORDS

Advanced packaging; through-glass via (TGV); fracture analysis; extended finite element method (XFEM)

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