IMEC shows progress in lead-free materials at IMAPS EMPC 2005

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IMEC announces advances in identification of lead-free (Pb-free) solder materials in four papers at the 2005 IMAPS European Microelectronics and Packaging Conference (EMPC). Progress is reported in the understanding of the thermomechanical and electromigration behavior of various Pb-free alloys for flip-chip and chip-sized package (CSP)/ball-grid array (BGA) applications. In fine-pitch applications, Co as an alternative to Cu for under-bump metallurgy was found to significantly improve the solder fatigue life. The results largely contribute to the selection of the best Pb-free composition and component finish in microelectronics applications which is imposed by the EU directive to introduce Pb-free soldering in the EU by July 1, 2006.

"Although many Pb-free alloys have been intensively studied, there is no worldwide consensus yet on the material of choice. Unlike SnPb, which has been commonly used in microelectronics for more than 50 years, the behavior of these Pb-free materials is still insufficiently understood," said Eric Beyne, Director Advanced Packaging and Interconnect Center at IMEC. "It's IMEC's aim to largely contribute to a worldwide consensus by intensive characterization and reliabilities studies which are essential to identify a Pb-free solution that is reliable in the long term."

To carry out these investigations, IMEC makes use of an extensive infrastructure, including a number of reliability test systems and failure and material analysis systems. IMEC has also developed simulation techniques to help understanding the observed failure mechanisms and provide guidelines for improvements to reliability.

Paper Topics

Thermomechanical analysis shows lifetime improvement of Pb-free flip-chip packages

Chips assembled with Pb-free solder have an improvement between 27 and 51% with respect to the lifetime of the packages assembled with the Pb-containing solder alloy. This result is obtained from a thermomechanical analysis using 3D FEM of various fine-pitch underfilled flip-chip packages with SnAgCu and SnPb solder alloys. The reliability study indicates that SnAgCu alloys may be used as an alternative solder to improve the resistance to fatigue when compared with standard Pb-containing solder.

Electromigration strongly impacts the stability and reliability of Pb-free solder joints

A novel test structure for flip-chip electromigration has been developed that monitors the resistance change of the bump stack and allows separating resistance changes at each side (anodic and cathodic) of the joint. It was found that electromigration leads to UBM consumption and void formation at the cathodic side, the latter leading to an accelerated failure. These observations demonstrate the big impact of electromigration on the stability and reliability of the solder joints. The novel test structure for flip-chip electromigration has been applied to a CuNiAu-Sn-CuNiAu test case.

Brittle-to-ductile fracture transition temperatures in bulk Pb-free solders

IMEC has determined that several candidate Pb-free solders show a ductile-to-brittle fracture transition dependent on temperature. Unlike the eutectic SnPb, the materials show a sharp change in their fracture toughness. Using a pendulum impact test, the transition temperature of high-purity Sn, Sn-0.5%Cu and Sn-0.5%Cu(Ni) alloys was measured to be around -125°C. The Ag-containing solders Sn-Ag and Sn-Ag-Cu show a transition at higher temperatures, in the range of -78°C to -45°C.

Sn-5%Ag was found to be ductile only above -30°C, impacting largely on its range of applications. These results are very important for the selection of the best Pb-free solder composition, in particular for applications used in harsh conditions.

Co under-bump metallurgy on Pb-free flip-chip solders improves the solder fatigue life

IMEC demonstrates with experimental and finite element modeling (FEM) results that the use of Co under-bump metallurgy (UBM) can improve the fatigue life of Sn solder joints by 20-40% as compared to Cu UBM. The modeling was performed by inclusion of intermetallic layers as structural components of the ultra-fine pitch flip-chip Sn joints. Sn is accepted as the most attractive solder material for Pb-free flip-chip bumping in fine-pitch applications using an electroplating process.