PhD Project between SLB (former Schlumberger) and LMS/Ecole polytechnique

Subject: Electronic solder joints microstructure evolution and damage (characterization and modeling) when subjected to harsh environments.

Nowadays electronic assemblies of oilfield industries are used in harsher and harsher conditions with usage temperature usually in-between 150°C and 200°C. One of the weakest points of the electronics in such environment is the solder interconnect system (see left figure). During downhole conditions, these electronics are subjected to multiaxial thermo-mechanical stresses stemming from 1) thermal cycling of a structure with a significant mismatch in thermo-elastic properties between its components, 2) repeated shocks, and 3) the excitation of a broad spectrum of vibration frequencies. High temperature exposure of the solder joints – a few hundreds of micron-wide, made of a tin-copper-silver alloy (see right figure) - induces detrimental evolutions of their microstructure, that make it more sensitive to creep and fatigue damage. A better understanding of these phenomena is necessary to develop a preventing strategy.

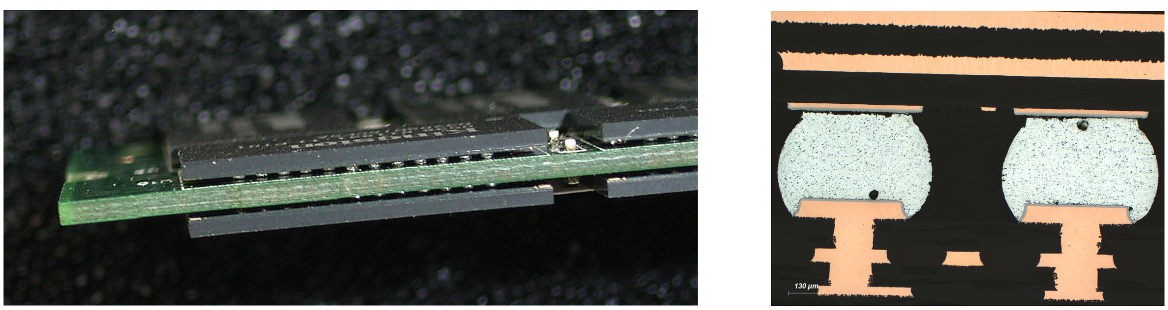

Figure: section of a part of a Ball Grid Array (BGA), a type of solder interconnect system. The diameter of such SnAgCu balls (on the right) is only a few hundred micrometers (sources: Wikipedia and SLB-Schlumberger).

In a recent PhD thesis, a process for manufacturing quasi-single crystal tensile specimens representative of the initial solder joints microstructure was developed. This allowed a characterization and analysis of the tensile creep and fatigue behaviors of as-manufactured solder joints between 20 and 185°C, and the identification of a crystal plasticity-based model, allowing 3D Finite Elements-based simulations.

Based on these developments, the present PhD project aims at characterizing and modeling the thermally-induced evolutions of the microstructure (recrystallization, growth of brittle intermetallic particles (called IMC), diffusion of elements from the substrate towards the solder joint assisted by the electric current…) and their impact on creep-fatigue damage of electronic assemblies. By measuring this impact, the project may also provide guidance on the manufacturing process of the assemblies to improve their performance.

The thesis will consist of two main parts:

1. Characterize the initial microstructures of solder joints and analyze the effect of its evolution (recrystallization, change in grains orientation, size and shape, growth of intermetallic particles and the different IMC phases) when subjected to thermal loadings (more representative of in-service loadings than tension-compression) up to 185°C. A particular challenge will be the development of representative tests on small specimens, that mimic copper-tin interfaces. The physical damage mechanisms in creep, fatigue, and their combination will have to be clarified, based on tests run inside a scanning electron microscope, with high resolution Digital Image Correlation (DIC) measurement of the local strain field.
2. Develop a microstructure-based constitutive model to predict the creep-fatigue damage experienced by solder joint for electronic components under such high temperature. Accounting for microstructural heterogeneities (mixture of tin dendrites and a Sn-Ag-Cu eutectic phase, with contrasted mechanical properties) in such models will be another challenge.

Ideal candidates should have an excellent scientific background, especially in Mechanics and Materials Science, be highly motivated and enjoy experimental work as well as theory, modeling and numerical simulations. The project will enfold its activities between the two partners: SLB (former Schlumberger) and Ecole Polytechnique (LMS) in France, which are very close to each other (15 km).

FINANCEMENT : Thèse CIFRE

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