Multiphysics Simulations for the Design of Probe-Heads Micro-Needles

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Abstract

The paper presents recent results concerning the experimental mechanical characterization, the numerical modeling and the design of micro-needles used in the construction of probe heads for wafer testing. The micro-needles must directly contact the pads for wafer testing of electronic and other microsystem devices. They must be flexible, with high electric conductivity and high resistance to electro-thermo-mechanical fatigue. The correct design of micro-needles can be only performed on the basis of accurate multi-physics simulations in which thermal, electrical and mechanical responses are correctly simulated in a fully coupled environment.
A fully coupled electro-thermal finite elements model of the micro-needles was defined. Due to the fact that the needles can be subject to high currents (over 1 A for a cross-section in the order of 40*40 µm2) and consequently high temperatures, we considered the electrical resistivity as a linear function of the temperature. The two main causes of heat dissipation are the anchors and the surrounding air. The model makes use of a stationary analysis and gives as output the temperature distribution along the needle. The simulation was repeated for various configurations: a single needle, a grid of nine needles and a grid of 100 needles. As a consequence, it was possible to understand the mutual influence of the presence of other micro-needles on the temperature distribution. In the cases where a grid of needles was studied, the convection inside the grid with respect to the conduction in air was neglected because of the small distances between needles. The convection was taken into account for the external needles only.
The results in terms of temperature distribution obtained with the coupled multi-physics simulation were used as input for a research-oriented thermo-mechanical FE code for the needles treated as slender beams. The influence of the temperature on the mechanical properties (Young's modulus, yield stress) was taken into account.
The two FE models combined were used to numerically reproduce the so-called CCC (Current Carrying Capability) test, which consists in the reaction force measurement of a single compressed needle subject to an increasing direct current.
Simulations evidenced higher temperature in the presence of several needles with respect to a single needle (Fig. 1, 2). The hot needles reduce the surrounding air cooling thus decreasing the heat dissipation by conduction in the air.
The CCC test was modeled with success (Fig. 2). As the current increases, the force decreases due to the diminution of the Young's modulus with temperature. At the end of the test, the micro-needle

is plastically deformed, this fact is explained by the diminution of the yield stress with temperature. The combined use of multi-physics simulation obtained with Comsol multi-physics and a research oriented FE code allowed to numerically simulate the CCC test. It was possible to show that the CCC can be reduced by an important amount in the case of a grid of micro-needles with respect to the single needle configuration.

Figures used in the abstract

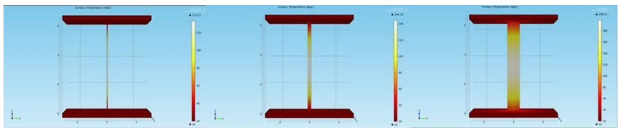

Figure 1: Results of the electro-thermal simulations

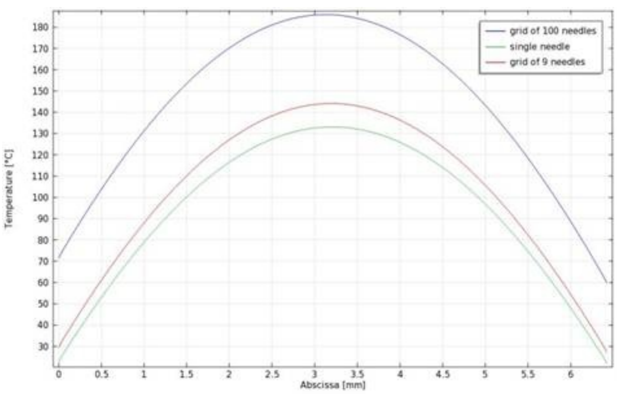

Figure 2: Temperature along the central micro-needle for a 1 A current

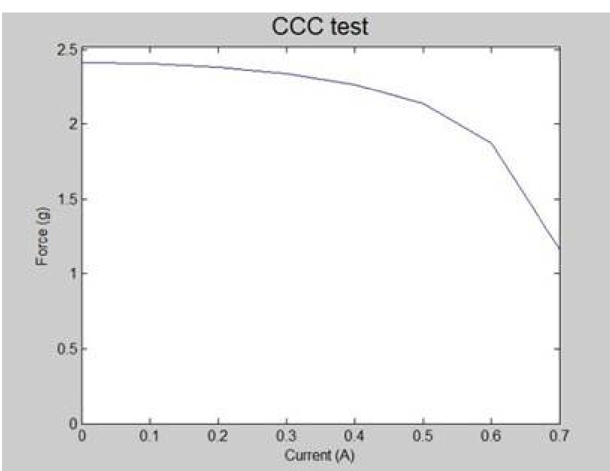

Figure 3: Simulated CCC test of a micro-needle