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Lifetime modeling and material requirements in power electronic modules

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With increasing concentration of energy dissipation in electronic components heat conduction becomes a decisive design criterion for high power electronic modules like Insulated Gate Bipolar Transistor (IGBT) modules. The changes in ambient temperature and moreover the heating during service causes thermally induced stresses between the different materials due to their different coefficient of thermal expansion. Thermal fatigue of the soft solder layer is enhanced by temperature cycles causing crack propagation, which reduces the heat transfer and thus the electric efficiency and service life time of the module. Thermally matching, conductive material can be achieved by metal matrix composite materials containing ceramic, diamond or graphite particles. The low thermal expansion of the particle constituent reduces that of the matrix according to its volume fraction within the composite. By selecting an appropriate material for the baseplate the induced thermo-mechanical stresses can dramatically be reduced. The requirements in view to thermal conductivity, coefficient of thermal expansion and Young’s modulus will be presented. This paper will review a comparison of industrially used AlSiC with new developed materials. To simulate the operation conditions of power electronic module these materials were subjected to environmental testing.

In view to the application of new baseplate materials in power electronic modules the reliability improvements have been investigated by FEM modeling. For that reason a viscoplastic model of the solder joint is used and the dissipated energy per thermal cycle is calculated. A systematic variation of the material parameters i.e. the thermal conductivity, the coefficient of thermal expansion and the Young’s modulus demonstrate the influence in view to solder fatigue and finally the ultimative lifetime. A concept of lifetime prognosis is presented which is using the solder crack propagation as dominating failure mechanism. Detailed solder material parameters in the required temperature range and mission profiles are necessary for the FEM model. The model allows the dissipated energy per thermal cycle to be correlated with a crack propagation in the solder layer. The growing crack finally is increasing the stress in the solder layer leading to a faster crack propagation. This concept will be demonstated for an PbSnAg solder interface.