Abstract

Residual stresses in metal matrix composites for heat sink applications during thermal cycling

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Metal matrix composites with superior thermal properties are designed for heat sinks under extreme conditions like in power electronic devices or in prototype fusion reactor systems to avoid delamination between the heat generating part and the heat sink and to maintain high thermal flux. Materials with a low thermal expansion coefficient combined with a high thermal conductivity are needed. Particles as well as fibers with high thermal conductivity and low thermal expansion are embedded into high conducting metals. The thermal expansion mismatch between the reinforcements and the matrix metal causes high residual stresses already from cooling during processing. Debonding at the internal interfaces and plastic deformation of the matrix are expected. The long term stability of MMC is tested by in situ investigation of the residual stress levels during thermal cycling and the effects of different reinforcement structures and interface designs. Synchrotron and complementary neutron diffraction experiments are performed during thermal cycling to investigate thermal fatigue damage. In situ high resolution micro tomography reveals the debonding mechanisms in the µm scale. The void volume fraction changes with temperature and increases with the number of cycles. Void shrinkage is observed in interpenetrated composites during heating, whereas void growth is observed in diamond particle reinforced metals. SiC-monofilament fibers in Cu break during heating. Residual stresses decrease as soon as damage advances. Synchrotron radiation provides the means of stress measurements and tomography simultaneously during thermal cycling.