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Martin Mueller
École Polytechnique Fédérale de Lausanne, martin.mueller@epfl.ch

Goran Zagar
École Polytechnique Fédérale de Lausanne

Marta Fornabaio
École Polytechnique Fédérale de Lausanne

Andreas Mortensen
École Polytechnique Fédérale de Lausanne

MICROSCOPIC THREE-POINT BENDING TEST TO PROBE PLATE-LIKE SILICON PARTICLES FROM ALSI ALLOYS

Martin G. Mueller, Laboratory of Mechanical Metallurgy, Institute of Materials,
École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
martin.mueller@epfl.ch
Goran Zagar, Laboratory of Mechanical Metallurgy, Institute of Materials, EPFL, Switzerland
Marta Fornabaio, Laboratory of Mechanical Metallurgy, Institute of Materials, EPFL, Switzerland
Andreas Mortensen, Laboratory of Mechanical Metallurgy, Institute of Materials, EPFL, Switzerland

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The strength of composite materials and alloys is often governed by the intrinsic strength of brittle microscopic particles that they contain. Approaches to measure the strength of alloy or composite reinforcing particles are usually indirect: average microscopic mechanical properties are estimated via a given model from macroscopic mechanical data conducted on the composite or alloy. Here we present an approach to directly measure the local strength of microscopic second-phase particles of high aspect ratio, by means of which one can identify and understand the role of their strength-limiting defects.

The approach is a microscopic three-point bending test conducted directly on individual microscopic plate-like silicon particles, which constitute, together with aluminium, the eutectic microconstituent in AlSi alloys. Silicon particles are extracted from the alloy by deep-etching and spread on a steel substrate. Focused Ion Beam (FIB) milling is used to carve a beam out of a silicon particle in such a way that the surface that will later on be subjected to tension upon beam bending, i.e. where strength will be measured, is not affected by the FIB nor by redeposition. The silicon beam is then transported using a micromanipulator over a hole previously produced by FIB milling into the substrate. The test is carried out using a nanoindenter with a custom-made ridge tip. Finite element modeling is used to evaluate the three-point bending tests and to explore the effect of misalignments on the strength uncertainty.

Tests are conducted in eutectic silicon plate-like particles both with and free of SEM-visible flaws. Results prove quantitatively that silicon particles can attain very high strengths when they are defect-free, whereas surface flaw-containing particles are much weaker.