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Three-Dimensional (3D) Microstructure Visualization and Finite Element Modeling of the Mechanical Behavior of Heterogeneous Materials

N. Chawla and V.V. Ganesh

Department of Chemical and Materials Engineering, Fulton School of Engineering, Arizona State University, Tempe, AZ 85287-6006, USA

Silicon carbide particle reinforced aluminum composites exhibit high strength and stiffness by combining strong, ceramic reinforcement particles in a soft aluminum matrix [1, 2]. Traditional methods of visualizing the microstructure of composites as well as other materials involve simplifying the three-dimensional (3D) structure to a two-dimensional (2D) representation by optical or scanning electron microscopy (SEM). While 2D representation of microstructures is common and gives some idea of the microstructure morphology, it is not fully representative of the 3D structure of the material. Serial sectioning is a technique that allows the quantification of 3D microstructures using classical metallography techniques coupled with computer-aided reconstruction [3]. While visualization of the 3D microstructure of the material is important, prediction of the behavior and properties of the material is equally important. Thus, a microstructure-based modeling approach is required to link the microstructure with the behavior of the material.

Here we have used a microstructure-based modeling approach by combining serial sectioning and computer-aided reconstruction with 3D finite element modeling (FEM) [4]. Figure 1 shows a schematic of the steps taken in developing a 3D virtual microstructure and modeling of the microstructure in FEM. Serial sectioning was used to reveal the 3D microstructure of SiC particle reinforced aluminum matrix composites. The reconstructed 3D microstructure obtained was then used as a basis for 3D FEM modeling of uniaxial tensile behavior. The process allowed 3D visualization of SiC particles as well as intrinsic and accurate microstructure-based modeling of the behavior of SiC/Al composites. The 3D microstructure of the composite is more accurate in predicting and visualizing the mechanical behavior of the composite than the simple SiC particle geometry employed in conventional unit cell models, Fig. 2.

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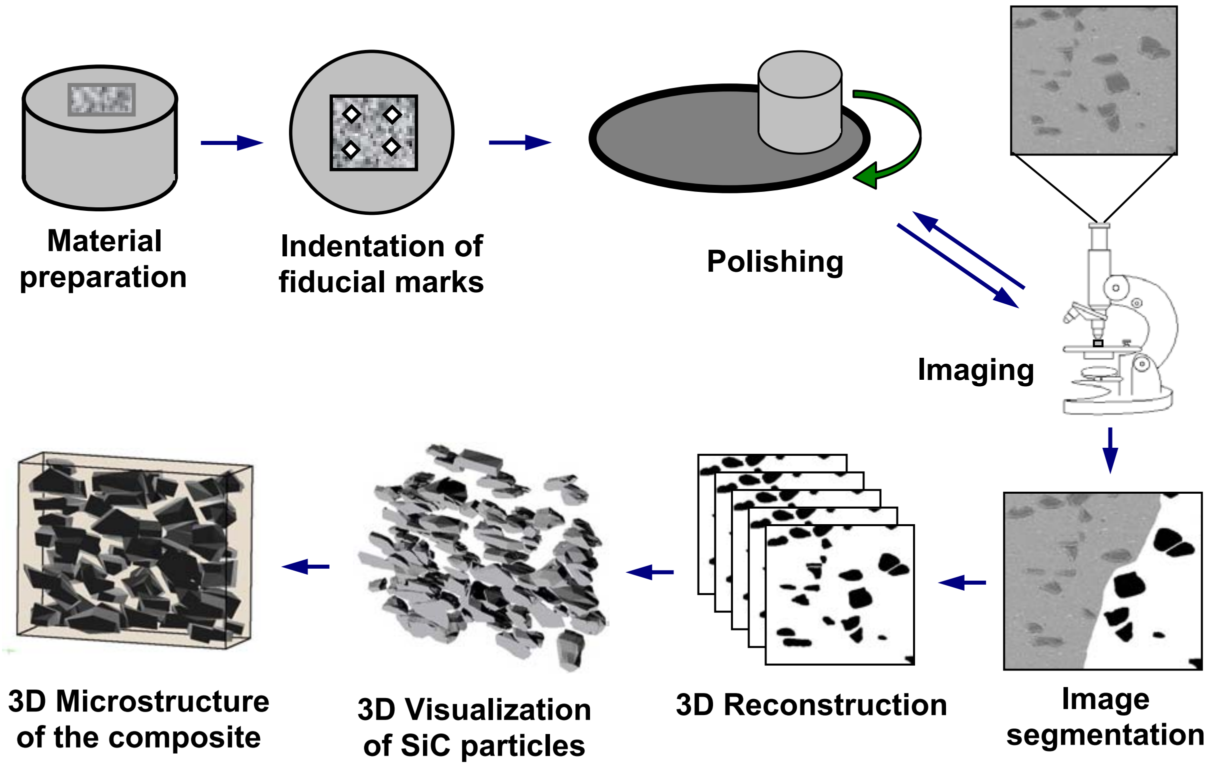
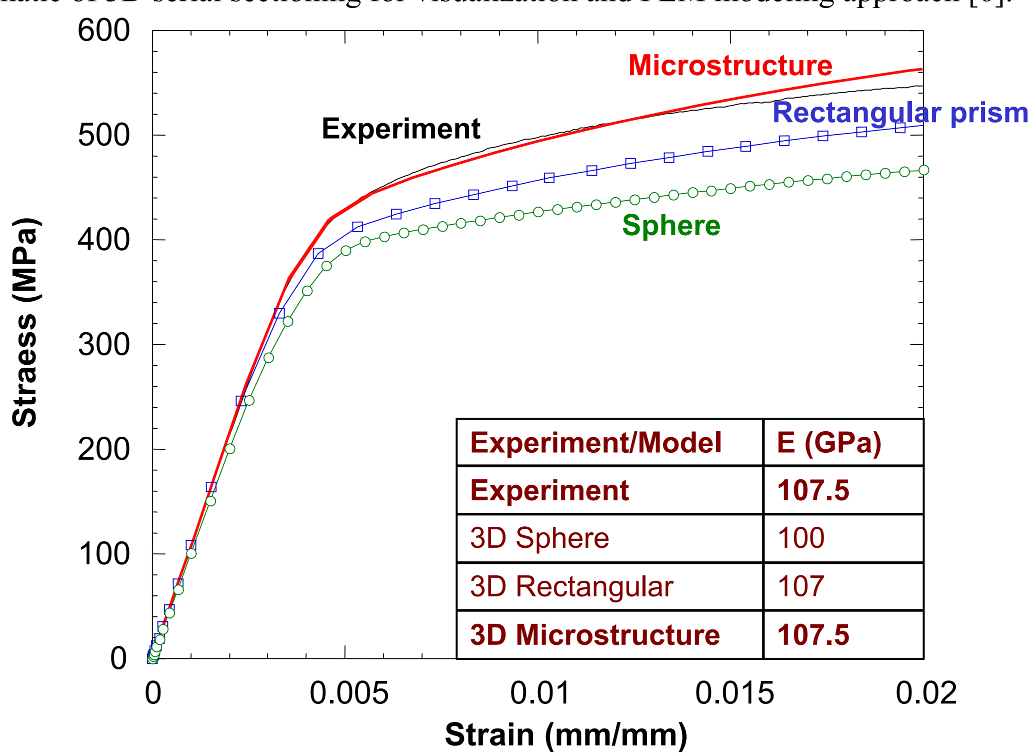


Fig. 1. Schematic of 3D serial sectioning for visualization and FEM modeling approach [6].



Experiment/Model	E (GPa)
Experiment	**107.5**
3D Sphere	100
3D Rectangular	107
3D Microstructure	**107.5**

Fig. 2. Comparison of tensile stress-strain behavior predicted by 3D microstructure-based FEM model with conventional unit-cell models. The 3D microstructure prediction is closes to the experimental behavior.

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