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GRAIN-SCALE DEFORMATION MECHANISMS IN ADDITIVELY MANUFACTURED FCC POLYCRYSTALS

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Abstract. Oligocrystals provide a unique material for in-depth analysis of deformation mechanisms in metals and alloys. In this paper, the deformation mechanisms in an aluminum bronze oligocrystal are investigated experimentally and numerically. An experimental sample containing several coarse columnar grains is produced by wire-feed electron-beam additive manufacturing. Based on the experimental data, a crystal plasticity finite element model is built to consider realistic grain shape and orientations. This study involves a comprehensive analysis of experimental data, numerical results and analytical estimates to reveal the peculiarities of slip activation in oligocrystal grains under compression. Experimental and numerical findings have shown that along with slip systems with the highest Schmid factors, other slip systems are activated in most grains to accommodate their plastic deformation. To elucidate why the slip systems with non-maximal Schmid factors became active, we examined the stress fields within the grains. It was revealed that the stress state at the grain scale deviated from uniaxial. Finally, a detailed numerical analysis of strain rate dynamics demonstrated that plastic deformation in particular grains developed in the form of narrow fronts. These fronts pe-riodically generated near the moving punch and subsequently propagated towards the opposite side of the sample. The study has shown that oligocrystal analysis provides valuable insights into the linkage between the intra- and intergrain deformation mechanisms with the overall material behavior.

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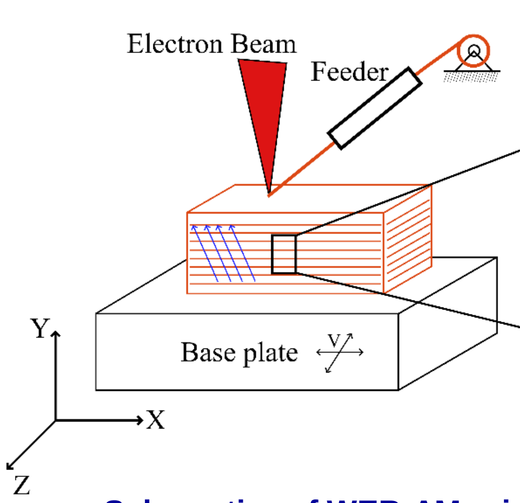
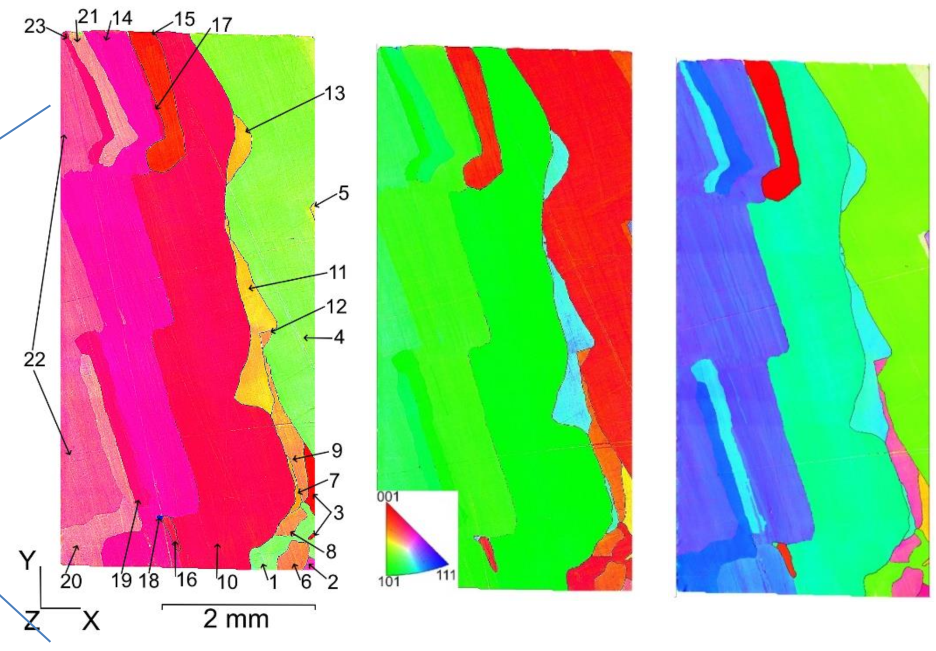
EXPERIMENTAL

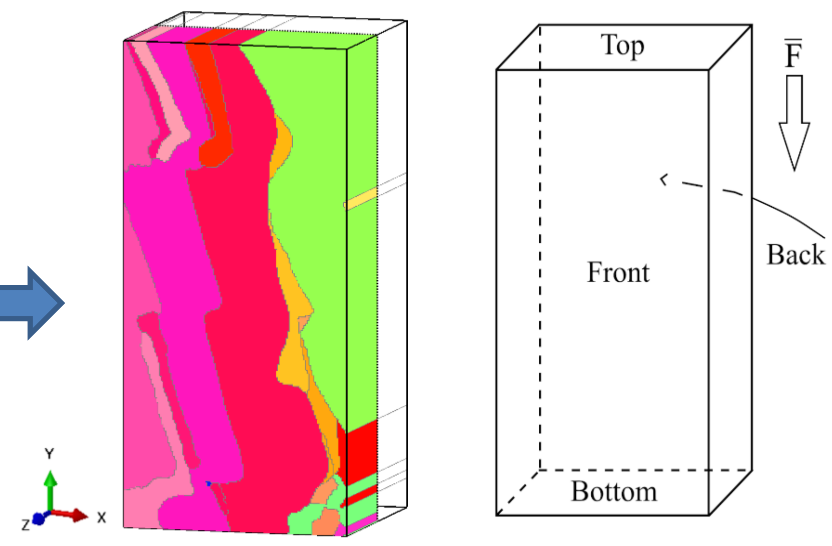


Schematics of WEB-AM printing and compression test of a Cu-7.5 wt.% Al specimen



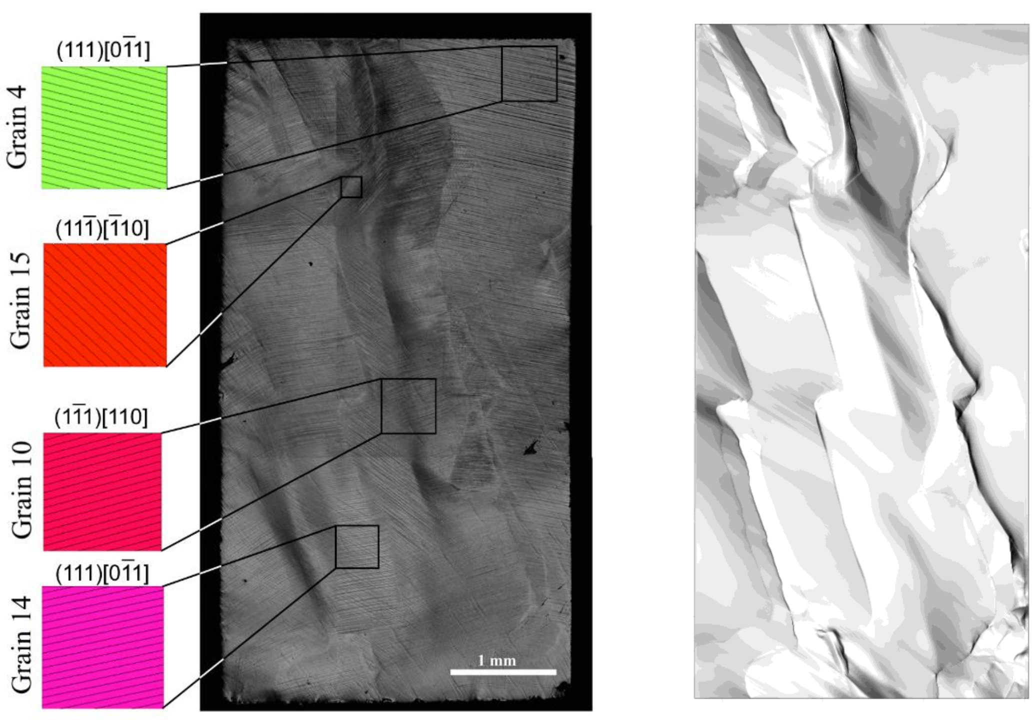
EBSD maps in IPF colors for the X, Y and Z directions

SIMULATION

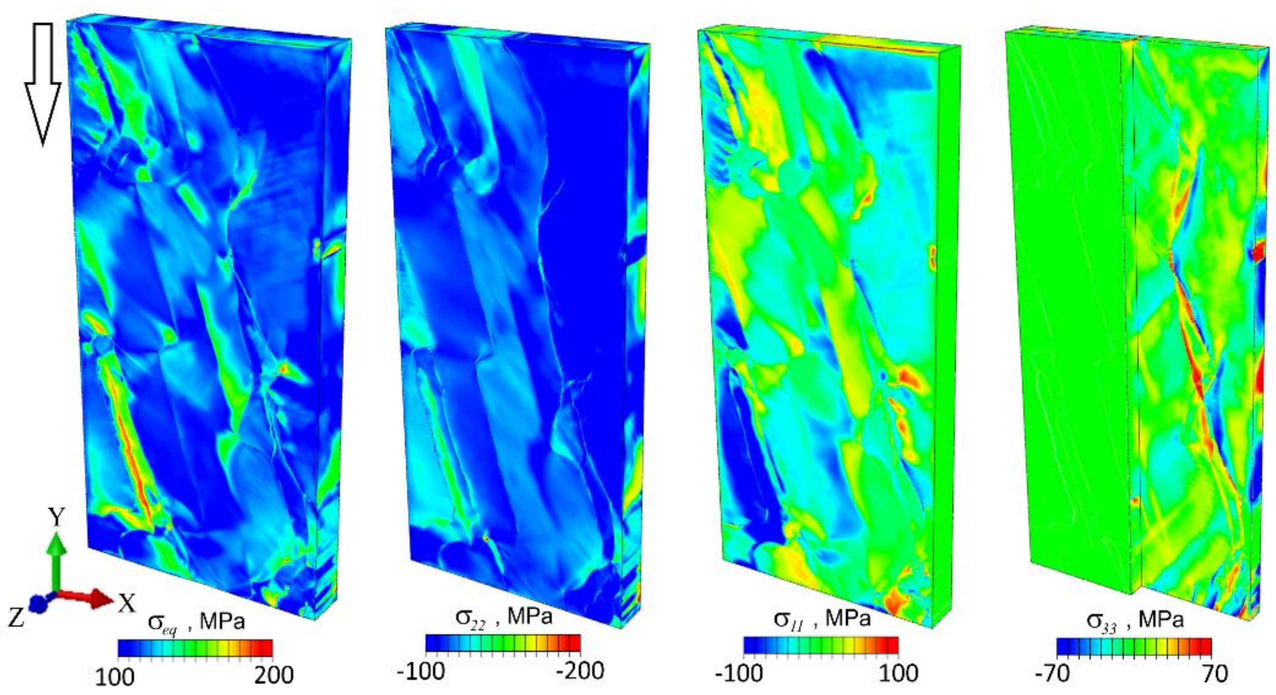


Crystal plasticity finite element model

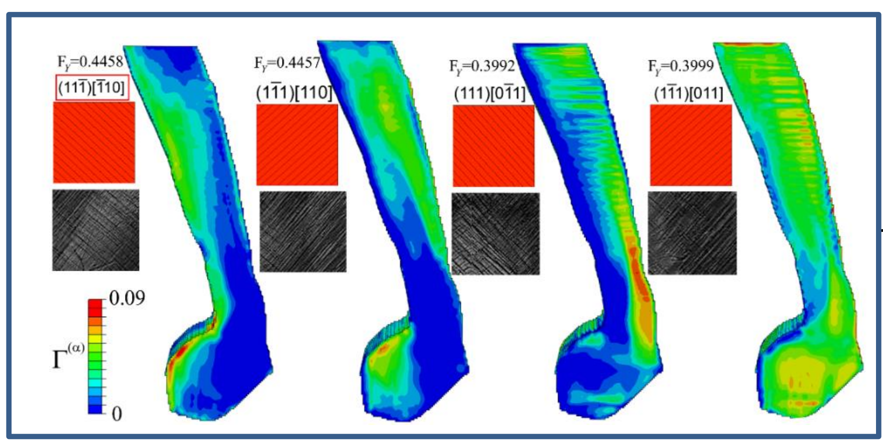
RESULTS FOR 5% COMPRESSION



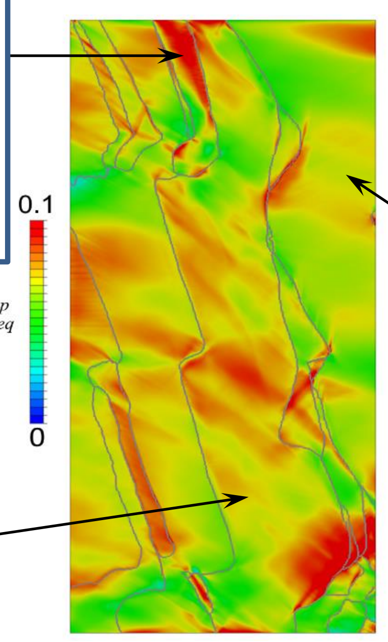
Experimental and numerical surface images and analytically predicted slip traces in four selected grains

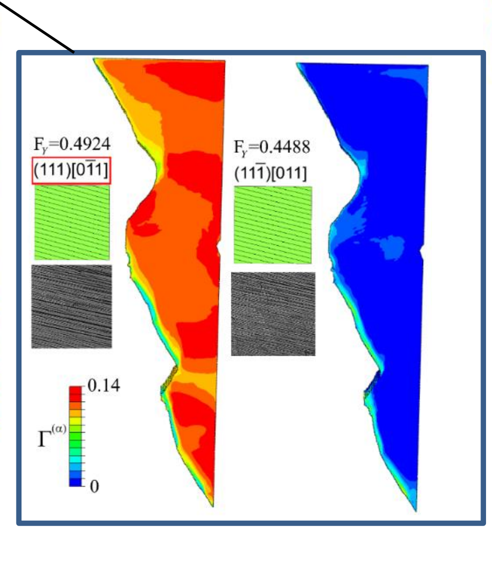


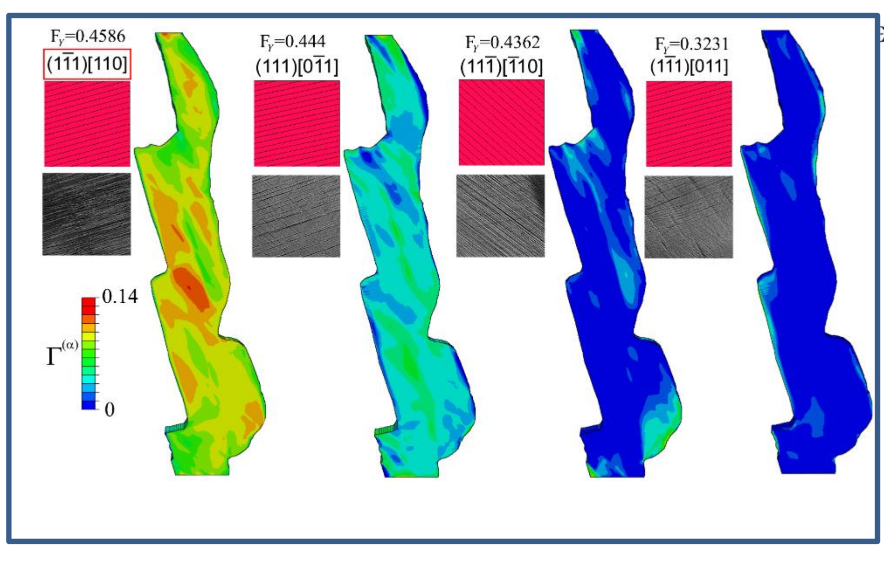
Stress tensor components

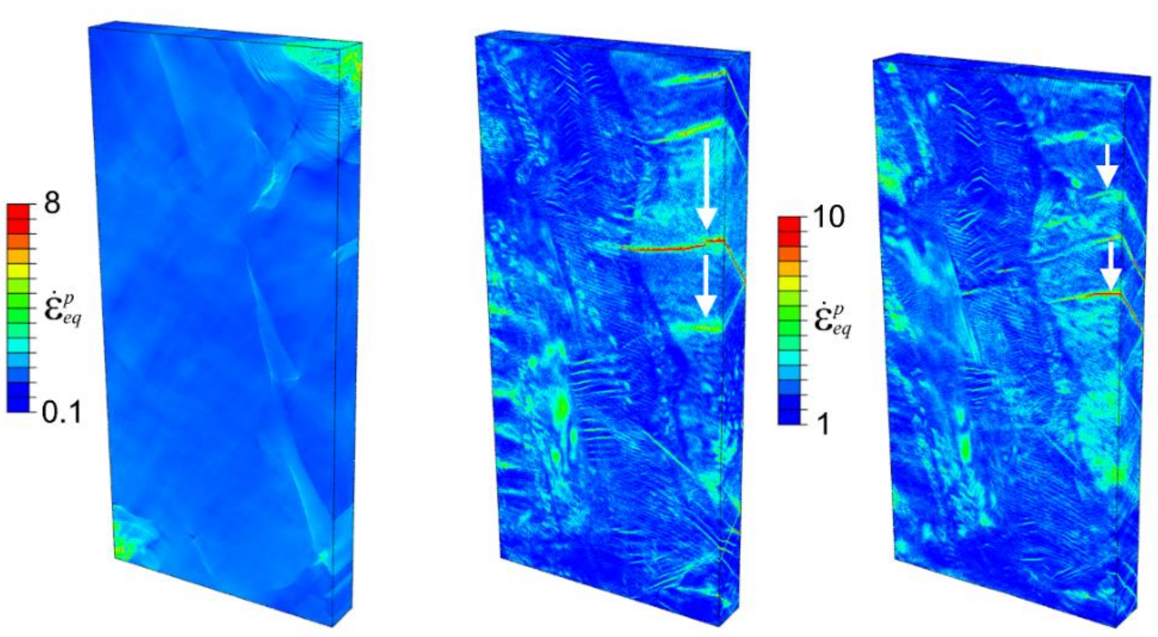


Calculated plastic strain field and amount of slip accumulated in selected grains in different slip systems









Snapshots of strain rate fields in the FE model at a compressive strain of 0.0004, 0.018 and 0.05