Recent Observations of Localized Deformation in Neutron Irradiated Cu

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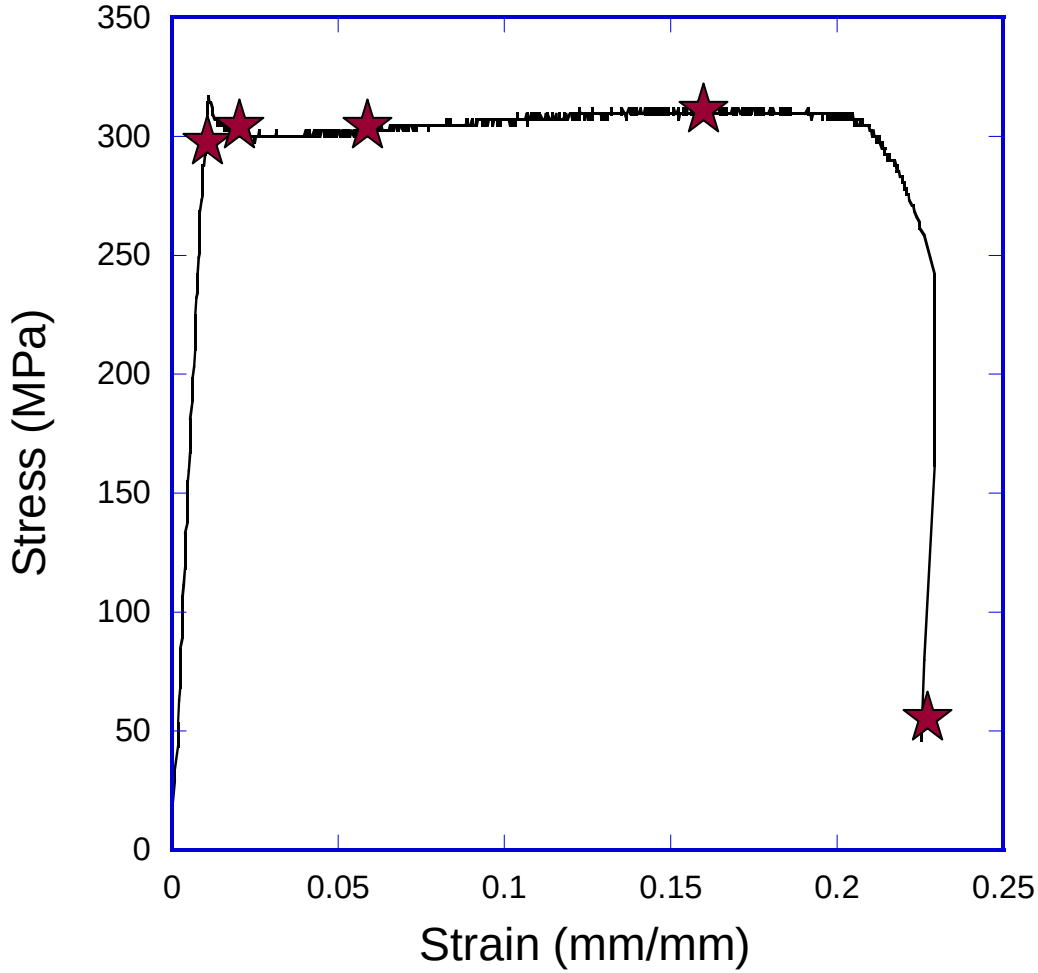
Recent Observations in Neutron-Irradiated Cu, 0.3 dpa, ~100°C

- Very limited channeling occurs before observable yield
- Yield drop related to the formation and propagation of channels
- Dislocation channeling continues up to large strains, perhaps even to the point of failure
- Channel deformation differs from grain to grain, related to orientation with respect to the stress axis

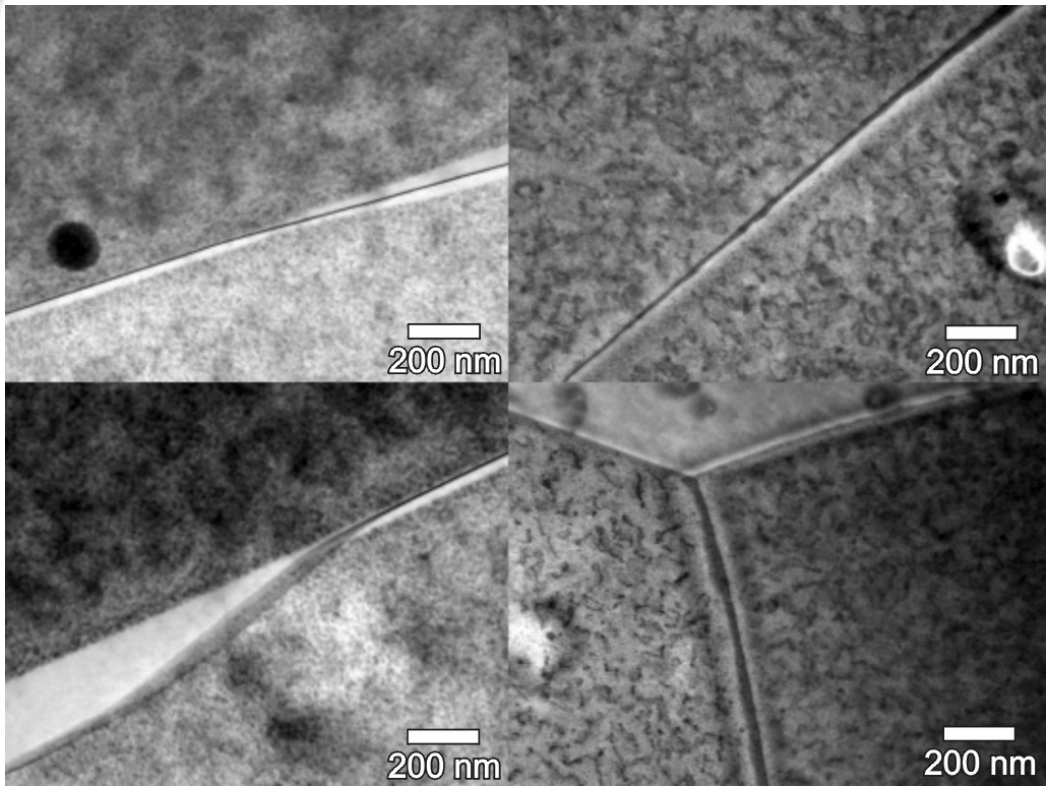
Observations (cont.)

- New channels form as the strain increases within a given grain
  - Smaller, much narrower channels form that link prior channels together, initiate from edges of prior channels, not GB's or interfaces
  - Other channels form on different orientations that cross from boundary to boundary, basically primary channels that activate from GB's
- Migrated GB's and defect free zones (DFZ's) along boundaries indicate significant dislocation interactions along GB
  - DFZ's present at very low strains and before yield, produce soft regions

Representative Tensile Curve 100°C, 0.3 dpa

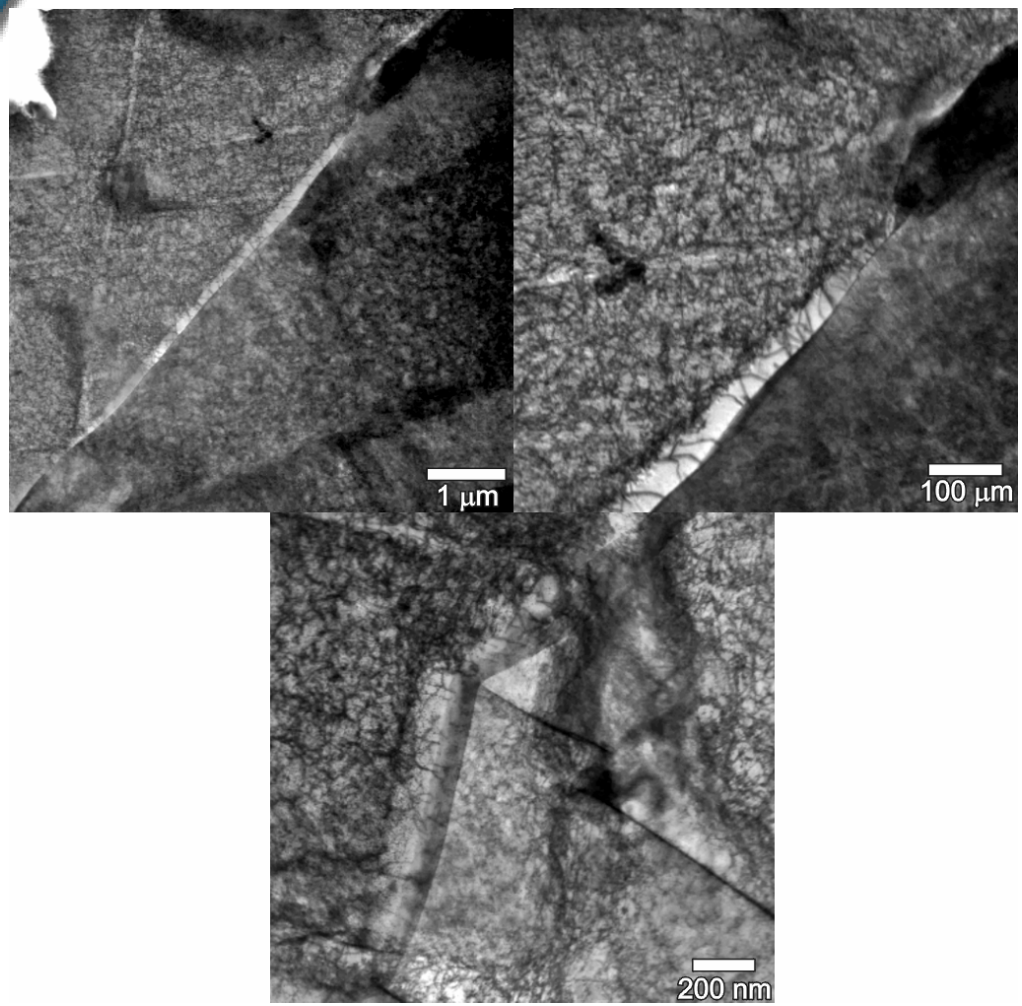


Migrated GB and DFZ's in Sample Tested to 90% Upper Yield Pt



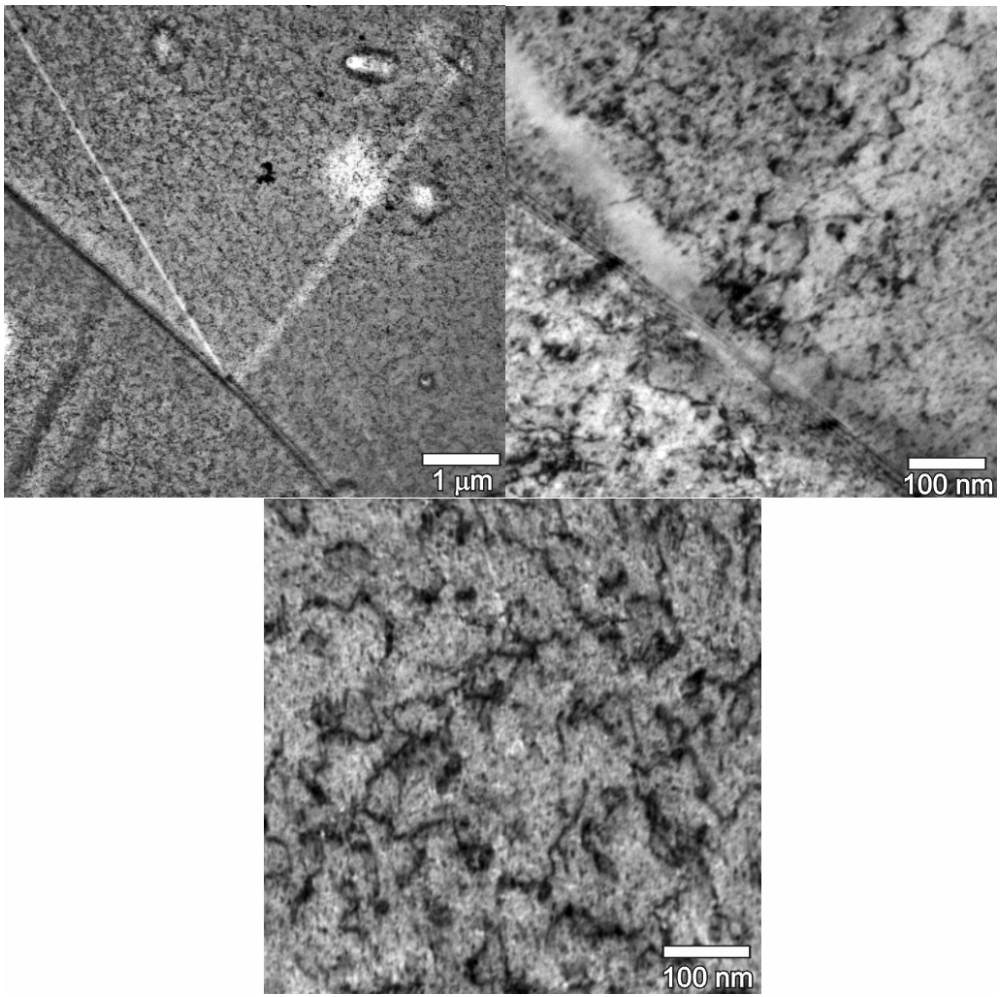
- DFZ's form along some boundaries
- Their width and extent along a given boundary varies considerably
- Very little dislocation movement in matrix

GB's in Sample Stopped Near UTS



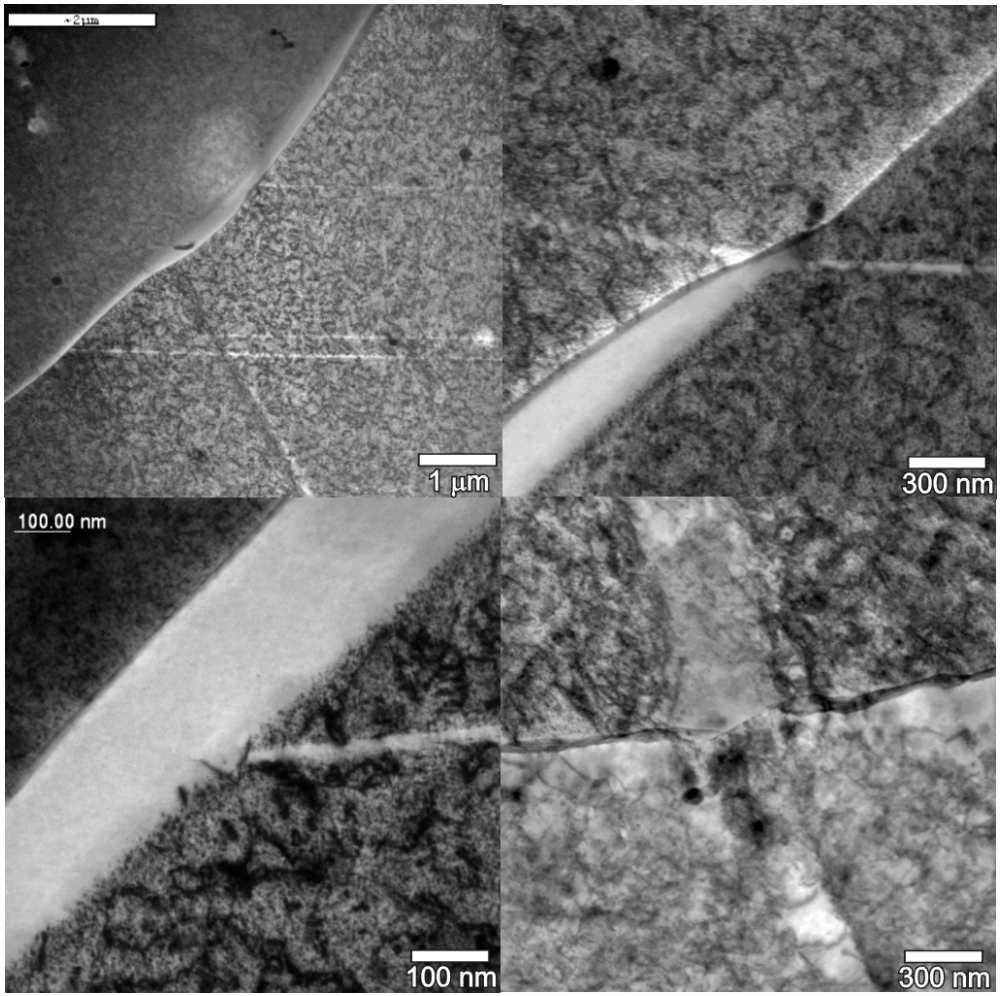
- Increasing dislocation activity in DFZ's, but more work needed for confirmation
- Channels initiated from these DFZ's?

Microstructure Stopped at 90% Upper Yield Pt



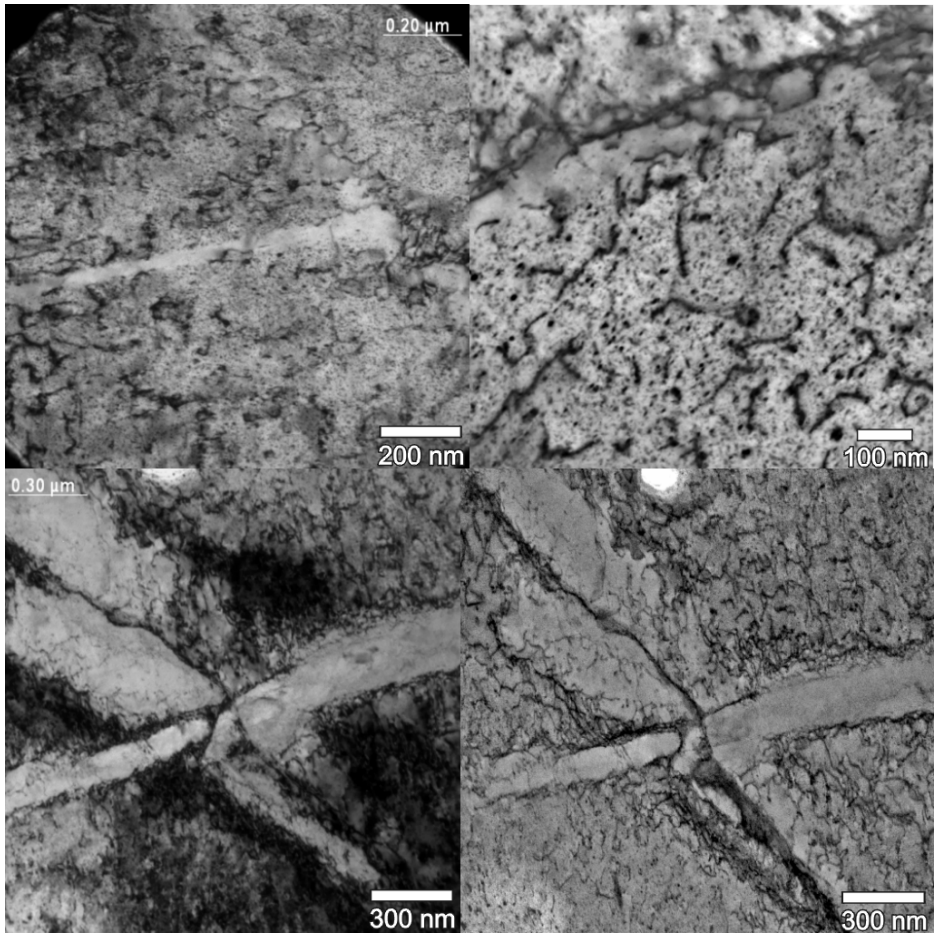
- Very few channels observed, 5-6 channels in the entire thinned region
- Dislocations may move slightly, but no general clearing observed

Microstructure Stopped at Lower Yield Pt



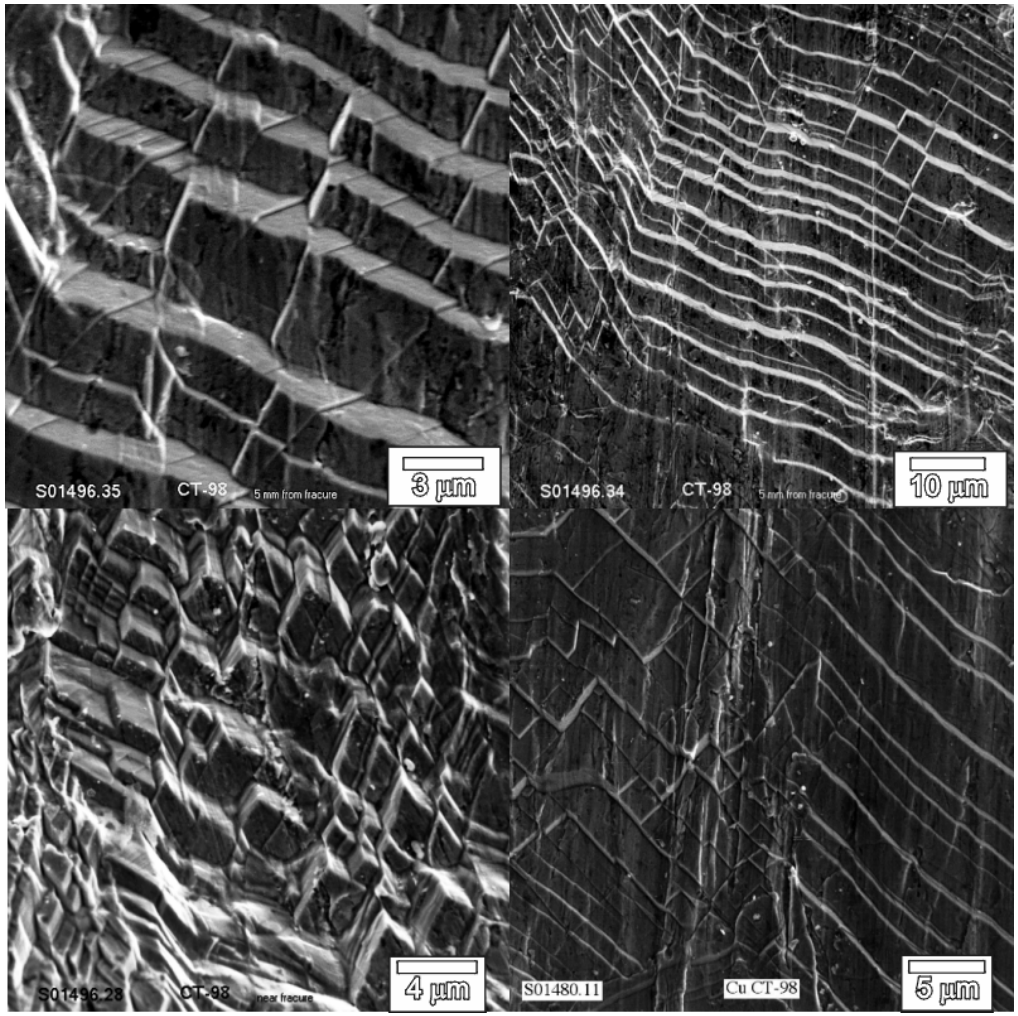
- Channels much more predominant after yielding
- All channels observed to run from boundary to boundary
- Not always associated with the DFZ's
- Cell walls and dislocation tangles observed at isolated GB intersections

Microstructure Stopped Near UTS, ~0.15 mm/mm Strain



- Channels have increased in density, but grain to grain variability persists
- Widespread clearing of defects still not visible between channels except at channel intersections
- Activity may consist of dislocations “percolating” through defects in matrix

Slip Steps on Surface of Sample Taken to Failure



- Slip steps appear to have no general slip between slip steps
- Very planar type deformation mode
- New channels activated as strain increases
- Strain occurs over much of the gage length, large grain-to-grain variation

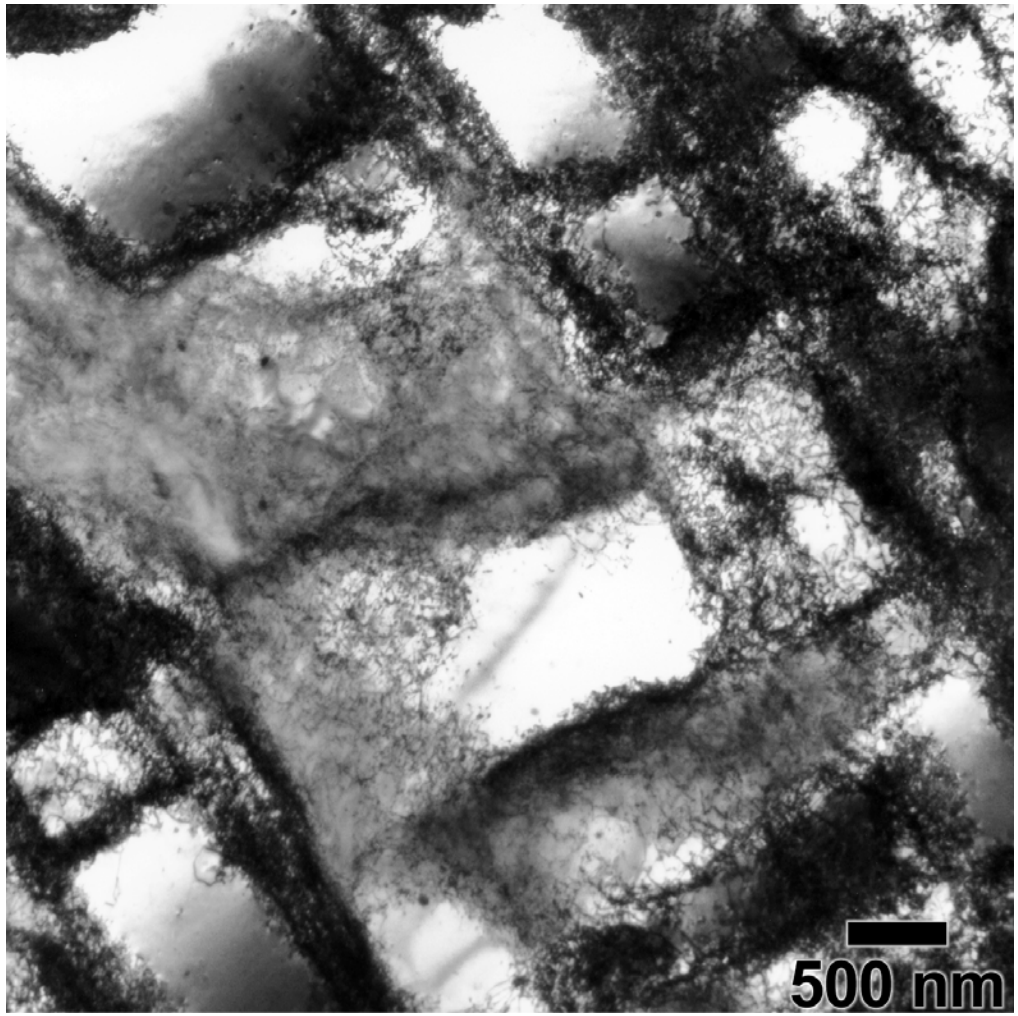
Directions for Future Research

- Grain boundaries and interfaces appear more important than ever in determining the yielding and deformation behavior
  - What is the stress needed to activate a GB source versus move through the defects in grain interiors? Effect of stress concentrations?
  - Range of GB source strengths?
  - DFZ and migrated GB's indicated that grain boundary sliding is occurring?
  - The low production of dislocations outside the channels, even at high plastic strains, suggests F-R sources are strongly locked

Future Research Directions

- Other mechanisms for accommodating the strain
  - Shear band formation due to low angle boundaries and cell wall formation along the edge of shear bands
  - Absorption and transmission of dislocations into and through grain boundaries
  - Activation of secondary and tertiary slip systems that produce linking channels

Characterization Problems

- TEM examines microstructural state well after the fact
  - In-situ straining may help to further elucidate the mechanism of channel initiation from GB's and interfaces
- Deformation modeling:
  - Consider limited plastic flow outside channels, formation of new channels as a function of strain, grain boundary sliding and DFZ's, slip transmission across boundaries, g-to-g variability, mechanisms for clearing defects, solute segregation
- Need to evaluate additional stress states such as compression and multiaxial loading to further understand channeling
- Extend this to examining crack tips in irradiated fracture toughness samples

PI Annealed Cu, 0.01 dpa, 100°C