Quantitative Analysis of Crack Propagation in Doped $MgAl_2O_4$ Spinel

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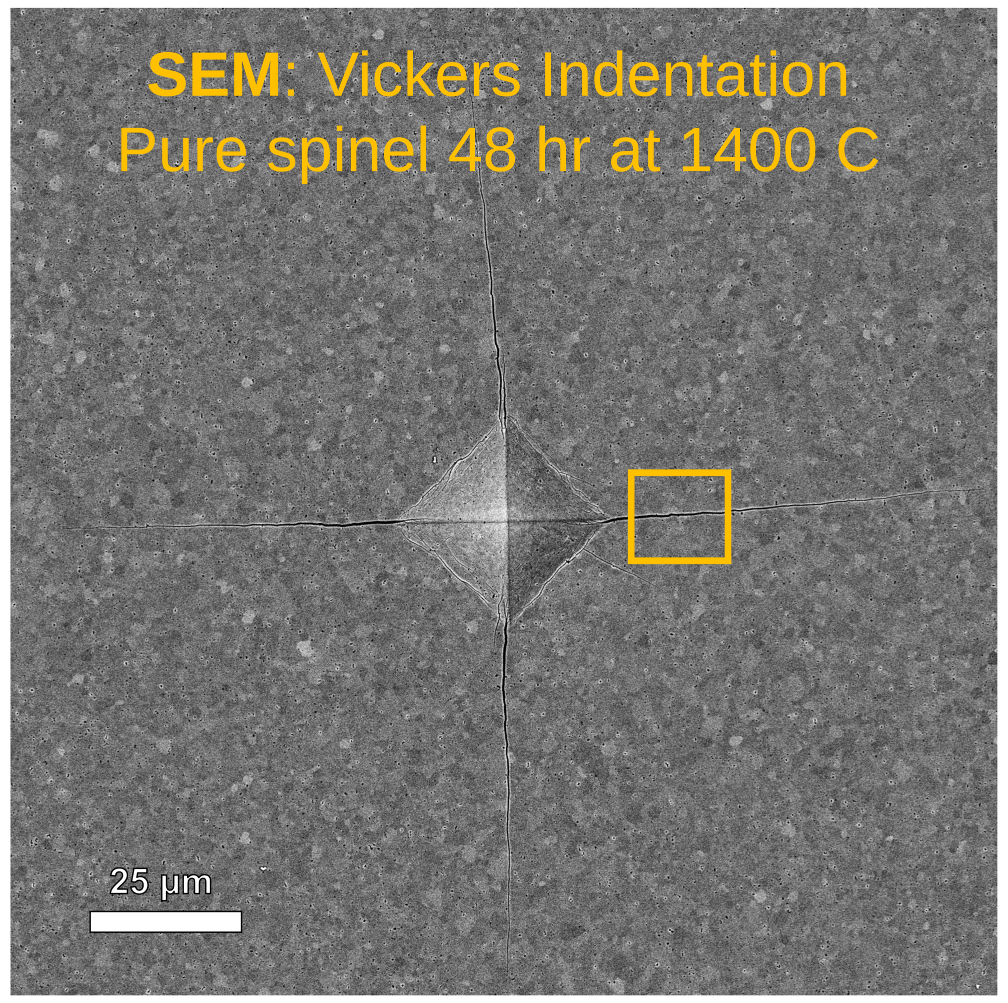
Introduction

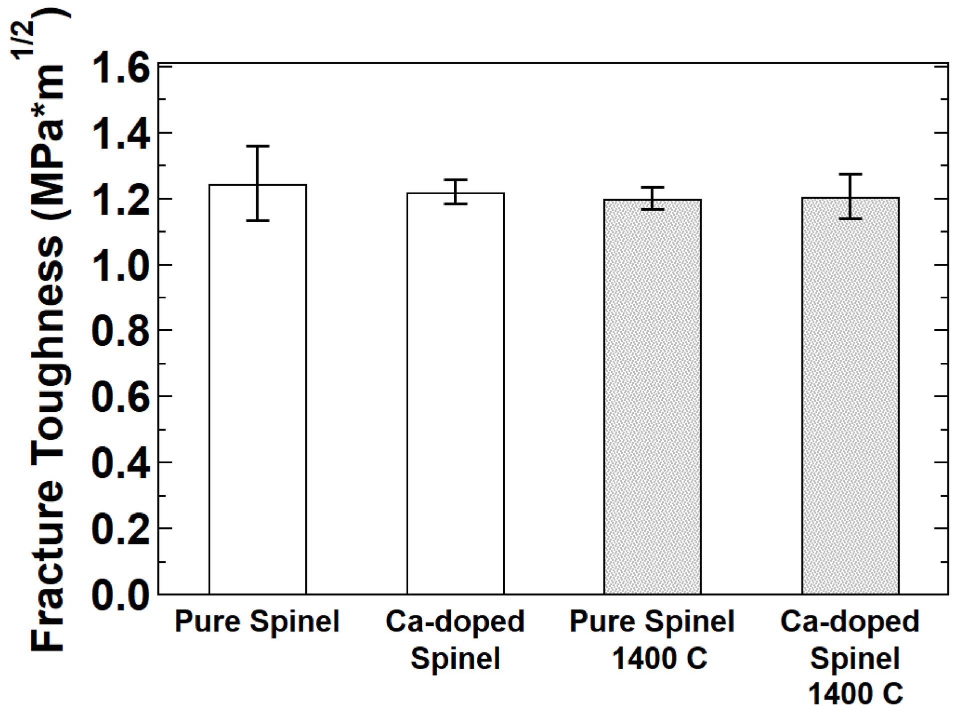
- Magnesium Aluminate Spinel ($MgAl_2O_4$) is a ceramic with high strength, high transparency and low density. Potential uses are in lens, extreme-condition windows, and transparent armor.
- Traditional processing methods of spinel uses LiF as a sintering aid, which causes grain-boundary embrittlement.
- Ionic Ca and Y are being investigated as alternative sintering aids to increase grain-boundary strength, while maintaining optical properties/transparency.
- Ca and Y were chosen due to their abundance (inexpensive) and ionic size relative to Mg and Al in crystal lattice.

Hardness Testing

- Samples were fabricated by hot pressing high purity magnesium aluminate powder with 500 ppm of the doping element. Samples were annealed at 1400° C. Then hardness was measured by microhardness testing and microstructure observation and grain orientation analysis were performed by a scanning electron microscope (SEM).
- Cracks were formed during hardness testing. The crack path relates to the strength of grains and their grain-boundaries.
- Gatan Digital Micrograph software was used to analyze the crack propagation behavior through orientation maps taken using electron backscatter diffraction (EBSD) analysis on SEM.

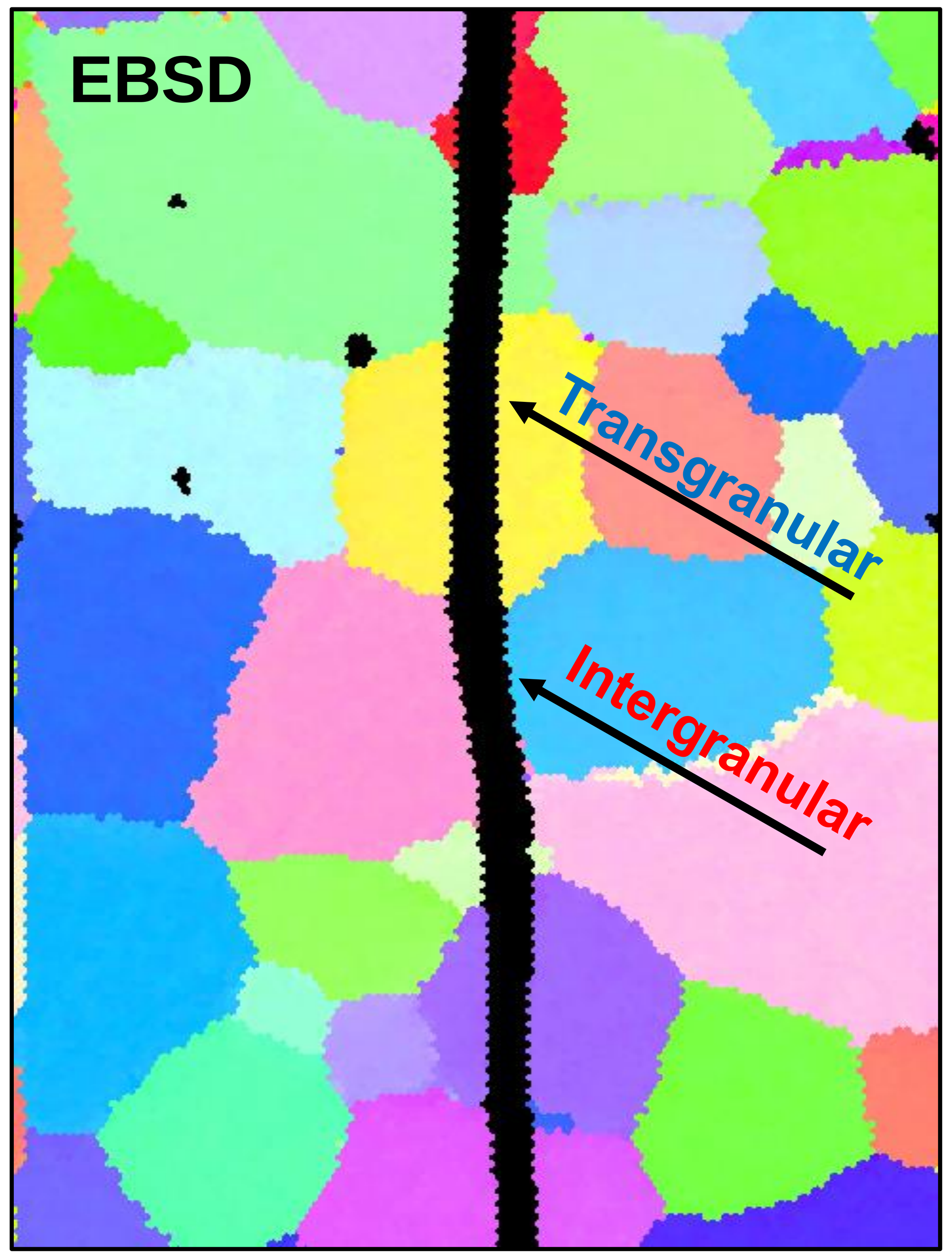


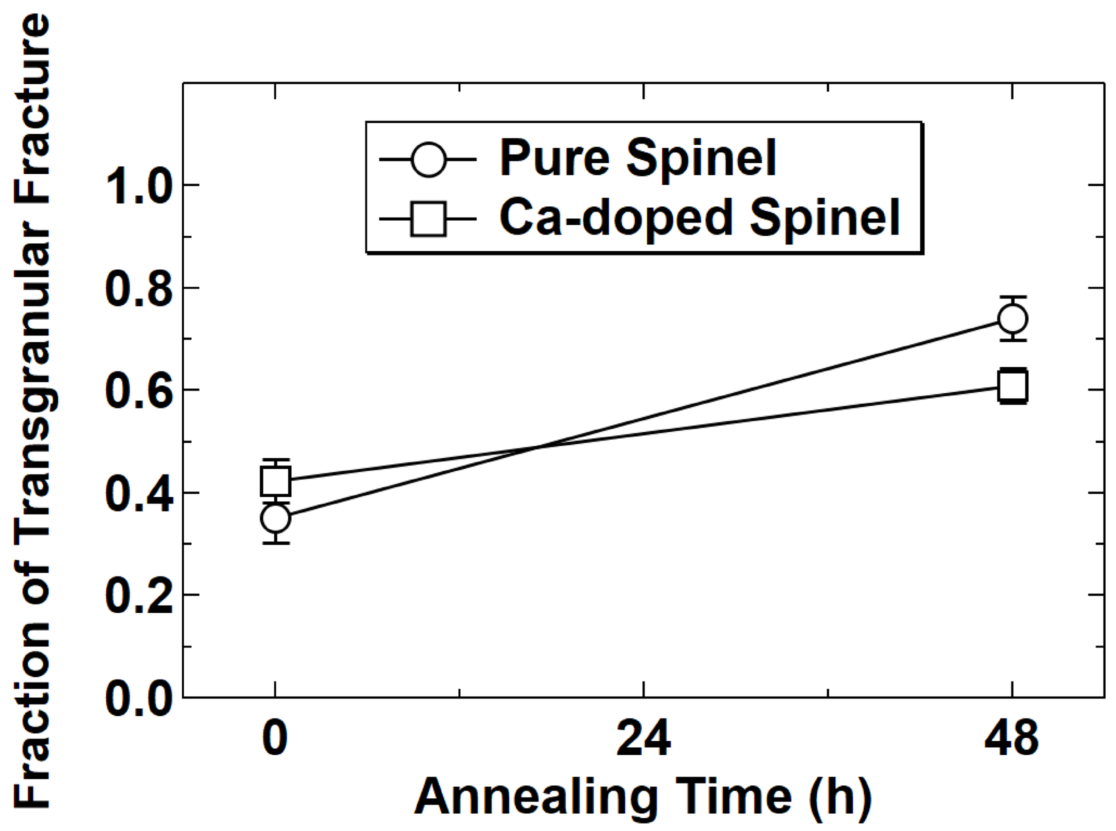
- Results show the fracture toughness was not compromised with the addition of dopants. (True before and after annealing.)



Quantitative Analysis of Crack Propagation

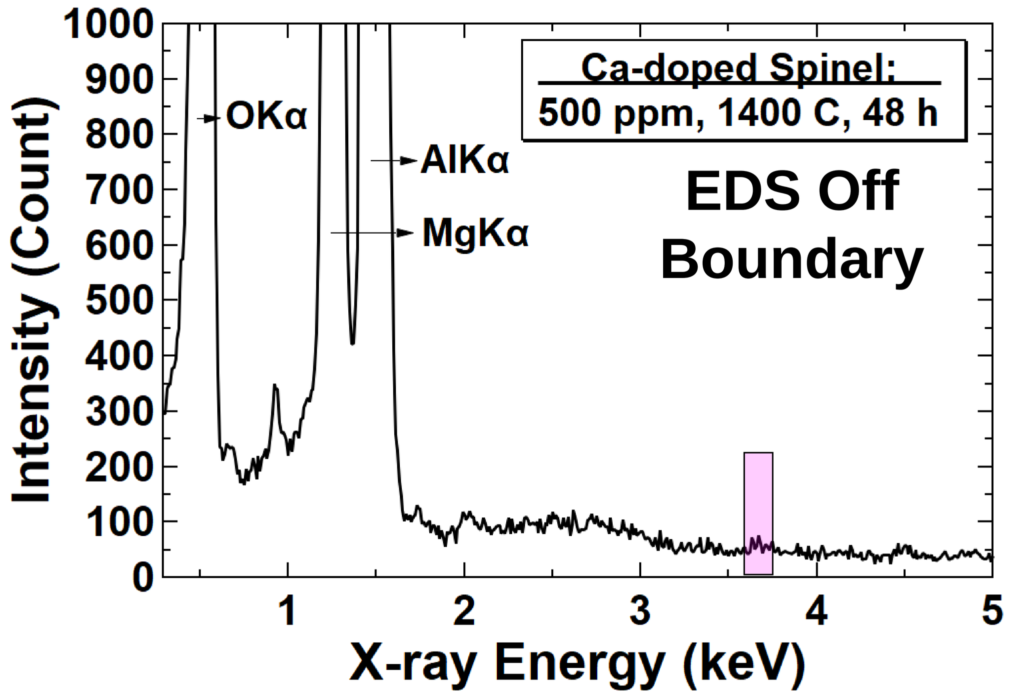
- The crack propagates through either the grains (**transgranular**) or between grains (**intergranular**). The ratio between these two fracture paths was counted along the crack using horizontal slices through the crack. The more **transgranular** fracture occurs, the stronger the grain boundaries are assumed to be.
- Analysis was semi-automated but required detailed refinements due to limitations of slicing code.

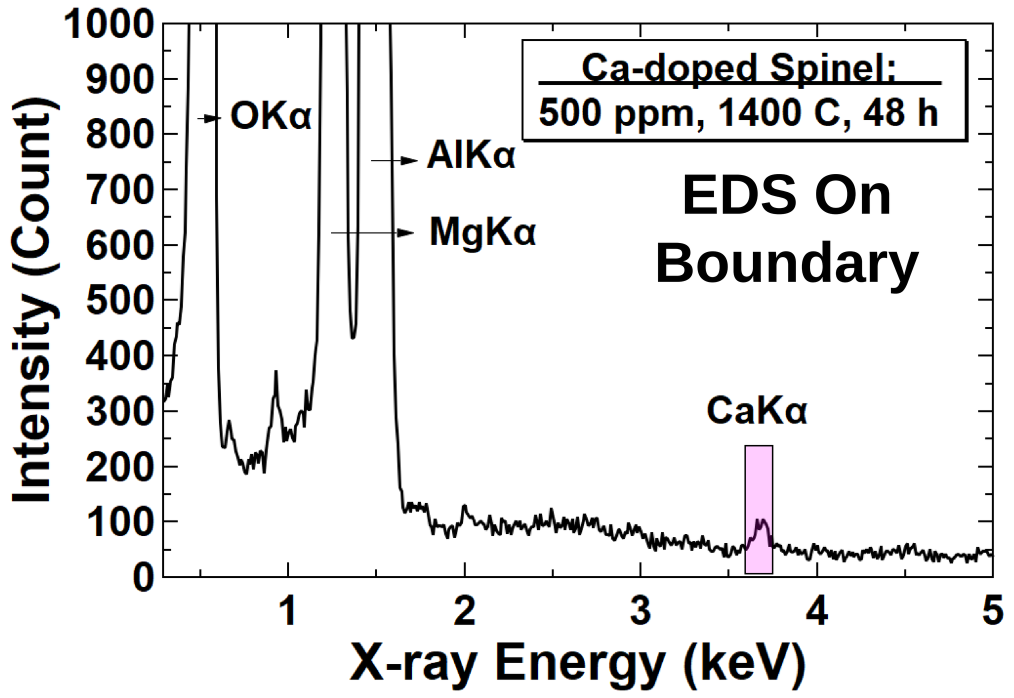




- There is a quantifiable difference in **transgranular** fracture with the addition of Ca as a dopant.
- Preliminary results show a statistically significant difference in Y-doped samples.

- Ca segregation to grain boundaries were confirmed by X-ray energy Dispersive Spectroscopy (EDS) in the aberration-corrected scanning transmission electron microscope (STEM). Therefore, the Ca dopant can be primarily responsible for the change in crack propagation path.





Conclusion

- Grain boundary strength is preserved after doping with Ca in comparison to pure magnesium aluminate spinel.
- The presence of dopants in magnesium aluminate spinel yields a quantifiable difference in the **transgranular** fracture.

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