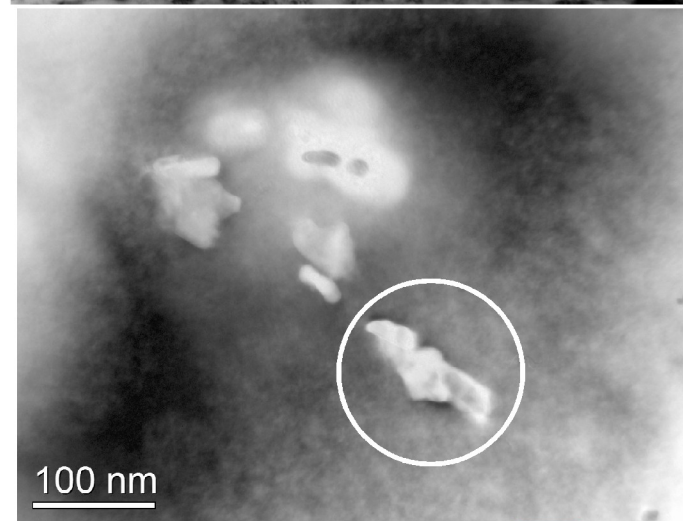
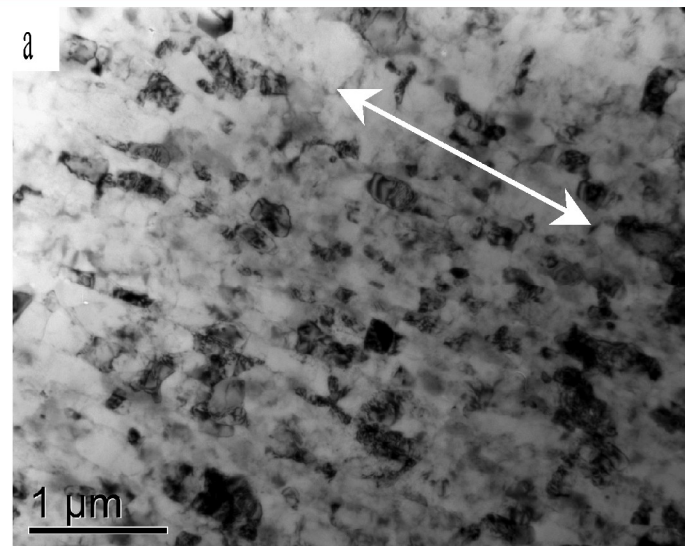
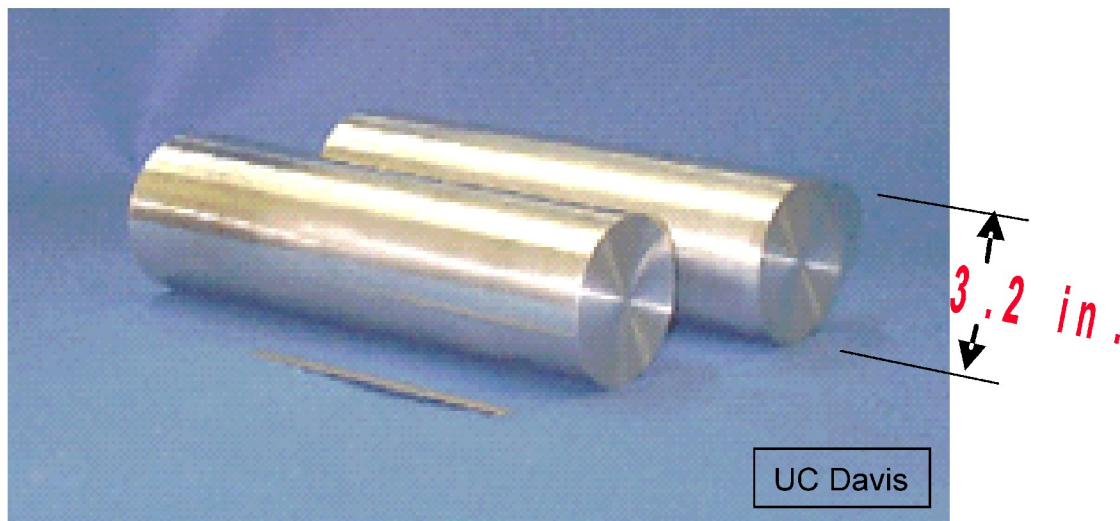


Solid Solutions in Ultra-Fine-Grained Al-Mg Alloys

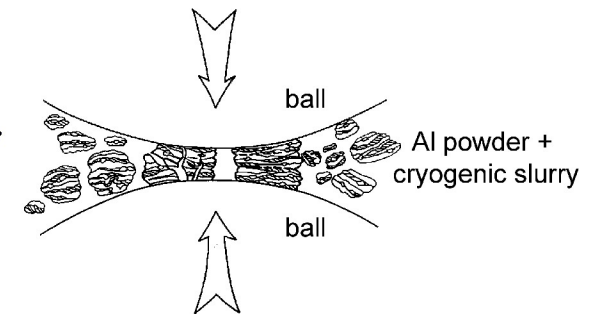
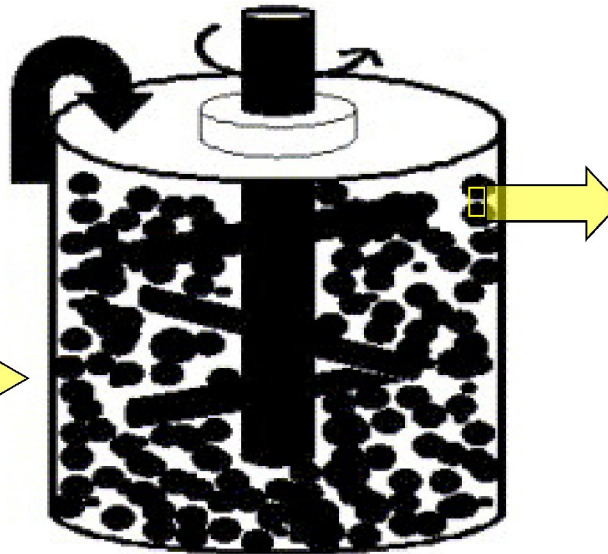
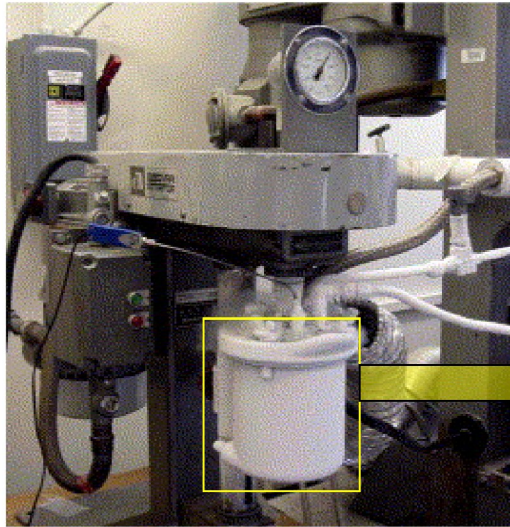
R. A. Karnesky
N. Y. C. Yang, C. San Marchi (SNL)
T. Topping, Z. Zhang, Y. Li,
E. J. Lavernia (UC Davis)

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

UFG Al-Mg: A **Bulk** Material with Properties that Arise from **Nanometer-Scale** Features



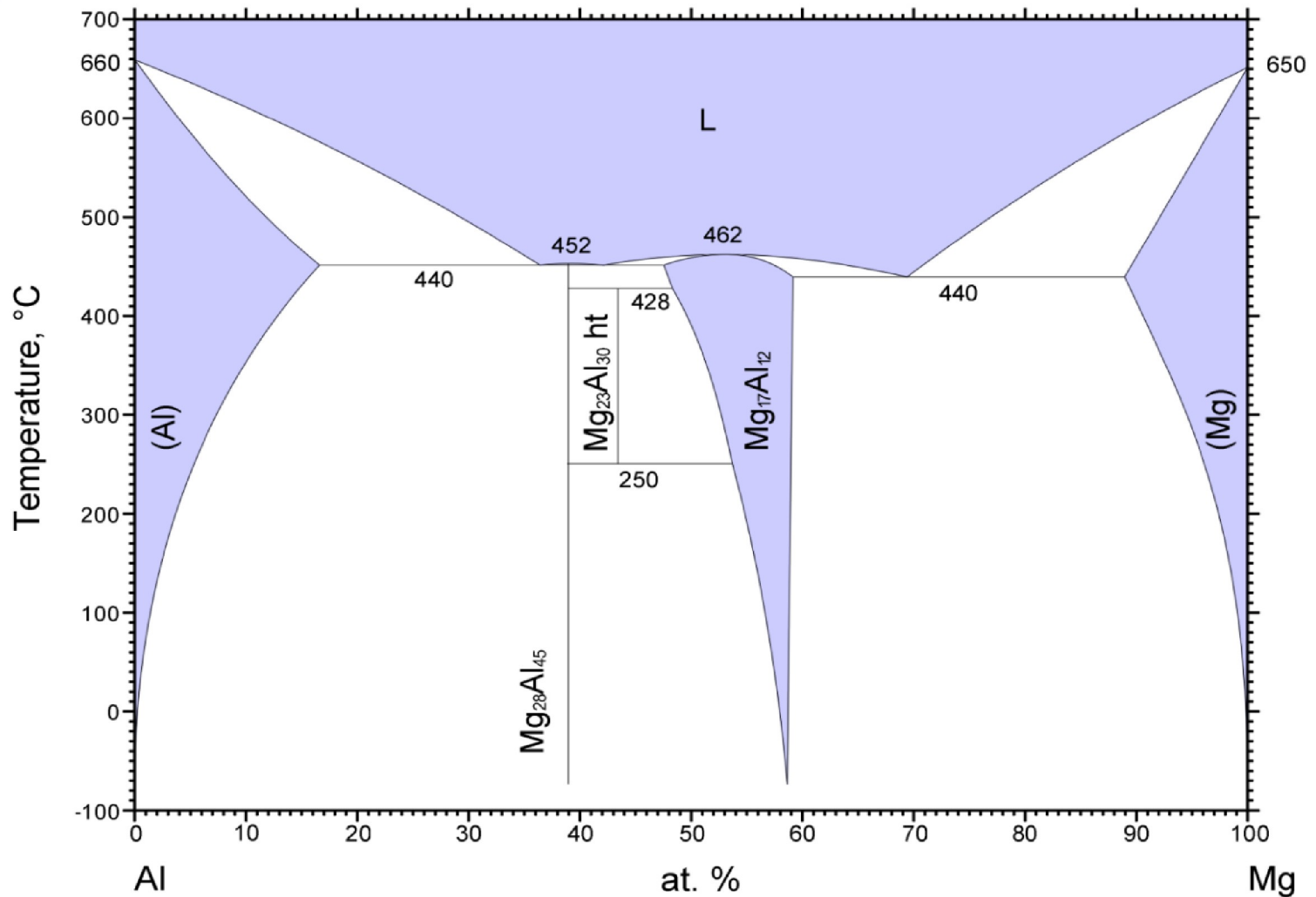
Processing of Cryomilled Al-Mg alloys and Grain Size



Witkin and Lavernia (2006)

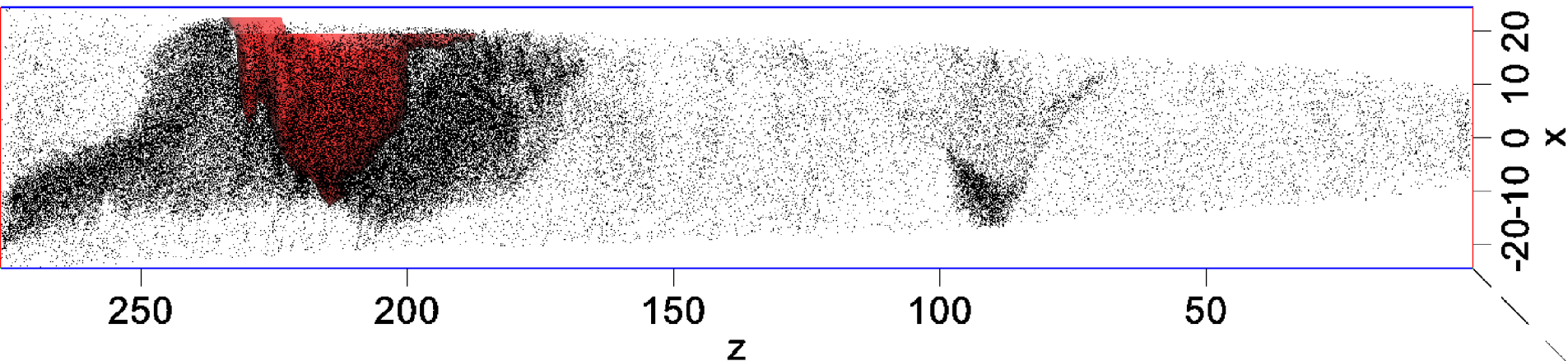
- Atomized ($d \sim 80$ nm)
- Thermally degassed ($d \sim 280$ nm)
- Cryomilled in LN_2 ($d \sim 30$ nm)
- Thermally degassed ($d \sim 140$ nm)
- Primary consolidation by HIP
- Secondary consolidation by extrusion ($d \sim 220$ nm)

Mg Solubility in Al

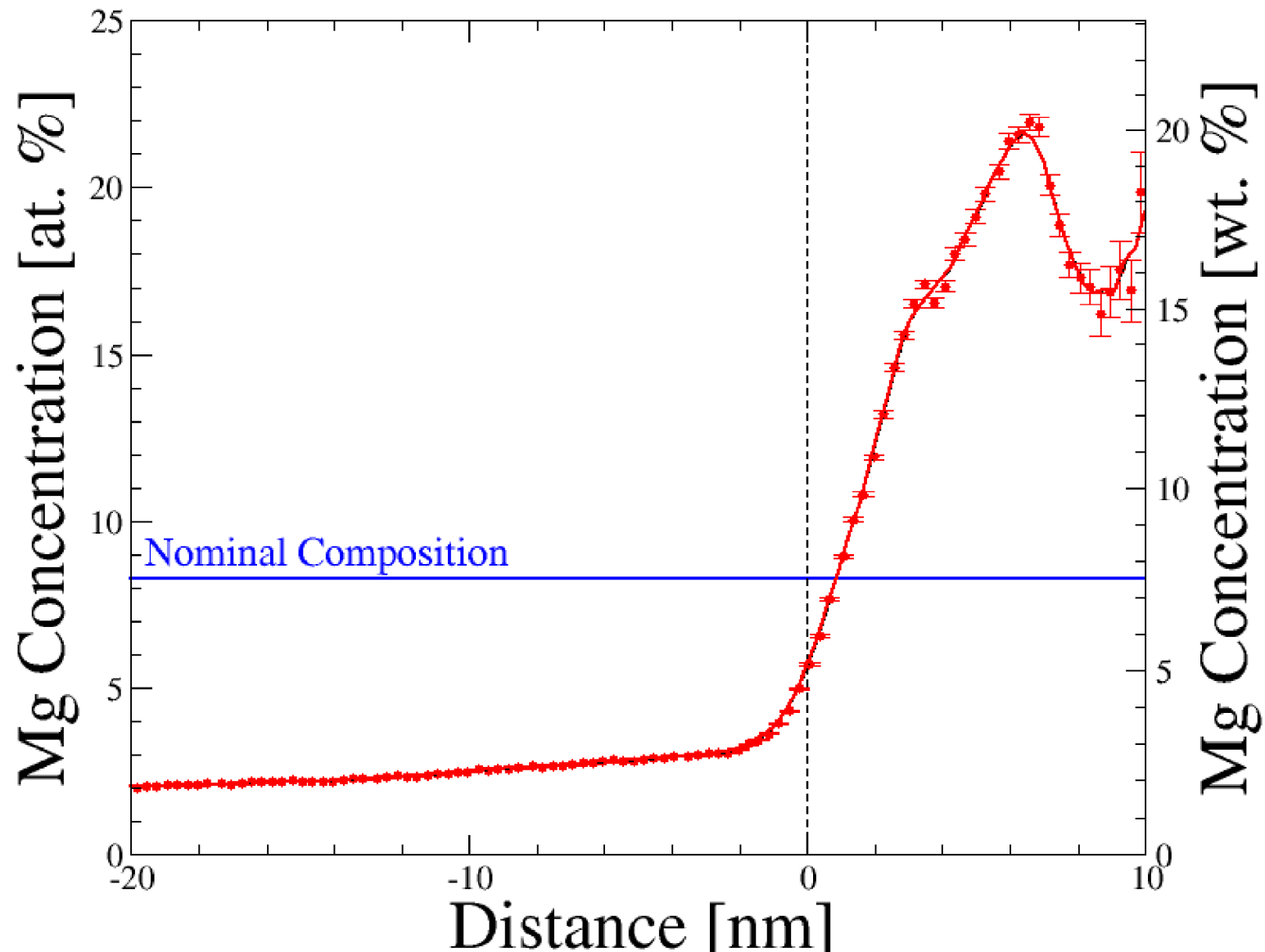


Significant Mg Segregation to GB in Al-7Mg

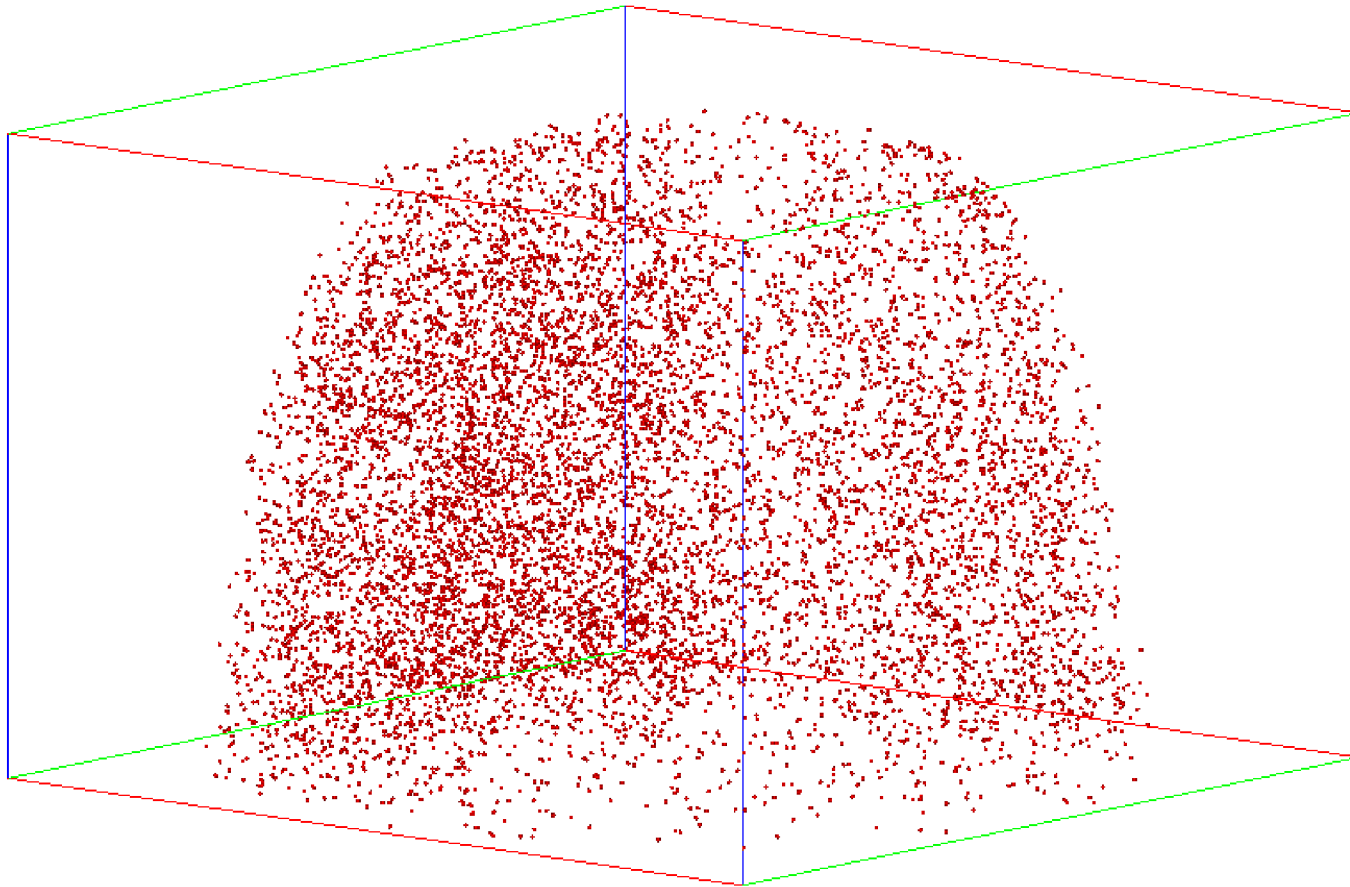
- 11M ion dataset
- Mg segregation at GB
- Large **MgO** at GB (should pin grains)



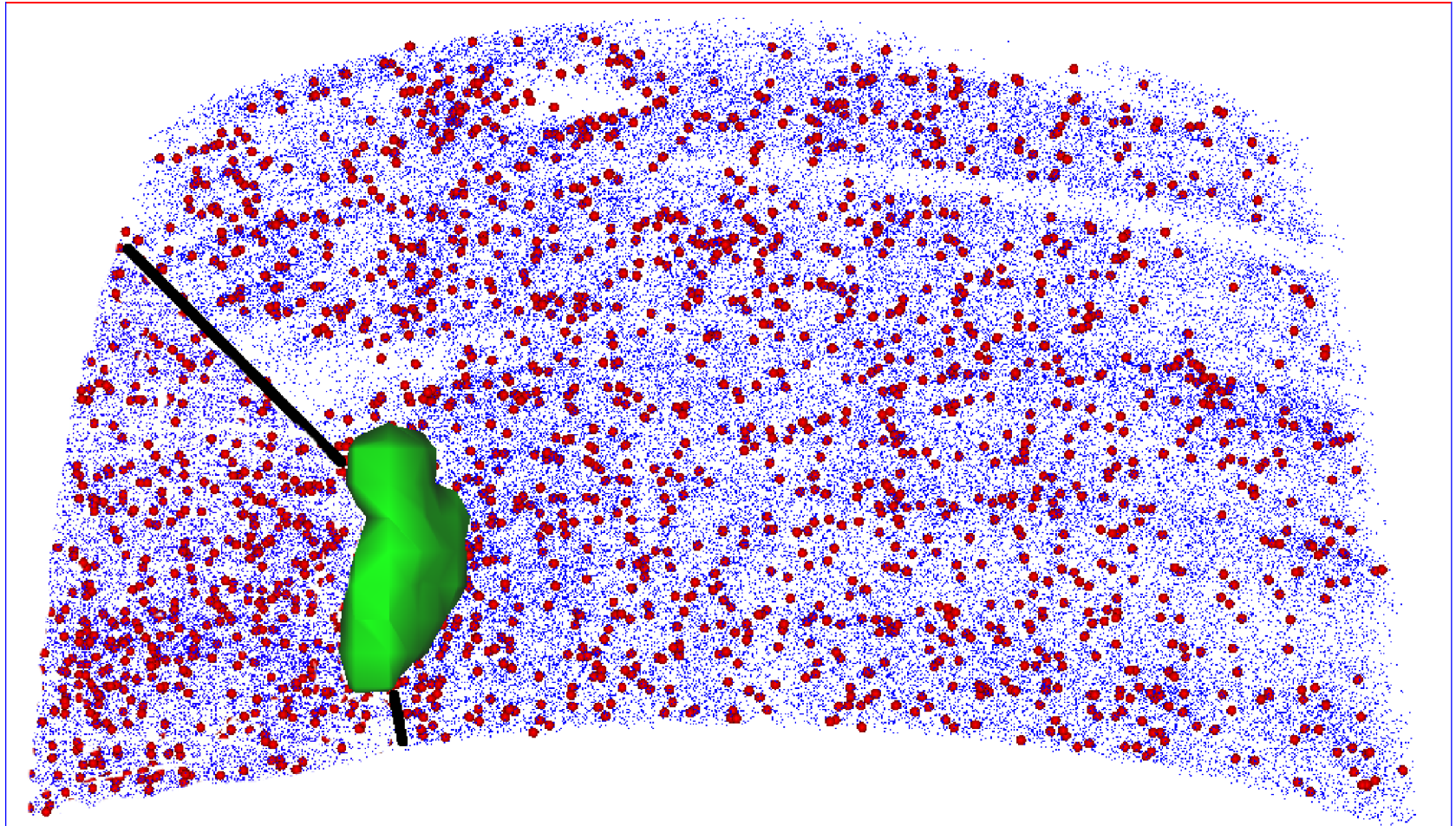
GB segregation of Mg



Composition in Al-1 Mg Grains Matches Nominal Composition

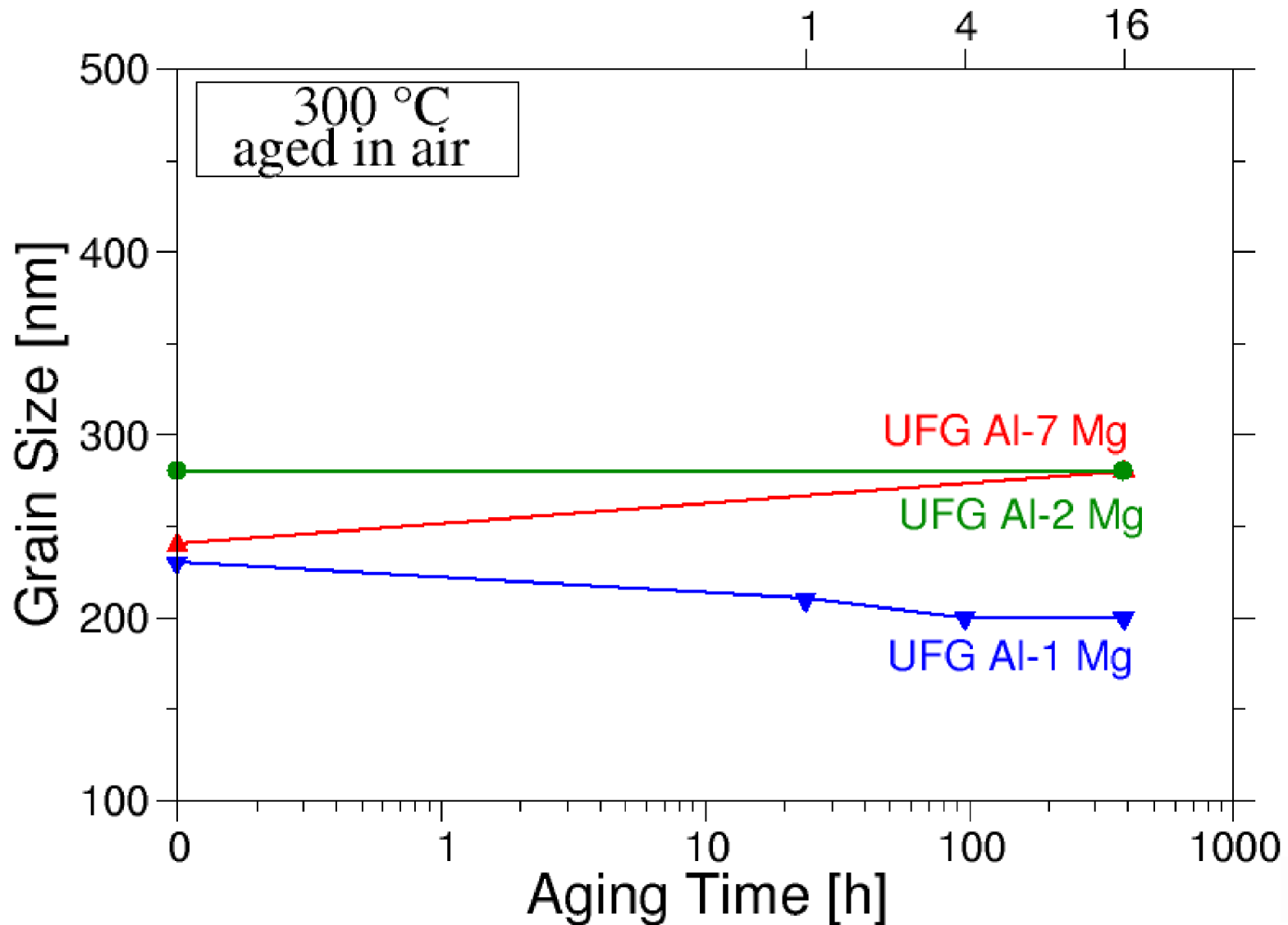


Little GB Segregation Observed in Al-2 Mg, Despite MgO



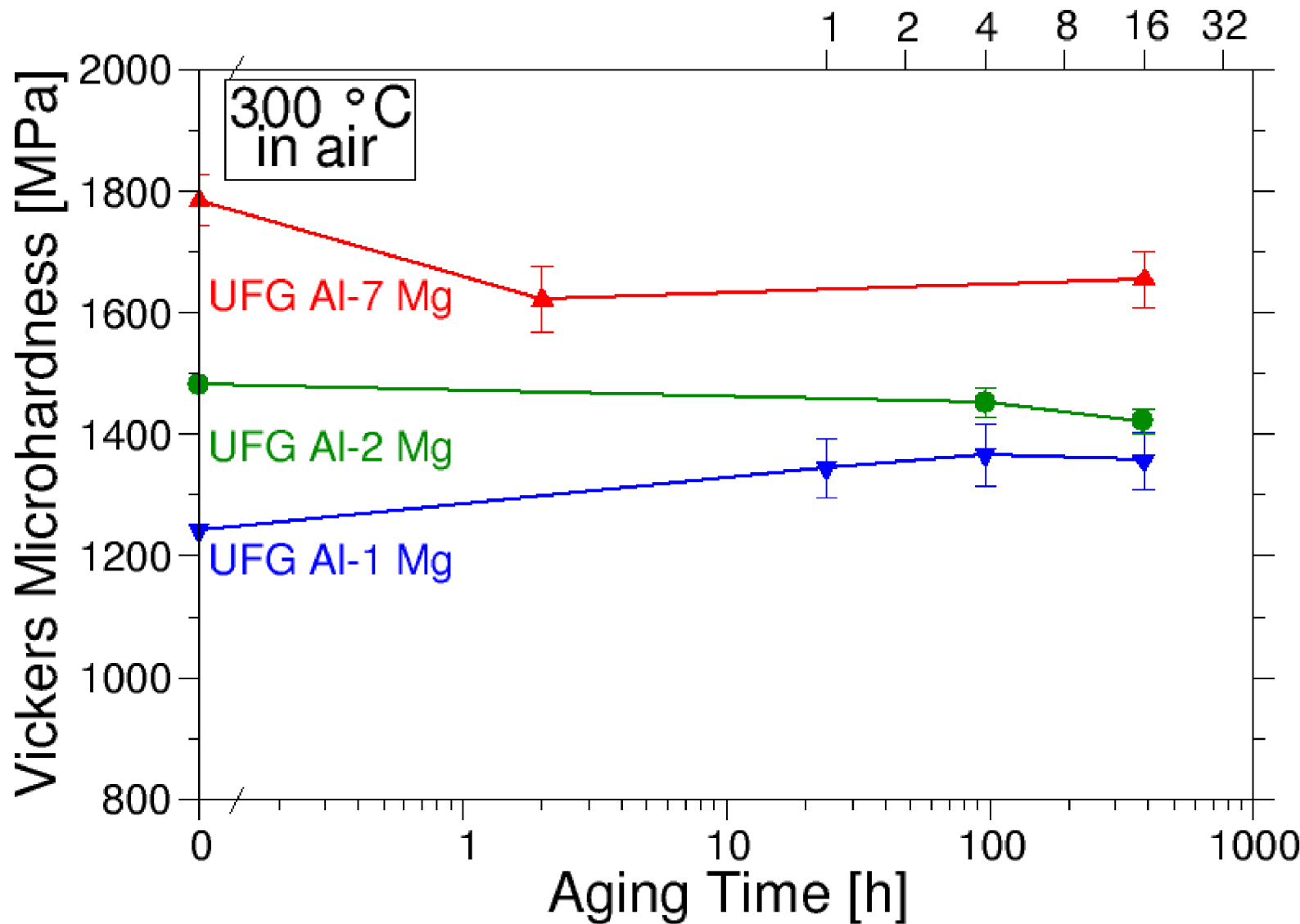
Grain Size Stability up to 300 C

Aging Time [days]



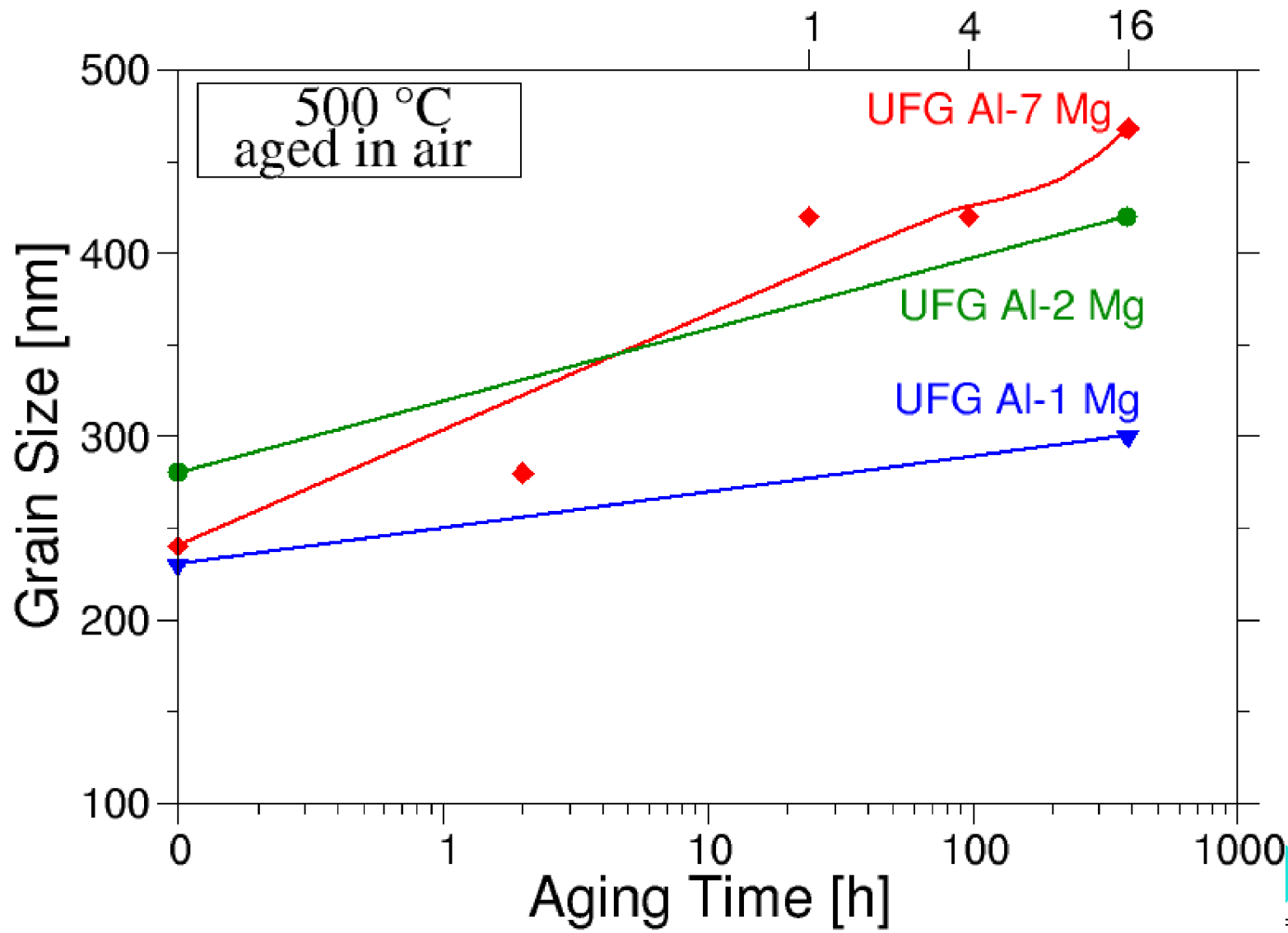
More Mg Leads to Greater Initial Microhardness: Thermally Stable at 300 C

Aging Time [days]

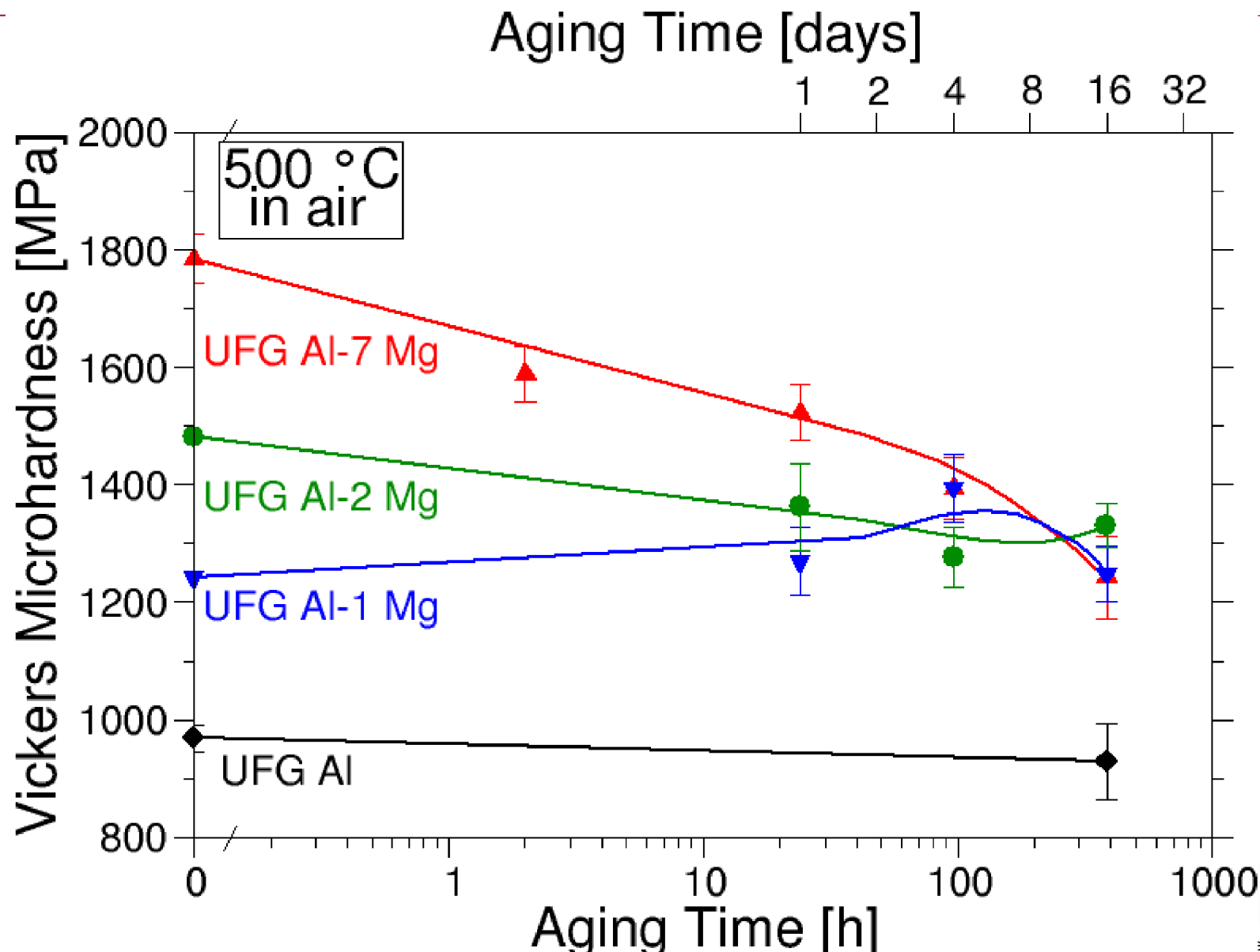


Grain Growth at 500 C

Aging Time [days]



Aging at 500 C decreases Microhardness of Al-7Mg





Summary

- UFG Al-Mg exhibits
 - Outstanding mechanical strength
 - Reasonable thermal stability
- Higher Mg content leads to greater solid solution strengthening, but to a limit:
 - Mg segregation to GB in Al-7.5% Mg
 - Grain growth, loss of hardness on 500 C aging, particularly in high-Mg alloys



Acknowledgements

- SNL LDRD funding
- UC Davis for materials
- J. Chames, M. Clift, R. Nishimoto, A. Gardea (Sandia)



Q&A

Local-Electrode Atom-Probe (LEAP) Tomography

Compositional and structural analysis at the atomic scale

- Pulse encodes **z**
- Area detector gives **(x,y)**
- TOF encodes **mass/charge**

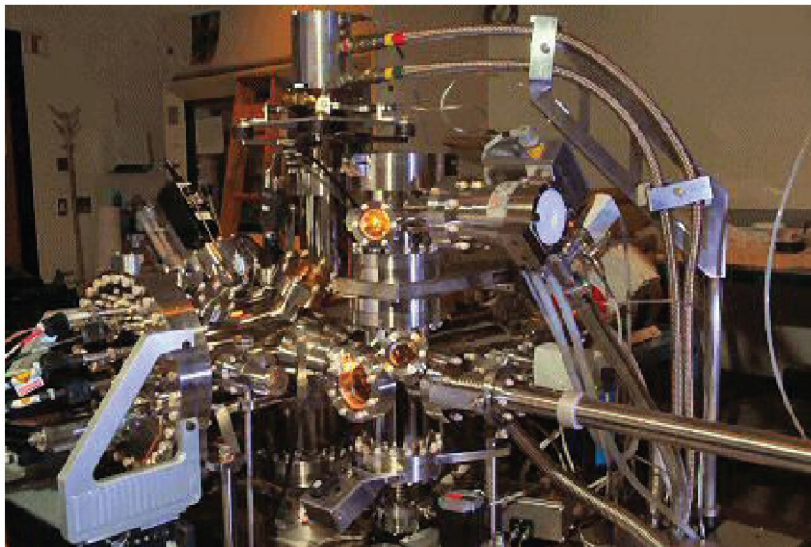
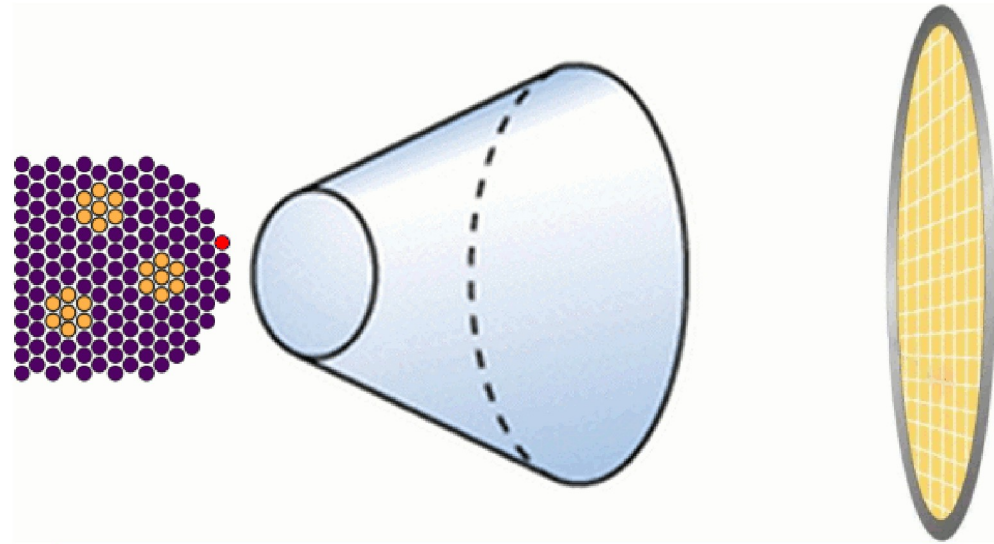
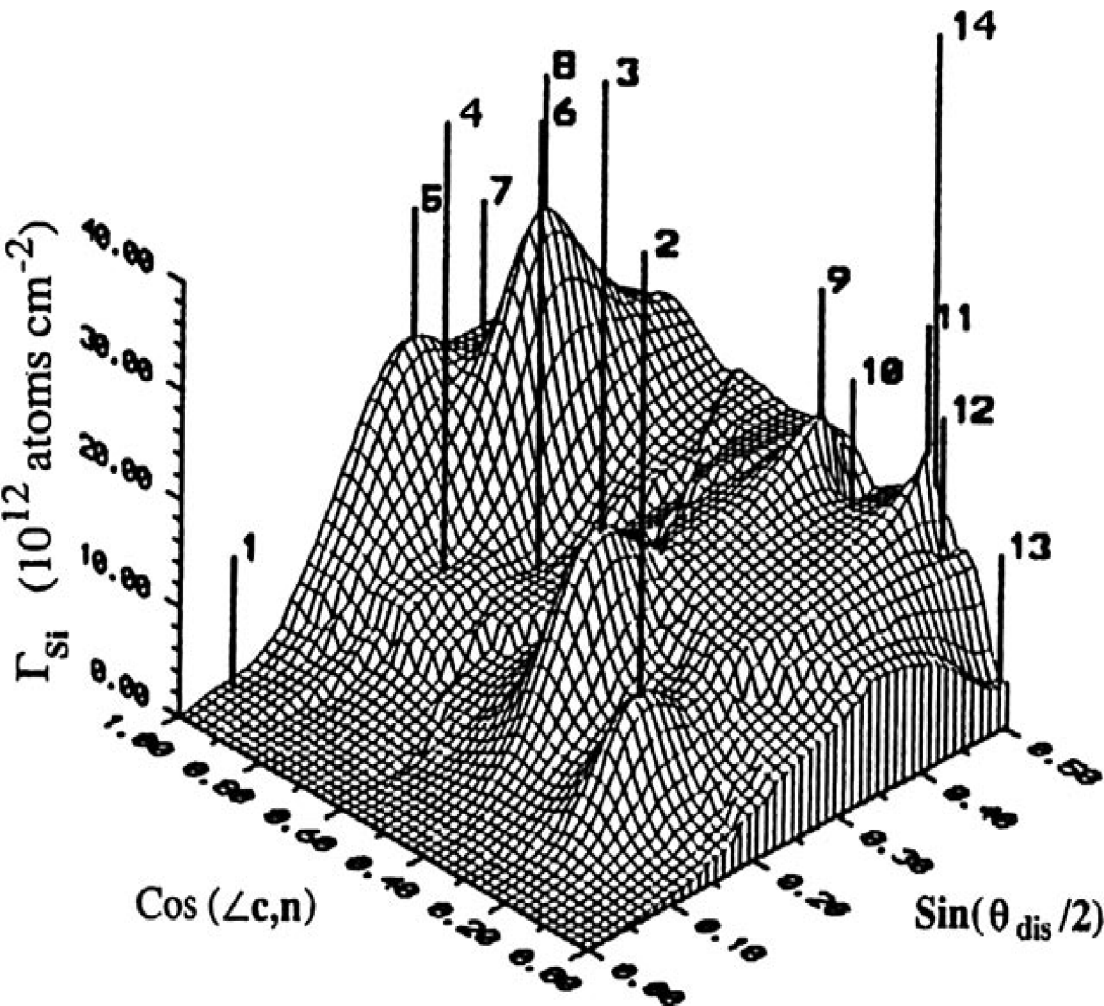


Photo courtesy of R.P. Koll

Instrument capability

- 10^6 – 10^7 nm³ analysis volume
- 3×10^{-11} – 10^{-10} torr UHV
- 20–100 K specimen temp.
- 200 kHz electrical pulsing

A Note on GB Segregation



- Complex function of GB's 5 DOF
- Possible to perform TEM on APT tip in CG specimens
- Hard in NC specimens
– MANY GBs