SAND2011-7862 C

SAND2011-7862C

Effects of ^{3}He in ErT_2

Clark S. Snow

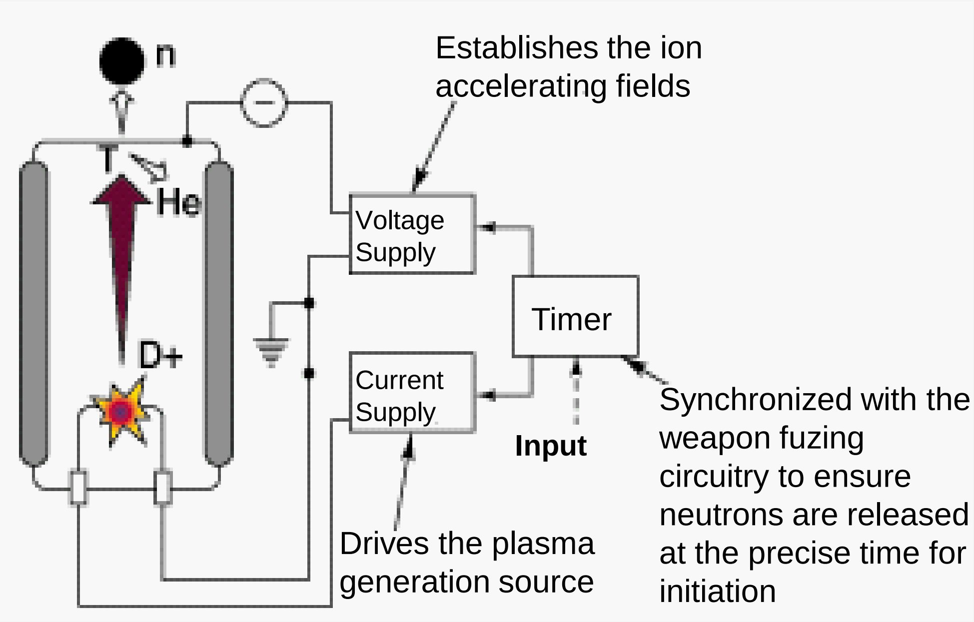
Jim Browning (ORNL), Gillian Bond (NMT Emeritus), Mark Rodriguez, Jim Knapp, and Ryan Wixom

JOWOG 22/4

November 14-16, 2011

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

What is a neutron tube?



- A neutron producing device
- Relies on the “DT” nuclear reaction to produce neutrons:

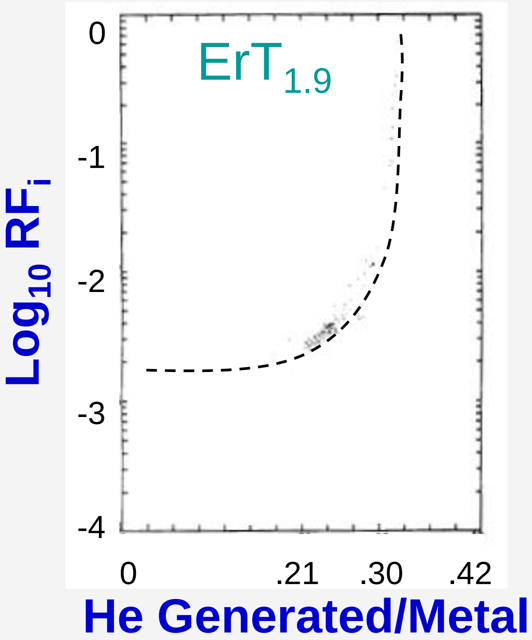
  $^{2}H + ^{3}H \rightarrow ^{4}He + n$

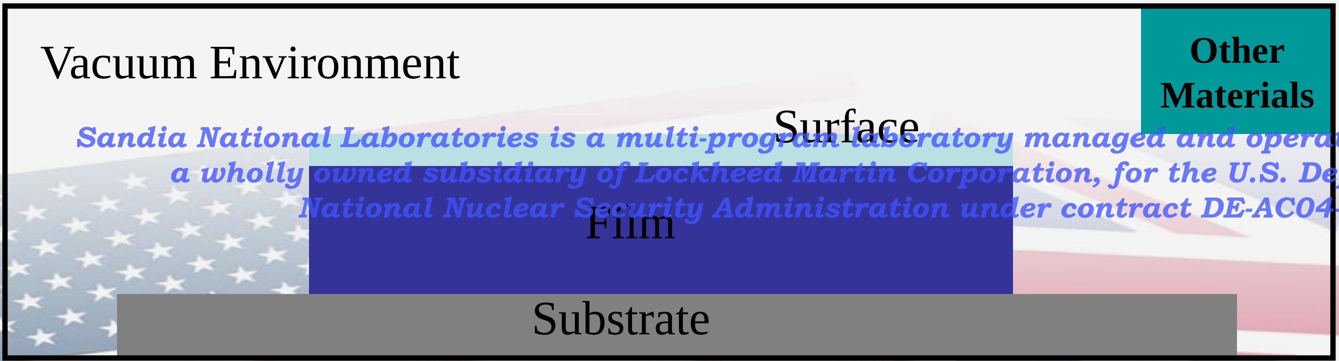
  Q=+17.6 MeV
- In our case, a beam of deuterium ions interact with tritium containing target.
- The target is an **erbium tritide film, ErT_2**.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

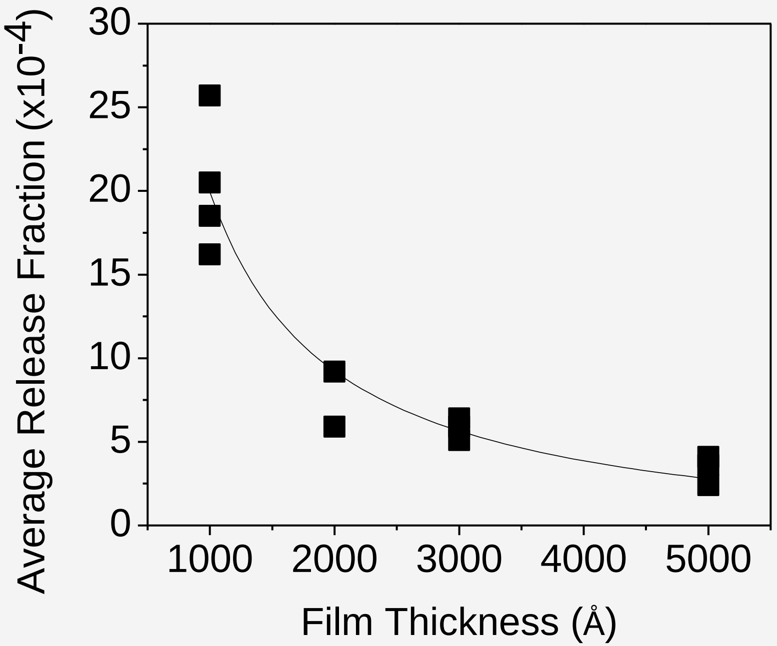
Conceptual problem

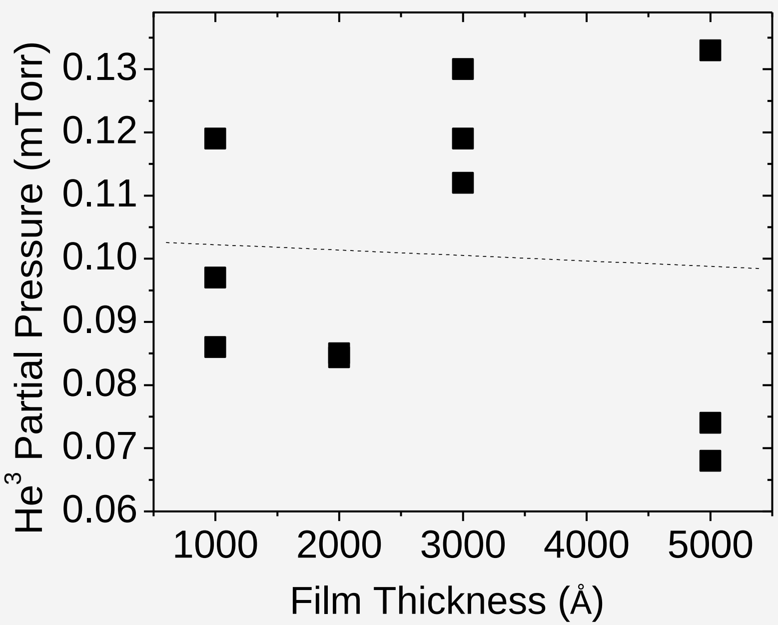
- Helium forms in tritide film
- Helium evolves in film, such that two phases of life: early release and critical release.





Early helium release comes from the near surface of $ErT_{2-x}He_x$

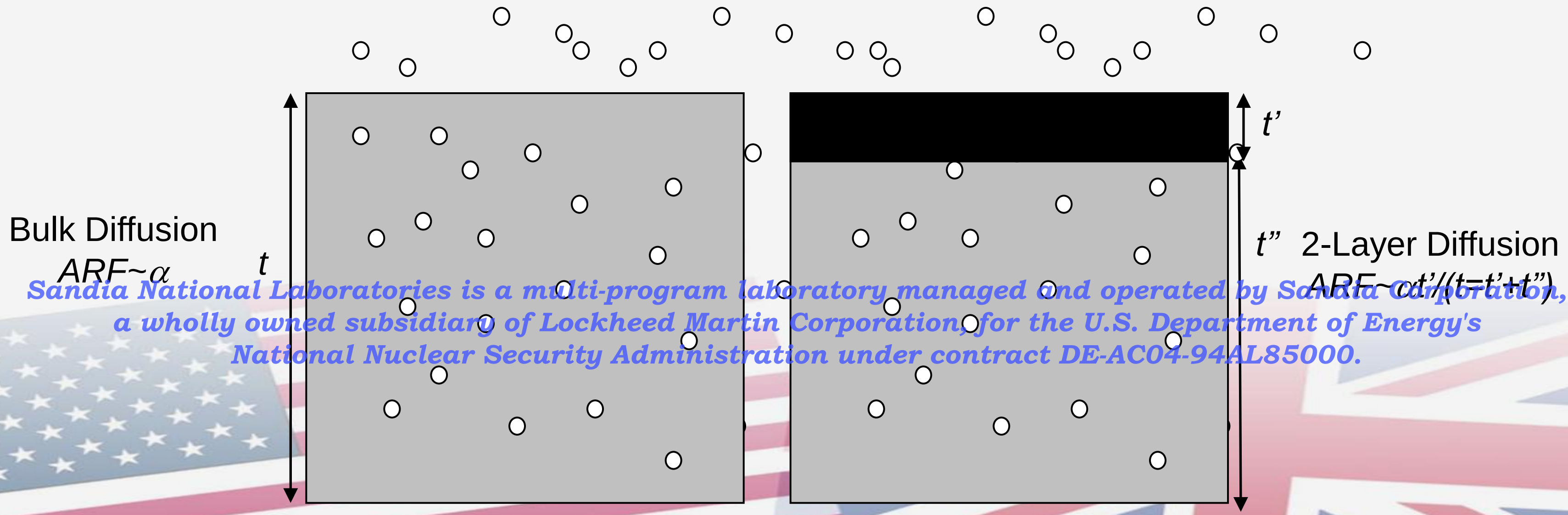




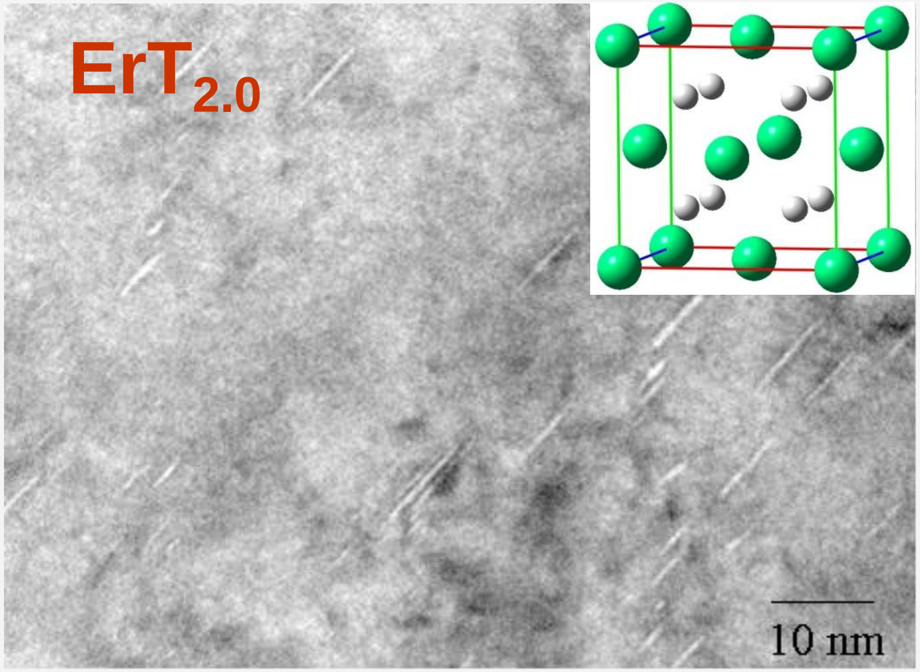
- Total helium released is constant.
- ARF varies inversely with thickness.

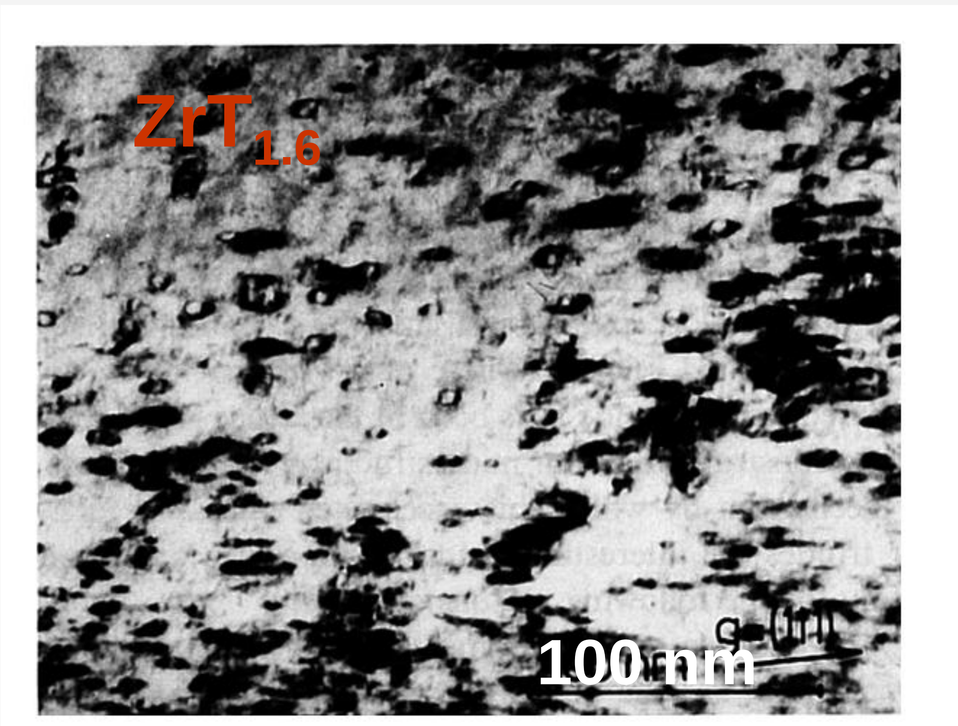
Explanation of ARF v. Thickness data

- If the helium evolved from the films uniformally, i.e. from all depths of the film equally, then the helium release fraction should scale with thickness.
- If the helium evolved from the bulk then the release fraction should be constant.
- If the helium evolved from the surface then the release fraction should vary inversely with thickness.



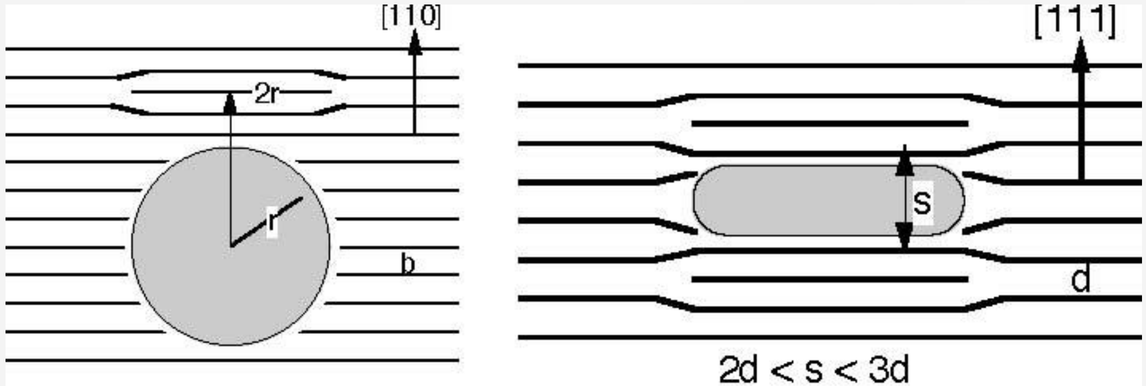
The majority of the generated helium is stored in helium bubbles.





Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Why platelets?



$$P_{LP} = \frac{2\gamma}{r} + \frac{\mu b}{r}$$

γ = surface energy
μ = strain energy
b = Burger's vector

$$P_{DE} \approx \frac{2\gamma}{s} + \frac{\mu d}{r}$$

Bubble geometry determined by ratio of $\frac{\gamma}{\mu b}$

FCC						HCP		BCC	
ErT_2	ScT_2	TiT_2	Ni	ZrT_2	PdT	Be	Ti-α	W	V-α
.061	.104	.117	.180	.258	.322	.051	.238	.103	.312
Platelets	Plat.	Sph.	Sph.	Sph.	Sph.	Plat.	Sph.	Plat.	Sph.

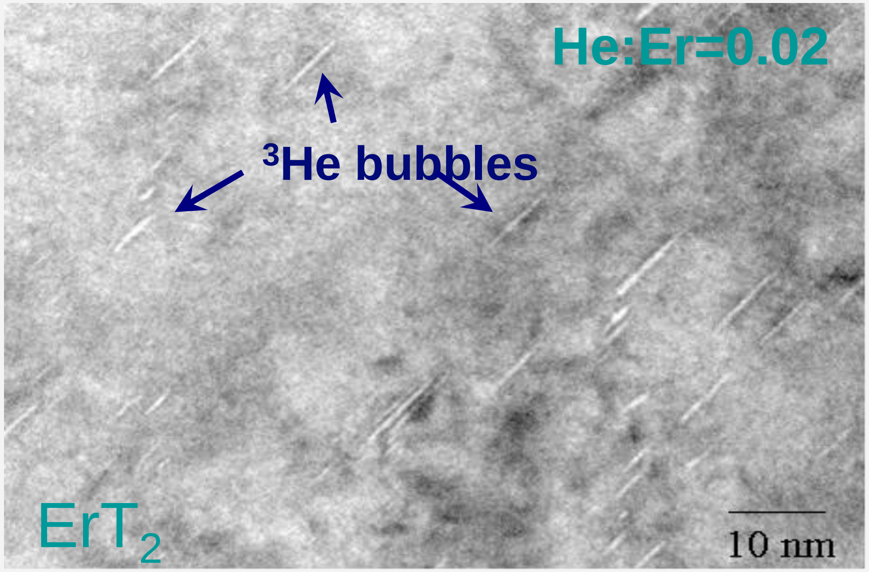
Don Cowgill, in *Effects of Hydrogen on Materials*, ed. By B. Somerday, P. Sofronis, and R. Jones, Proceedings of the 2008 International Hydrogen Conference, Sep. 7-10, 2008, Jackson, WY.

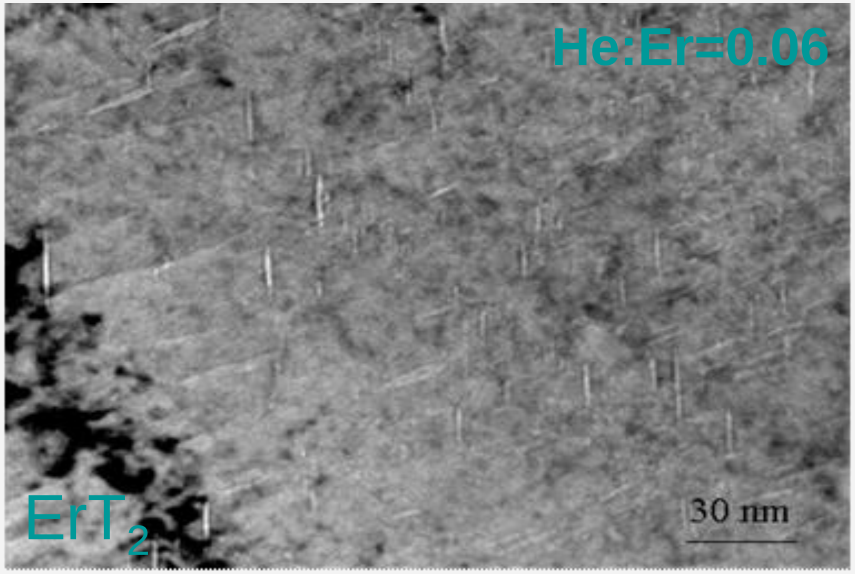
TEM studies of helium bubbles

Measurements by G. Bond, samples by B. Ritchey

- JEOL 2000FX 200keV TEM
  - Noran EDX SiLi detector
  - Stacked geometry used for sample
    - Pair of films glued face to face
    - Sandwich inserted into Mo tube with Mo bracing strips
    - Tube back-filled with epoxy
    - After curing, tube cut into disks
    - Resulting samples dimpled to ~20µm in thickness
    - Ion milled at +/- 4° with 3-5keV Ar ion beam until perforation

Helium bubbles in $ErT_{2-x}He_x$

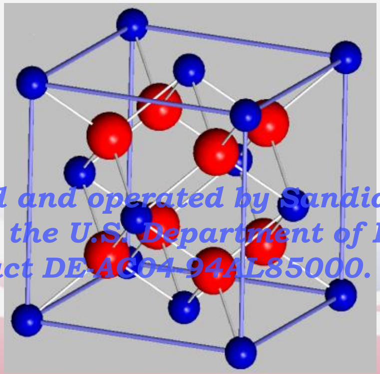




- TEM cross-section and plan view, bright-field, ~{110} zone:

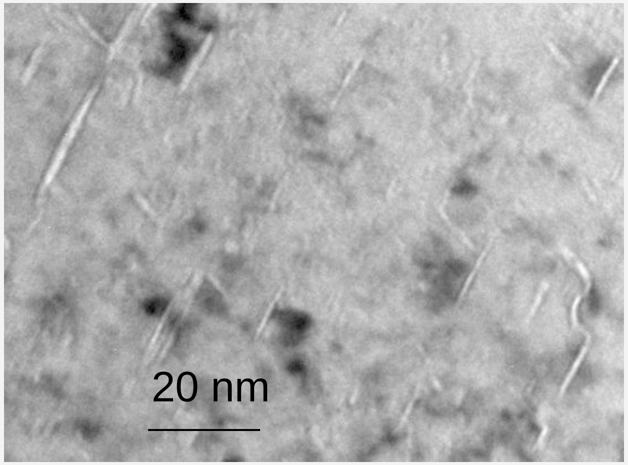
- Bubble populations are visible on two different sets of {111} planes

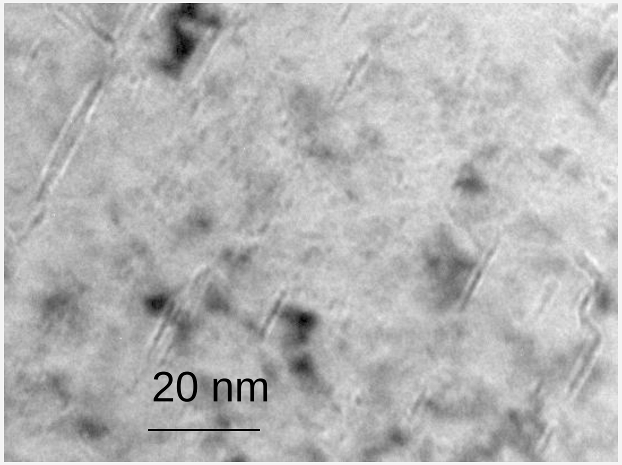
β-phase fluorite structure

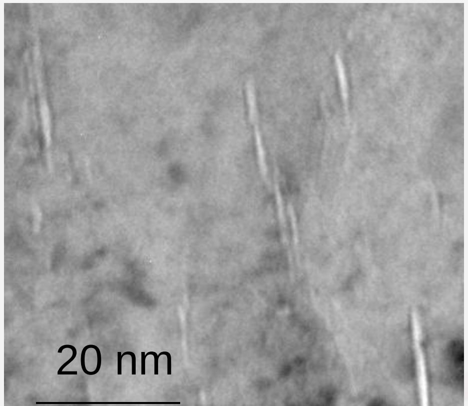


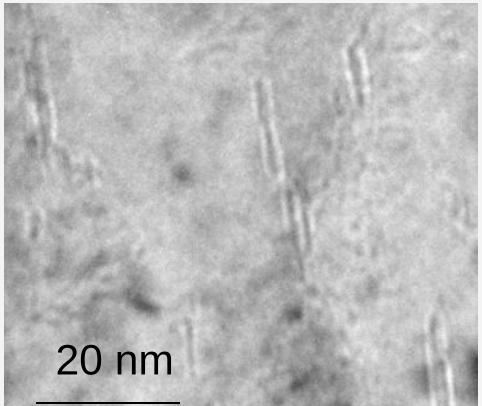
H:M = 2.0

Helium bubbles at He:Er 0.098





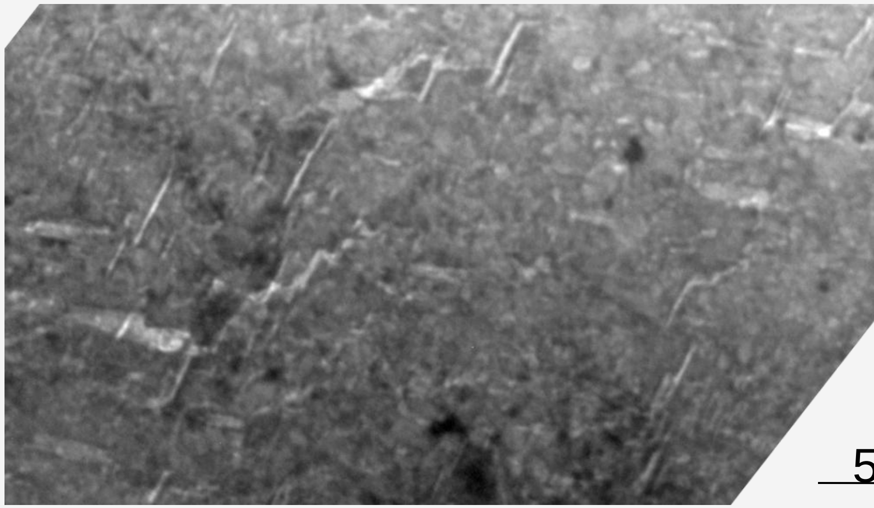




Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

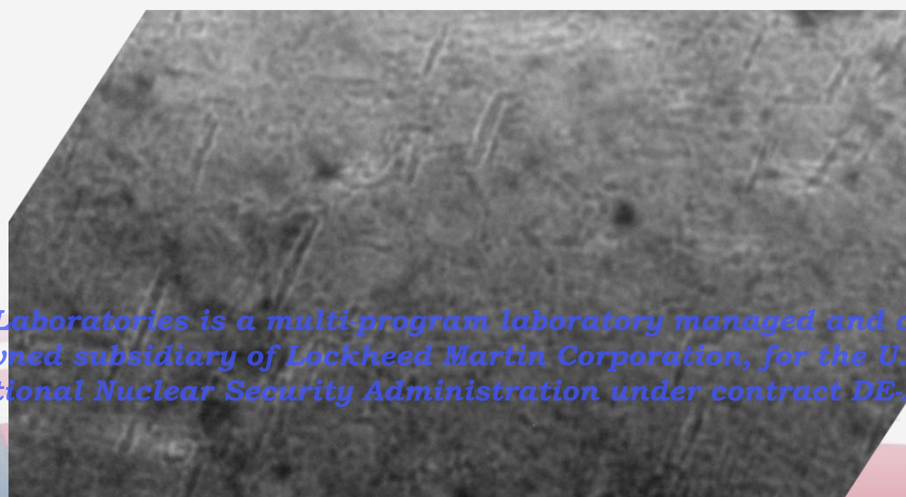
342 days, He:Er 0.098, plan view (PV), bright field, under and over focus

Helium bubbles at He:Er 0.37



Under focus

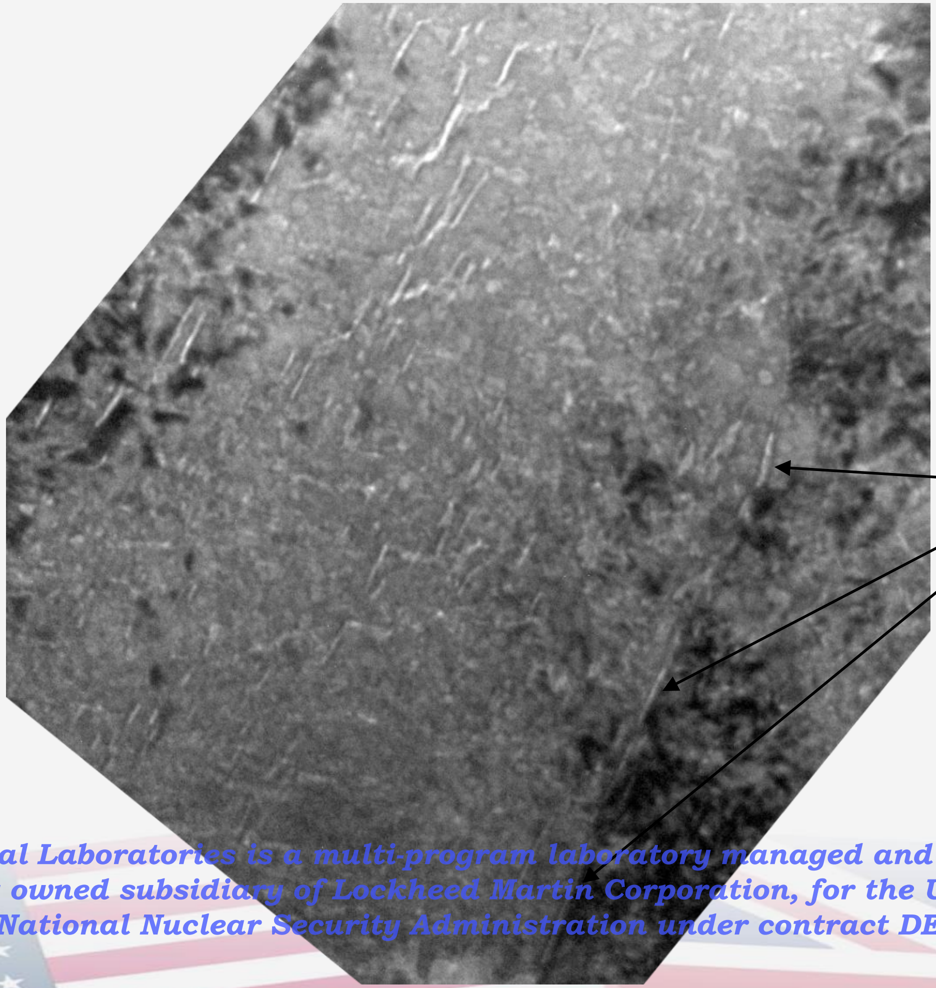
50 nm



Over focus

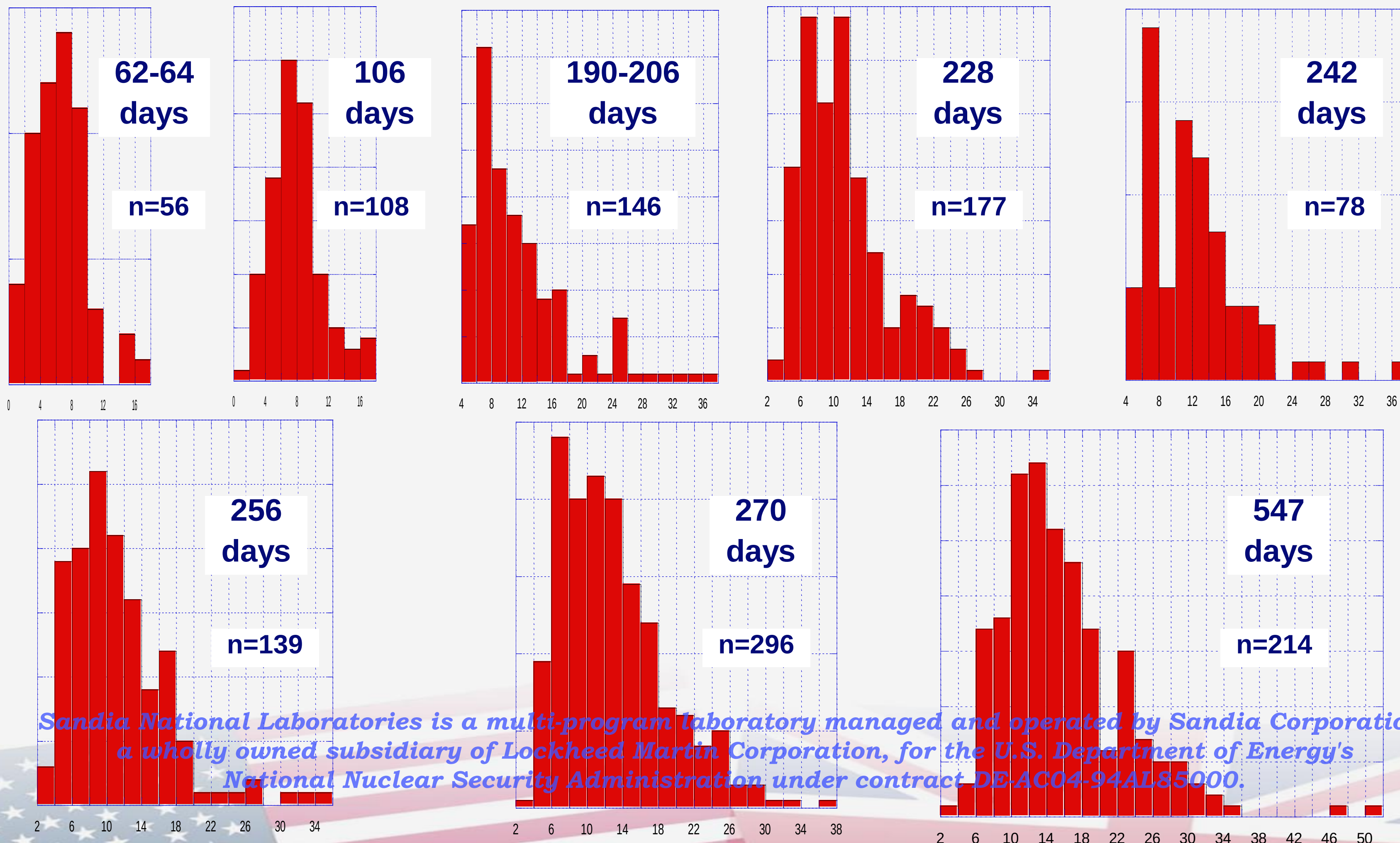
1302 days

Helium bubbles begin to decorate the grain boundaries



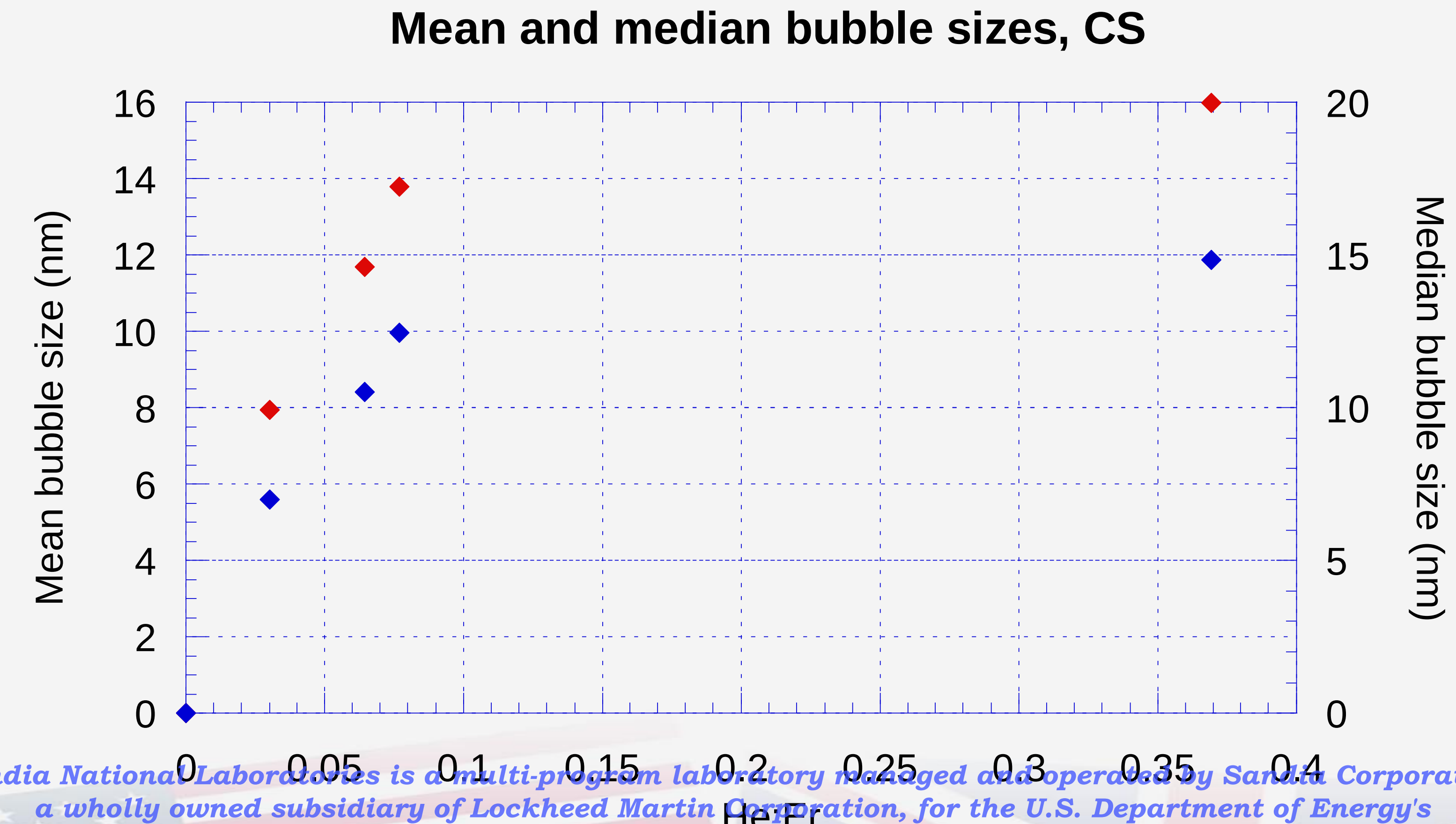
1305 days

Helium Bubble Growth in $ErT_{2-x}He_x$



Data by Gillian Bond NMTech and James Browning ORNL

Bubble Sizes in $ErT_{2-x}He_x$

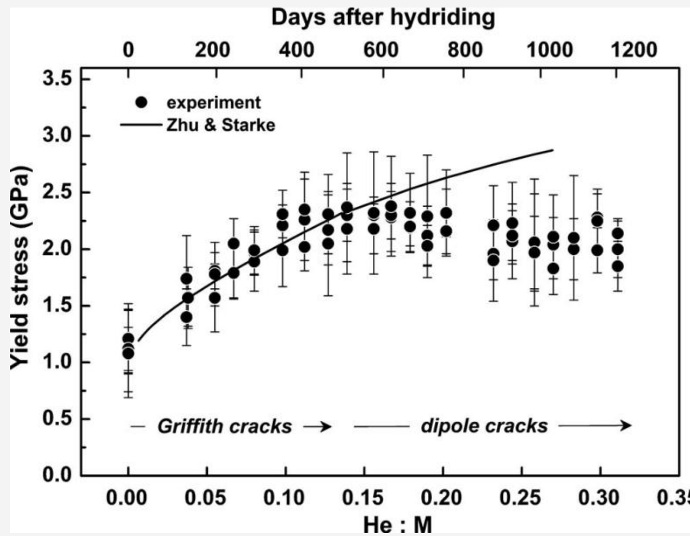


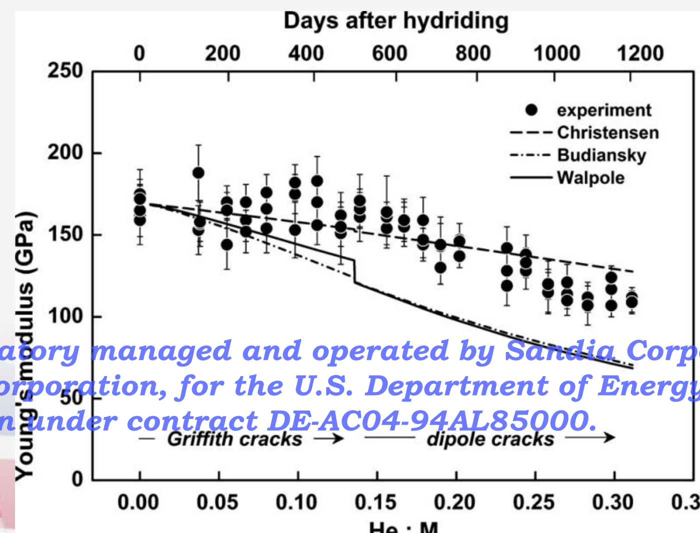
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

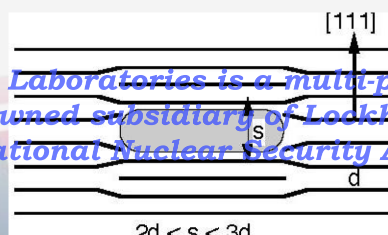
G. M. Bond et al., Journal of Applied Physics **107**, 083514 (2010).

Evolution of mechanical Properties

- Griffith cracks early in life.
- Transition to dipole cracks.
- Transition occurs around 0.15 He/M.

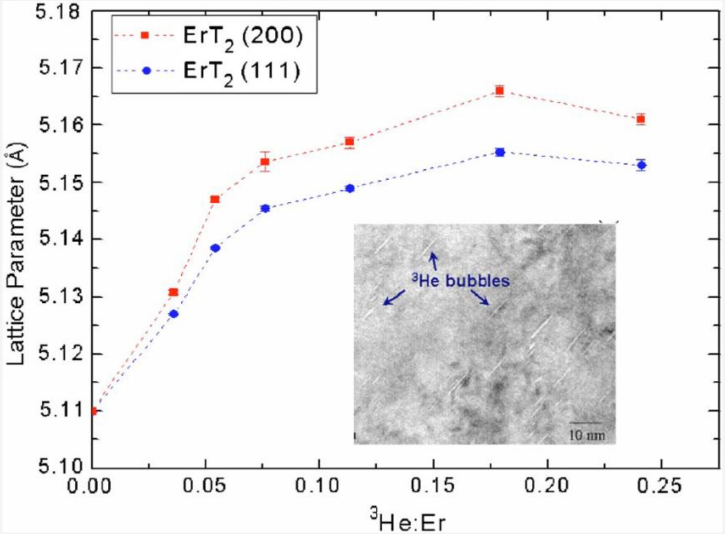




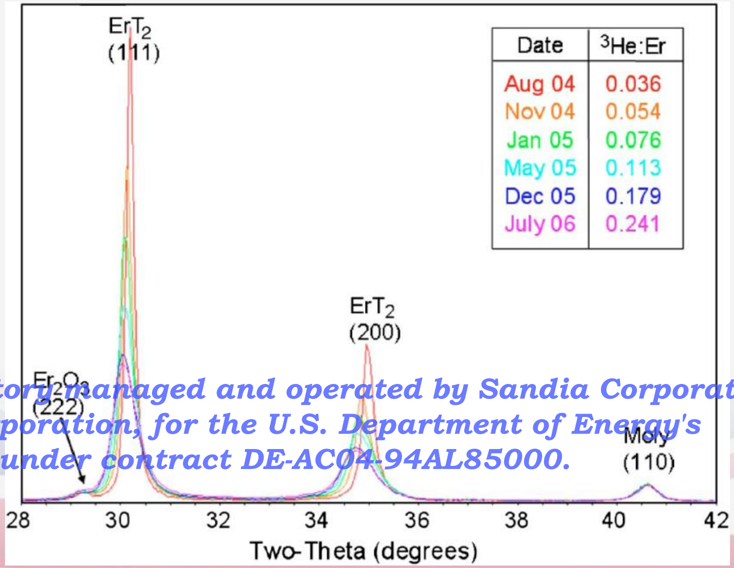


J. A. Knapp et al., *Journal of Applied Physics* **105** , 053501 (2009).

Evolution of the Lattice



- Griffith cracks cause lattice to swell linearly and uniformly early in life.
- Transition to dipole cracks ~0.10 - 0.15 He/M
- Films have (200) out-of-plane texture which allows lattice to expand.



M. A. Rodriguez et al., *Powder Diffraction* **22(2)** , June 2007 pp. 118-121.

Conclusions

- Helium released from $ErT_{2-x}He_x$ occurs in two phases.
  - Early release that is from the surface.
  - Critical release when helium bubbles fracture.
- Helium bubbles produce Griffiths cracks which grow via dipole loop punching.
- Geometry of bubble dependent on strain energy, surface energy, and the Burgers vector.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.