Victoria
UNIVERSITY OF WELLINGTON
Te Whare Wānanga
o te Ūpoko o te Ika a Māui

Growth and texturing of rare earth nitride thin films

Q2.3 MRS

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- Joe Trodahl

Canterbury University (PLD)

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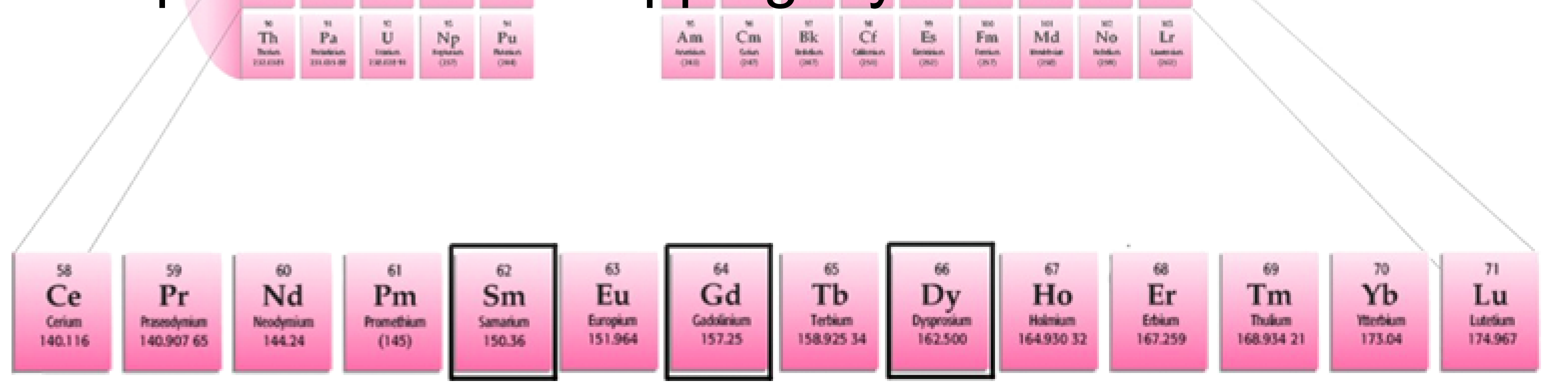
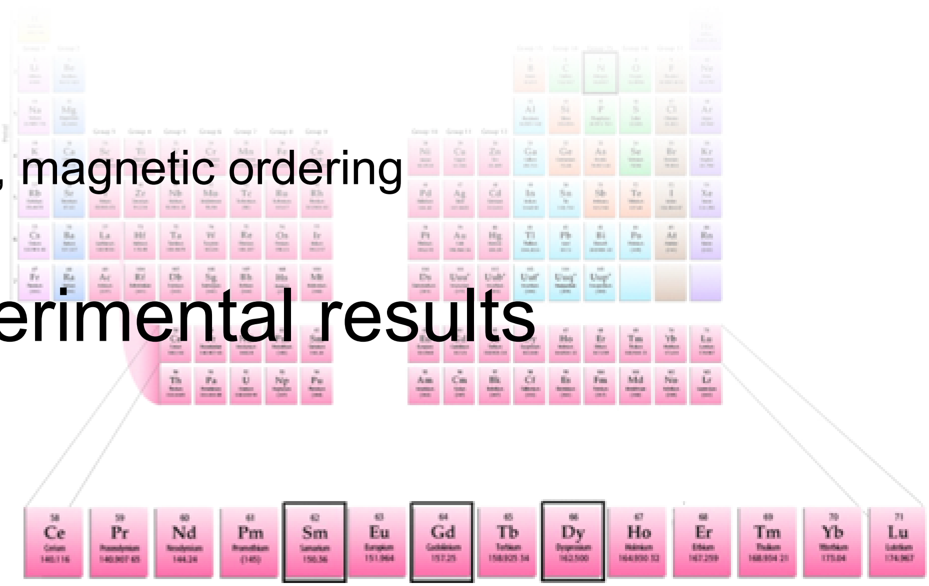
Rare earth nitrides

- Across the RE series you get very…
  - similar chemical properties (5d and 6s electrons)
  - different magnetic properties (unfilled 4f shell)
- All have simple cubic rock salt (NaCl) structure
- React with water in atmosphere
  - Need to passivate with capping layer



Rare earth nitrides

- Interesting questions
  - Electronic structure calculations are challenging
    - localized 4f electrons are tough to deal with
    - Many different predictions
    - Metallic, half-metallic and semi-conducting states predicted
  - Magnetic ordering
    - SmN magnetism
      - Small magnetic moment, magnetic ordering
      - see Claire Meyer Q10.6
- Very clear need for experimental results

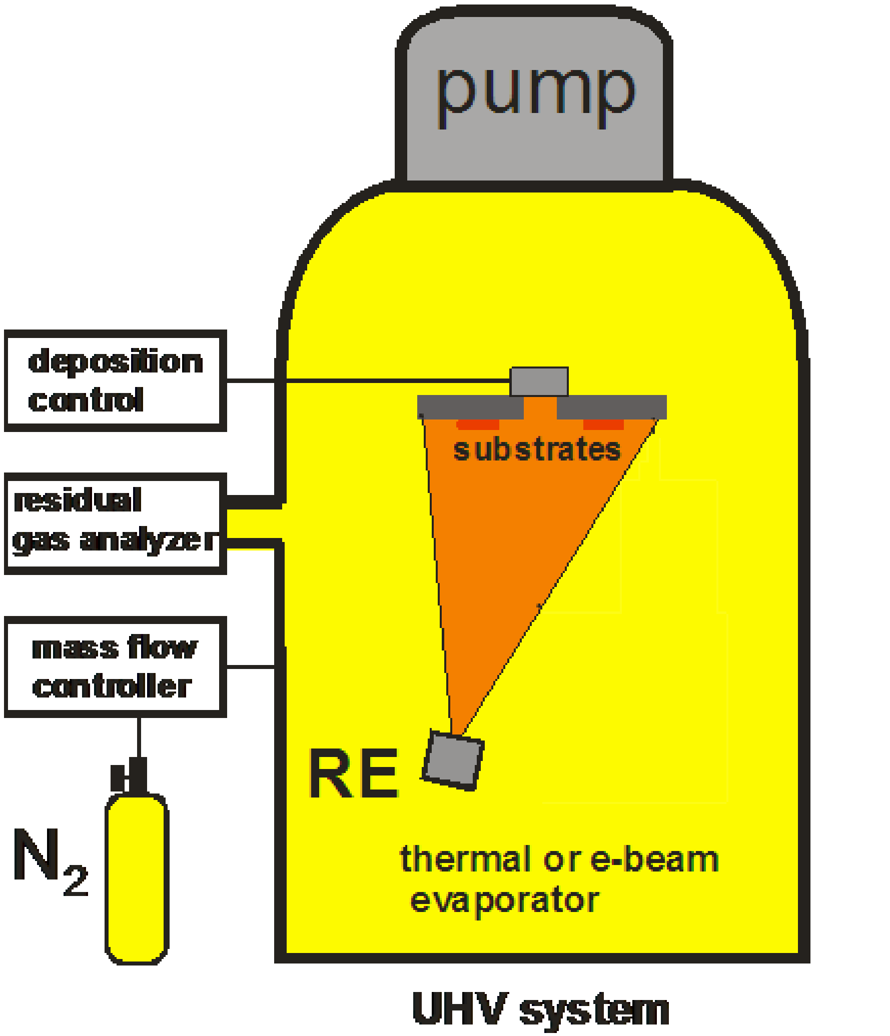


Growth methods

- MBE
  - *Gerlach et al*, Appl. Phys. Lett. **90**, 061919 (2007)
- $RE(NH_2)_2$ -> REN
  - *Imamura et al*, J. All. Comp. 16169 (2007)
- Reactive Ion-Beam sputtering
  - *Leuenberger et al*, PRB **72**, 014427 (2005)
- Thermal evaporation (VUW)
  - *Granville et al*, PRB **73**, 235335 (2006)

Thermal evaporation

- UHV
- Partial pressure of N_2 gas
  - $P_{N_2} \sim 10^{-4}$mbar
- This works!
- GaN or MgF_2 capping layer



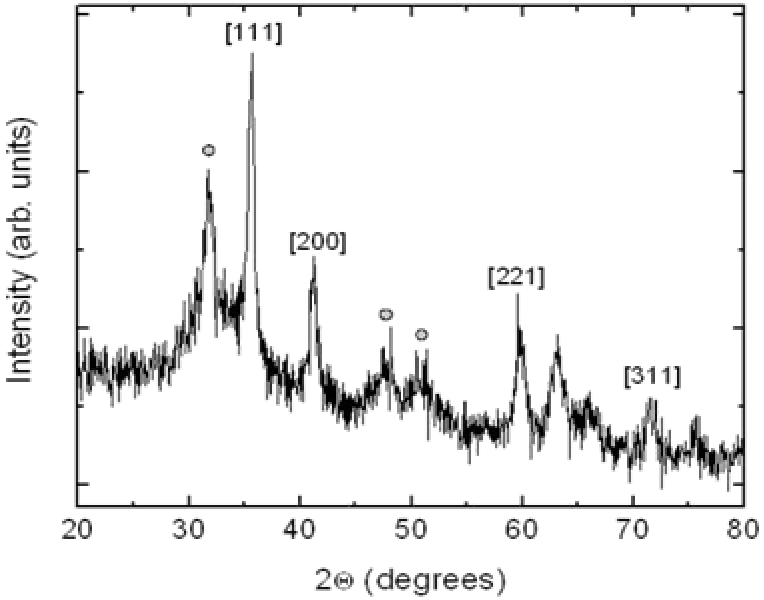
Characterization

- SmN, GdN, DyN, ErN, LuN
- Good 1:1 stoichiometry ± 2% (RBS)
- Low O content, uniform films (SIMS)
- Semiconducting (transport)

Characterization - XRD

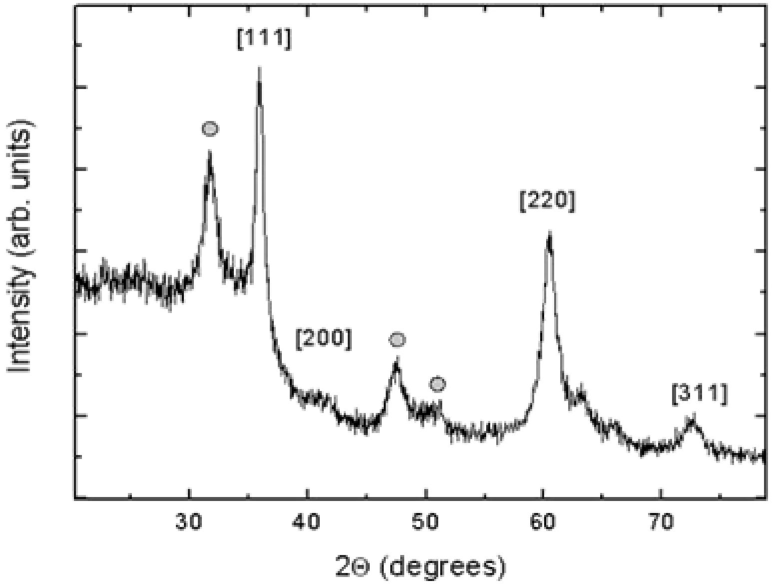
- Typical REN
- Randomly oriented nanocrystals (~10nm)

SmN

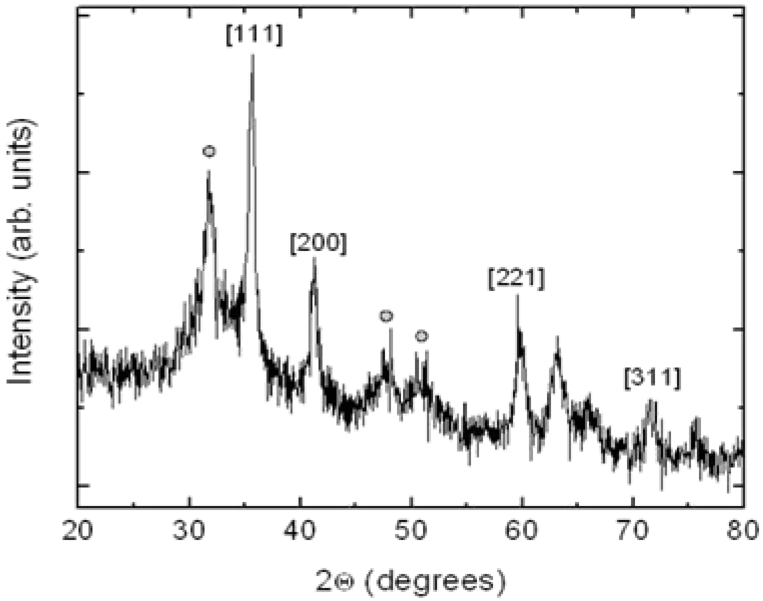


Characterization - XRD

GdN (!)

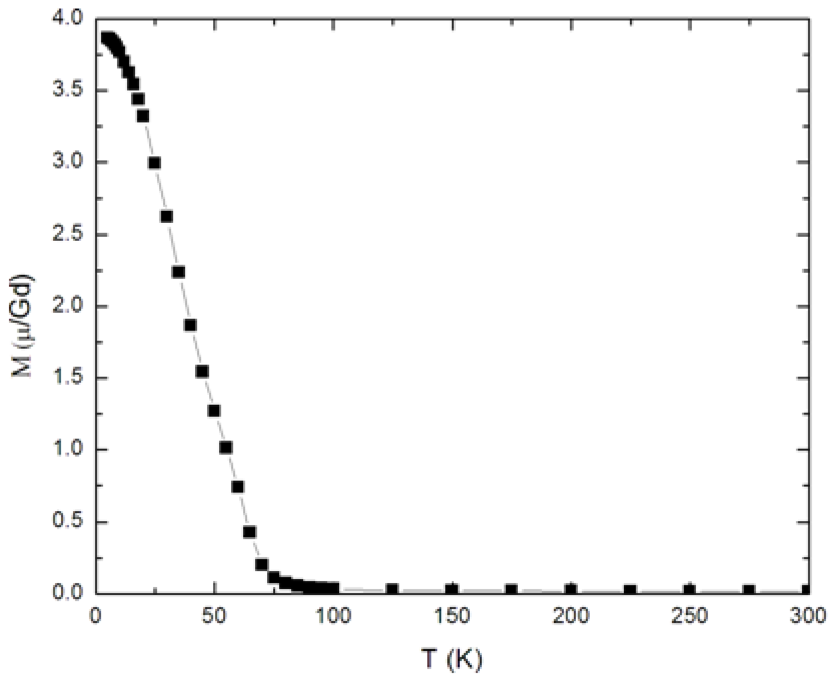


SmN



Characterization

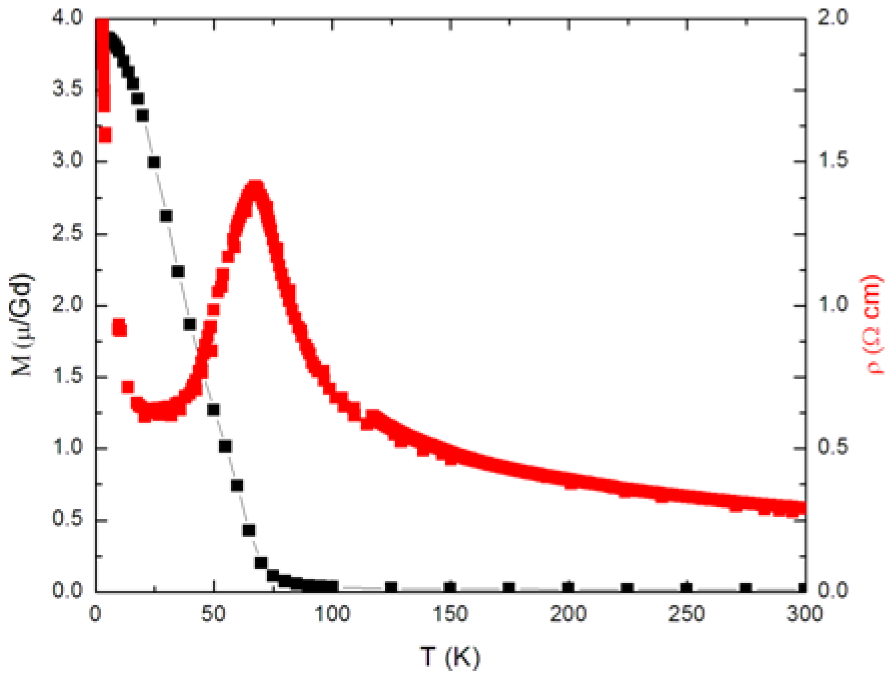
- Clear magnetic transitions (GdN: 70K)
- Coercive field ~ 250 Oe



Granville et al, “Semiconducting ground state of GdN thin films”
Phys. Rev. B, **73**, 235335 (2006)

Characterization

- Semiconducting behaviour
  - smaller gap in ferromagnetic ground state



Granville et al, "Semiconducting ground state of GdN thin films"
Phys. Rev. B, **73**, 235335 (2006)

Pulsed Laser Deposition (PLD)

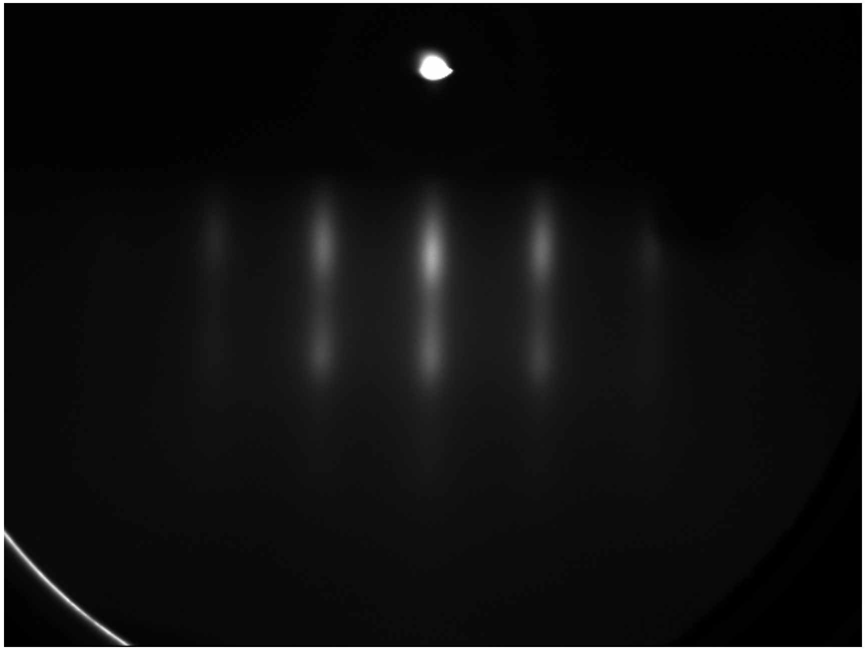
- Laser ablation of RE metal source
- Similar to thermal evaporation techniques except that evaporation rate is time dependant (depends on pulse frequency)
- Main advantages
  - Can grow at elevated temperature
  - Novel capping materials possible
  - RHEED for *in situ* characterization

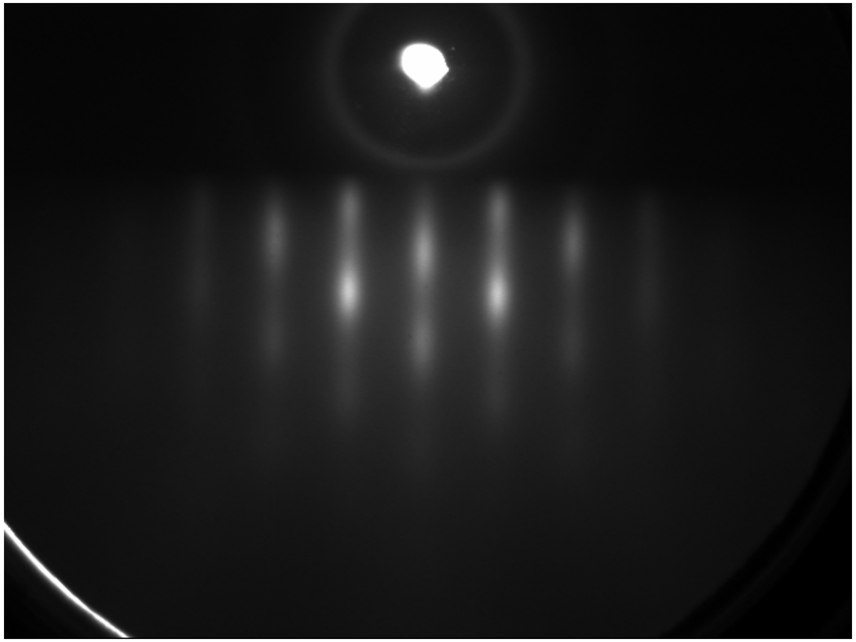
PLD - GdN

- Have grown thin films of GdN
- At elevated temperatures: ~700° C
- Substrates: Si, Sapphire, YSZ
- Capping layer: YSZ

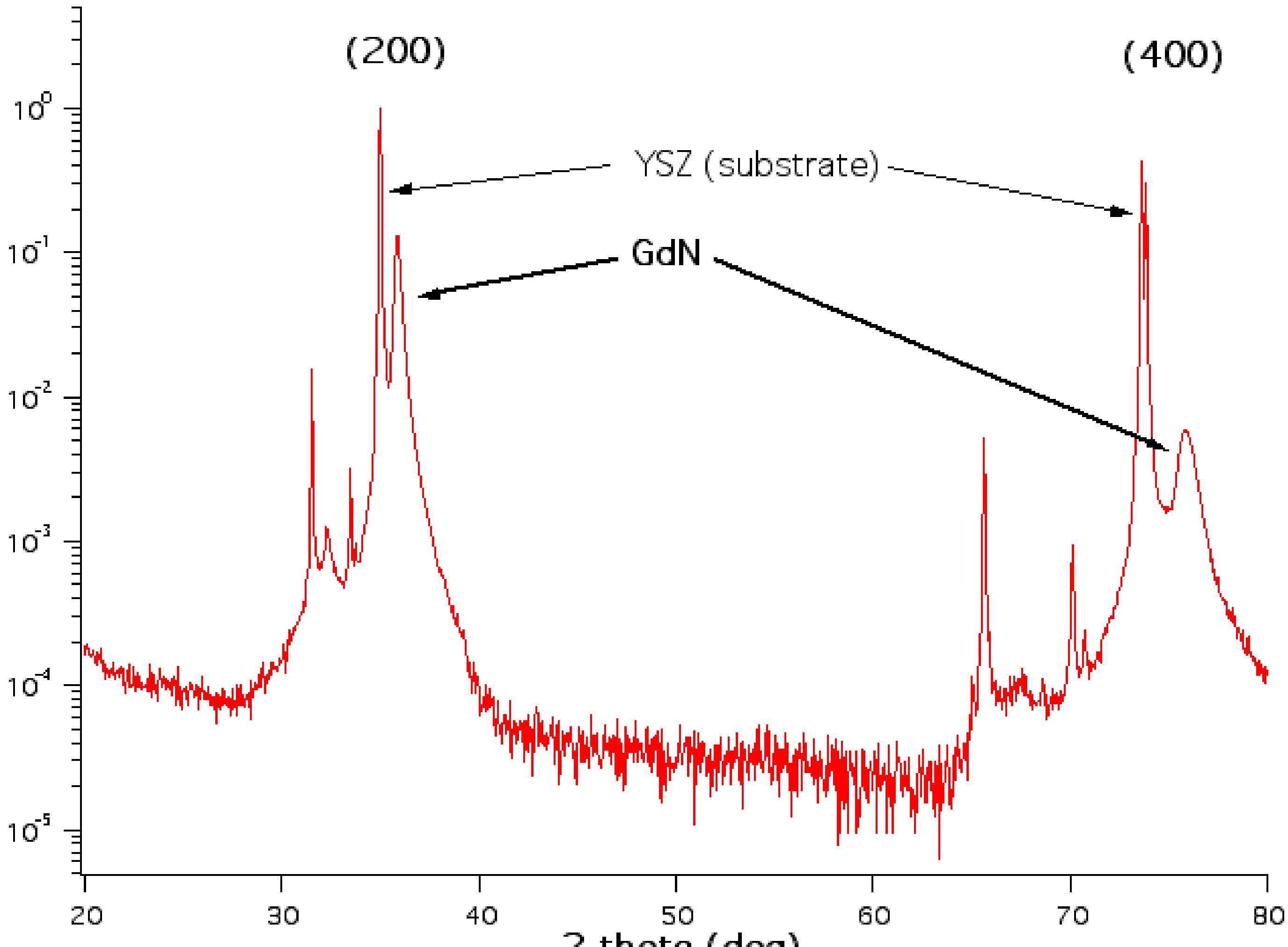
Characterization - RHEED

- RHEED taken along 2 different directions
  - Match RHEED of substrates (in-plane epitaxy)





Characterization - XRD



Characterization - Magnetic

- Magnetization saturates at very small field strengths
- Coercive field ~ 20 Oe
  - Order of magnitude smaller than thermal samples

Many parameters to explore

- Rare earths
- Substrates
  - Si
  - YSZ (lattice matched, but oxygen is a worry)
  - Sapphire
- Growth temperature
- Growth pressure
- Activated N_2
- Capping layers

Summary

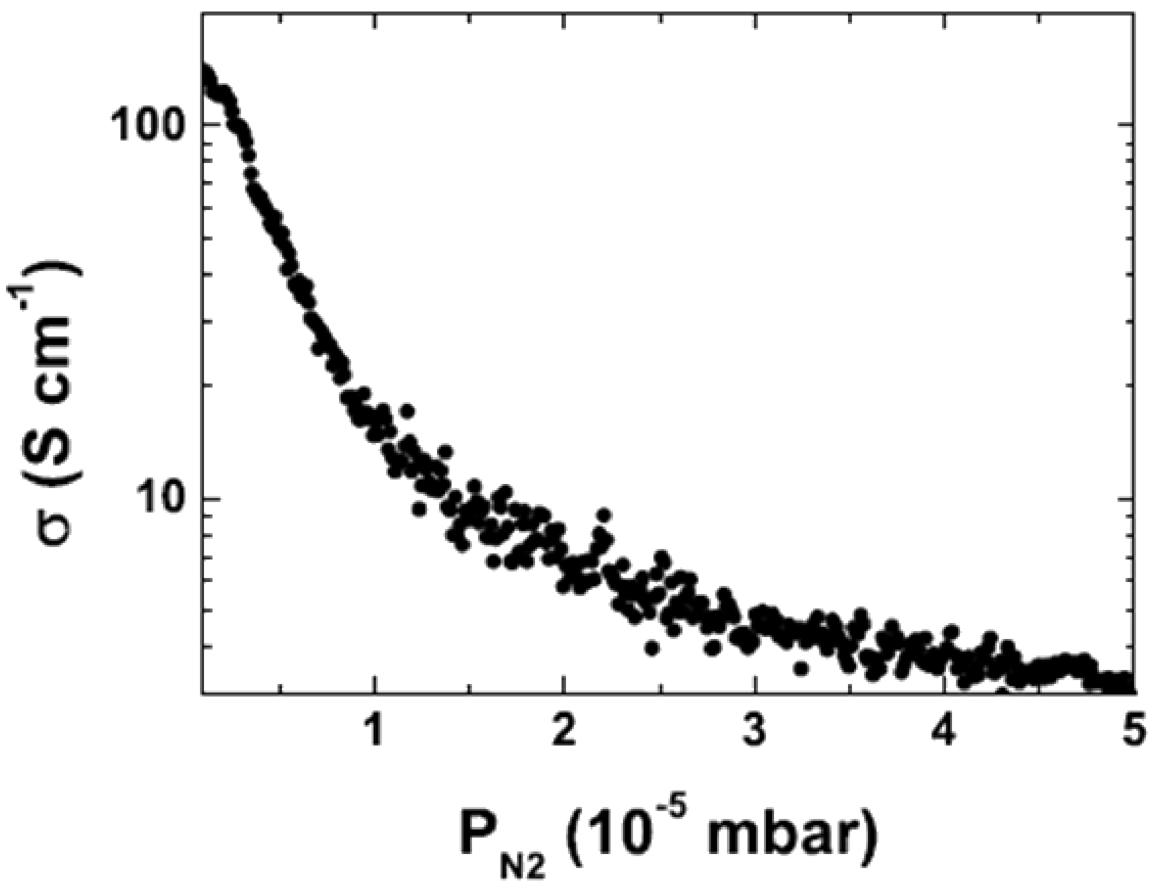
- Both theory and measurements of nanocrystalline films indicate interesting properties
- Further advances require quality epitaxial films before they can be answered
- This has been achieved as a proof of concept
- Much more work to do

Thank You

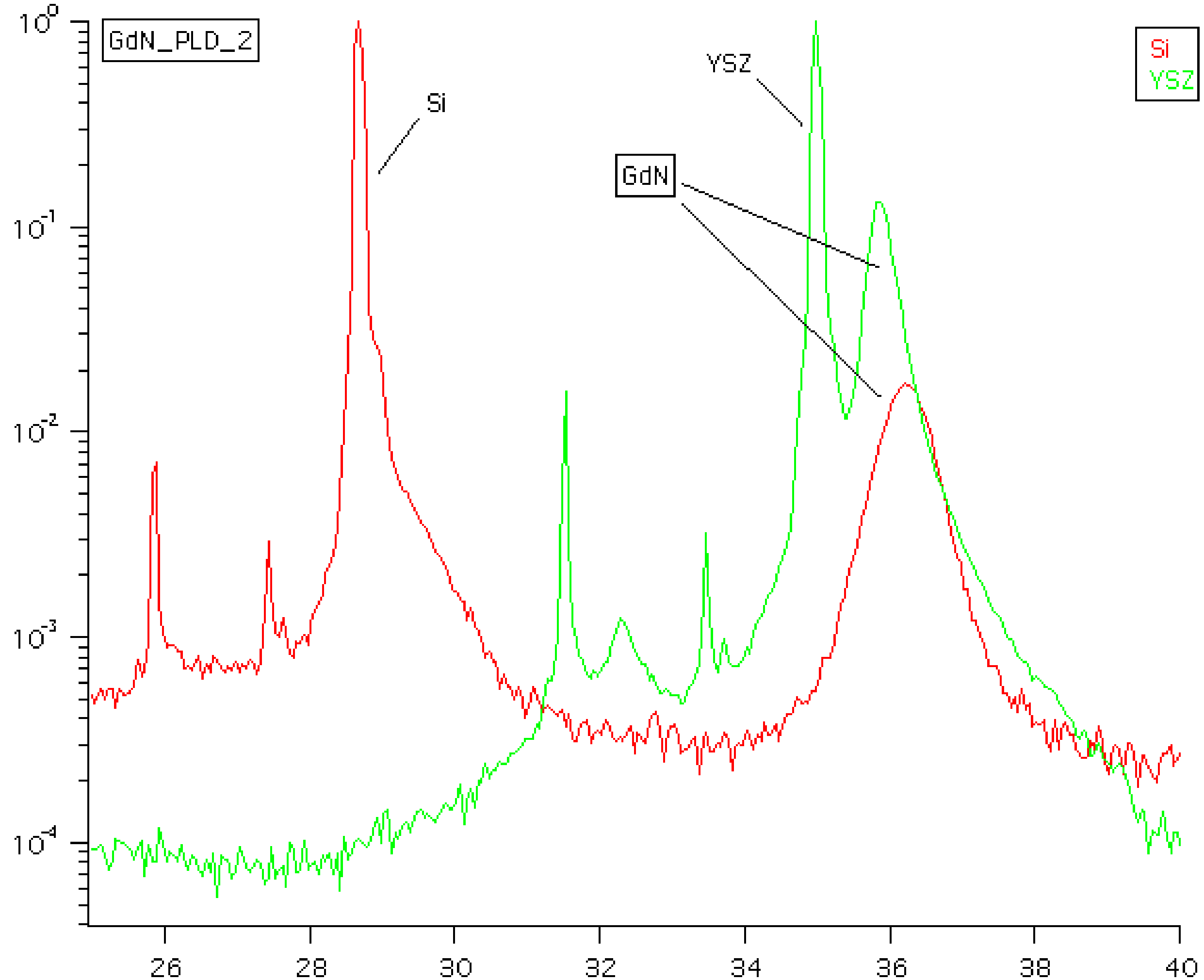
Claire Meyer (Q10.6)
Magnetic properties of REN thin films

Appendix

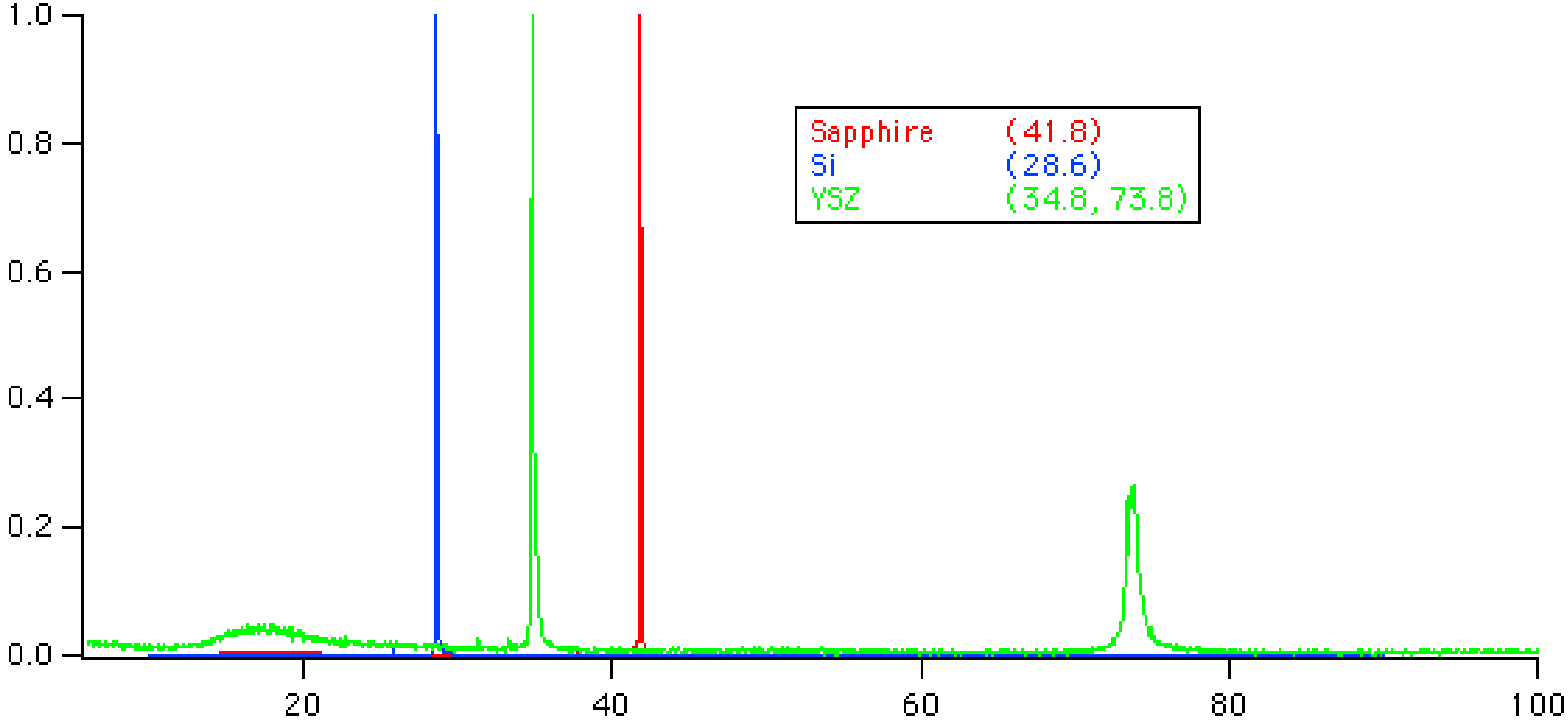
Extra Info - N_2 Pressure



Extra Info - PLD XRD

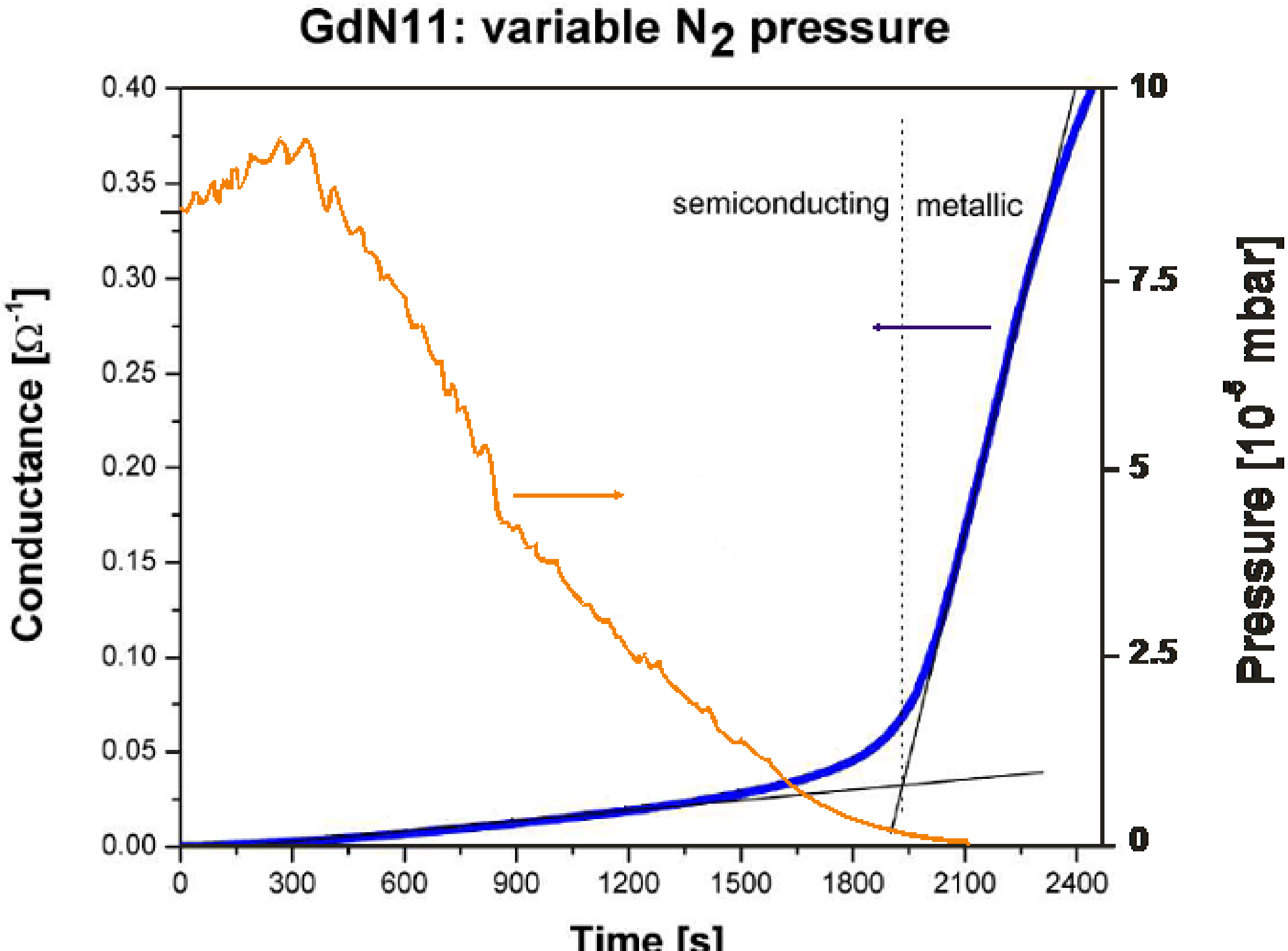


Extra Info – Substrates



Extra Info – RBS

Extra Info – N_2 content



Extra Info – SIMS profile

- N_2 GdN (GaN cap)