B2-RuAl Intermetallic Compound

Thin-Film Synthesis, Mechanical Properties and Cyclic Oxidation Behaviour

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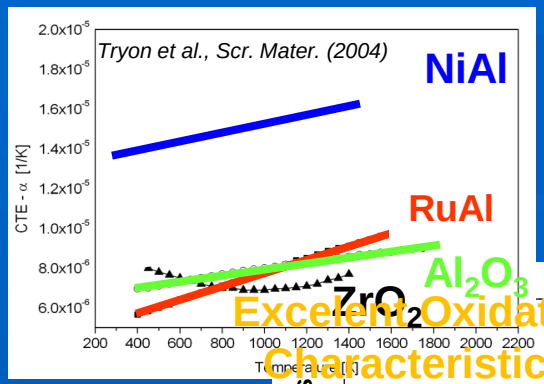
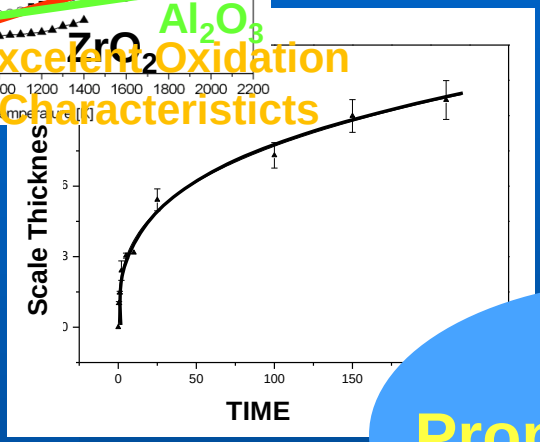
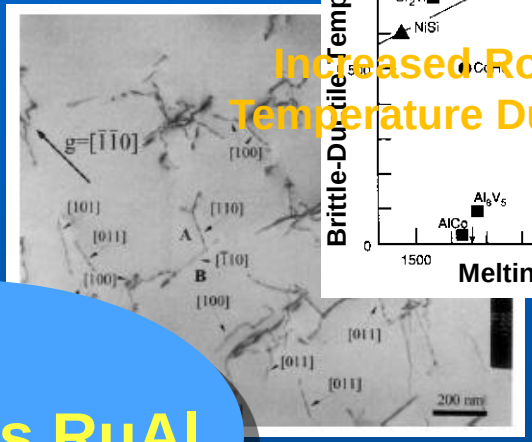
Why B2-RuAl?

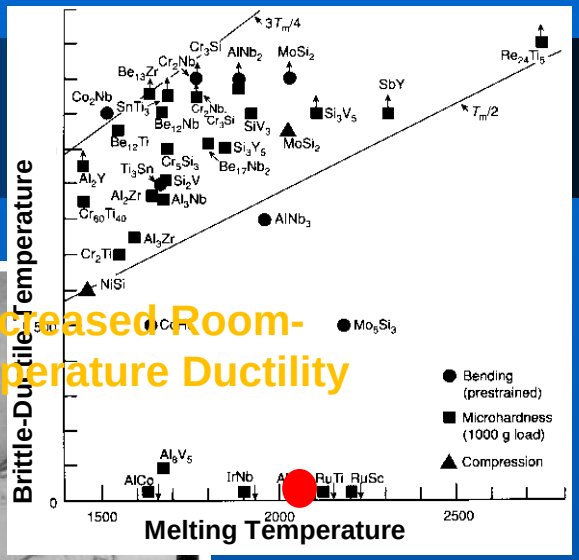


Excellent Oxidation Characteristicts

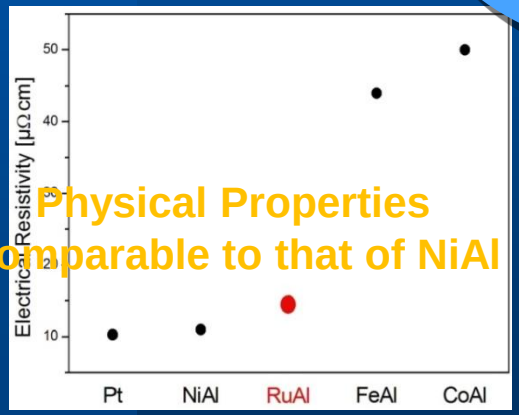




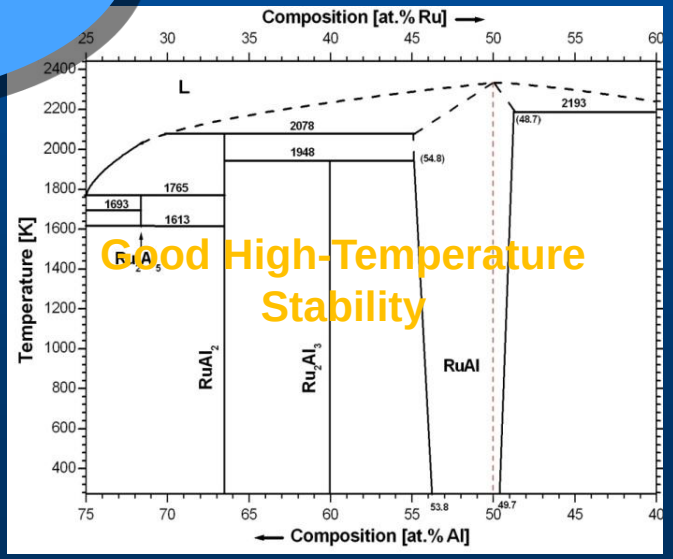
Increased Room-Temperature Ductility



Properties RuAl



Physical Properties Comparable to that of NiAl

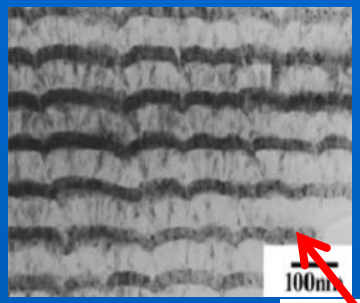


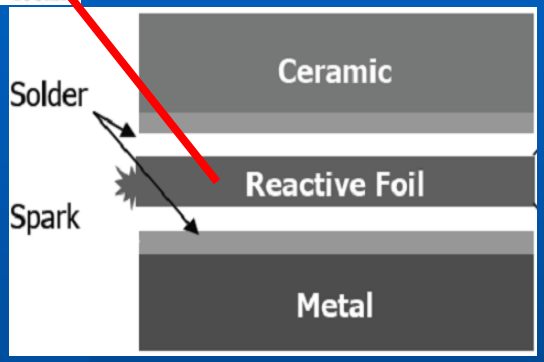
Good High-Temperature Stability

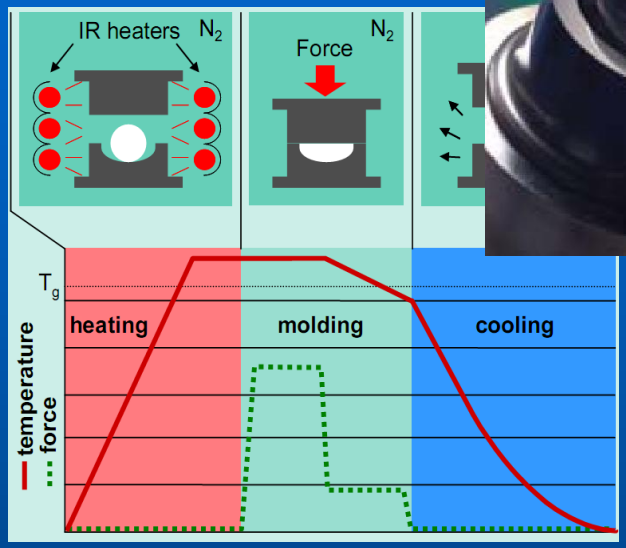
Properties of RuAl (Review)

F. Mücklich et al., Intermetallics 13 (2005) 5
F. Mücklich et al., Intermetallics 16 (2008) 593

Thin-Film Applications







Reactive Bonding

- *Thermodynamics*
- *Phase Formation*
- *SHS Characteristics*

Protective Working Layers

- *Phase Formation*
- *Mechanical Properties and Wear Behaviour*
- *Cyclic Oxidation*

RuAl Thin-Film Synthesis using metallic multilayers

Large Periods

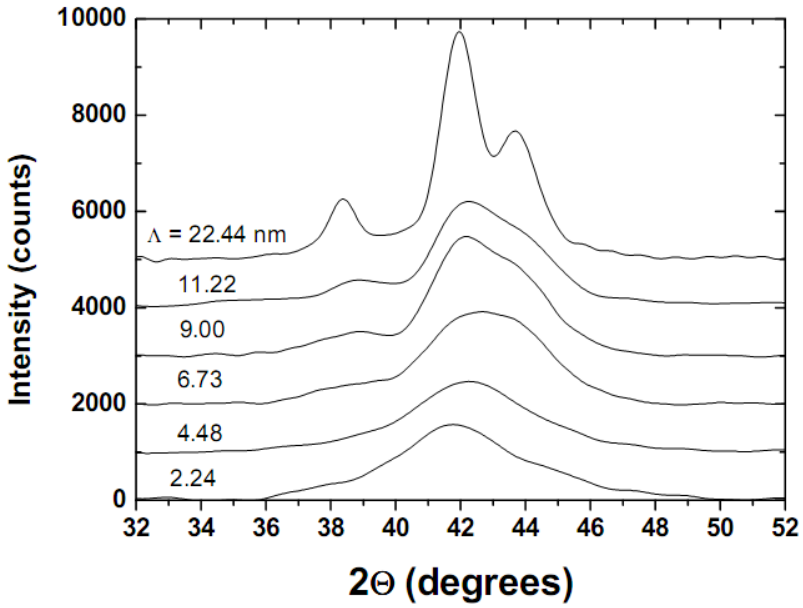
Small Periods

Outline

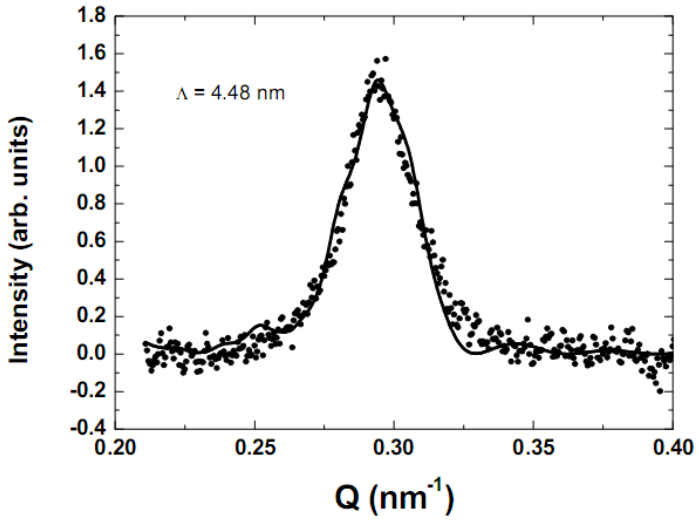
- Motivation
- Thin-Film Synthesis
- Mechanical Characterization
- Cyclic Oxidation Behaviour

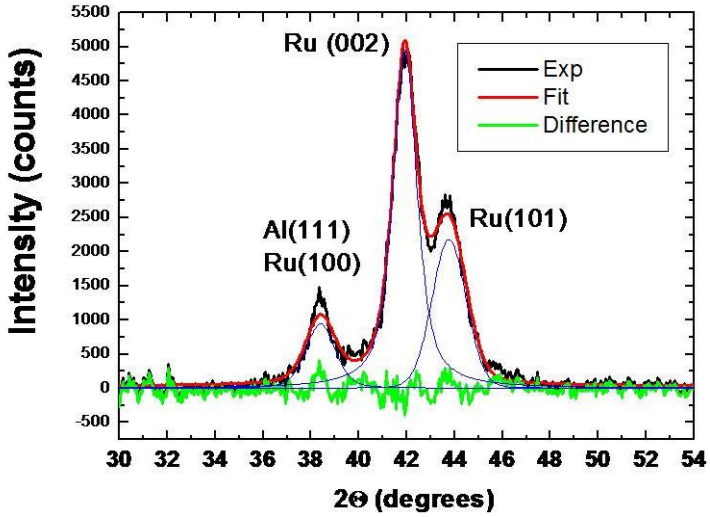
*- **Small Period** Ru/Al-Multilayers -*

Λ< 5 nm
epitaxial growth between Ru and Al-sublayer

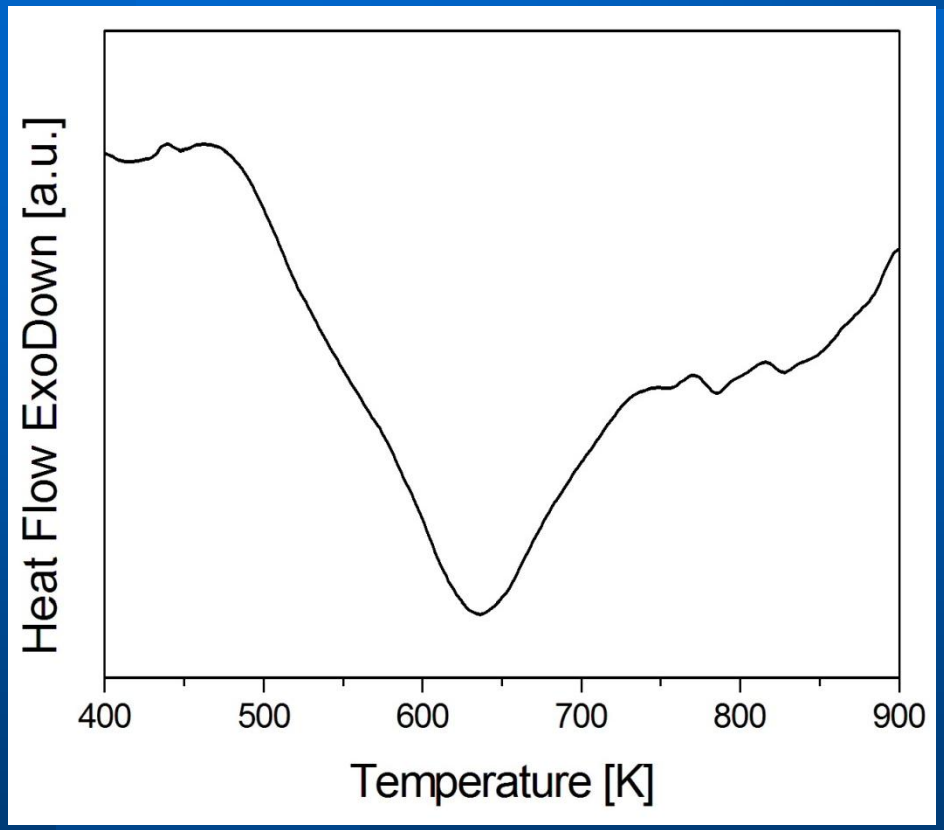


Λ> 5 nm
Epitaxy is lost! Growth of polycrystalline MLs

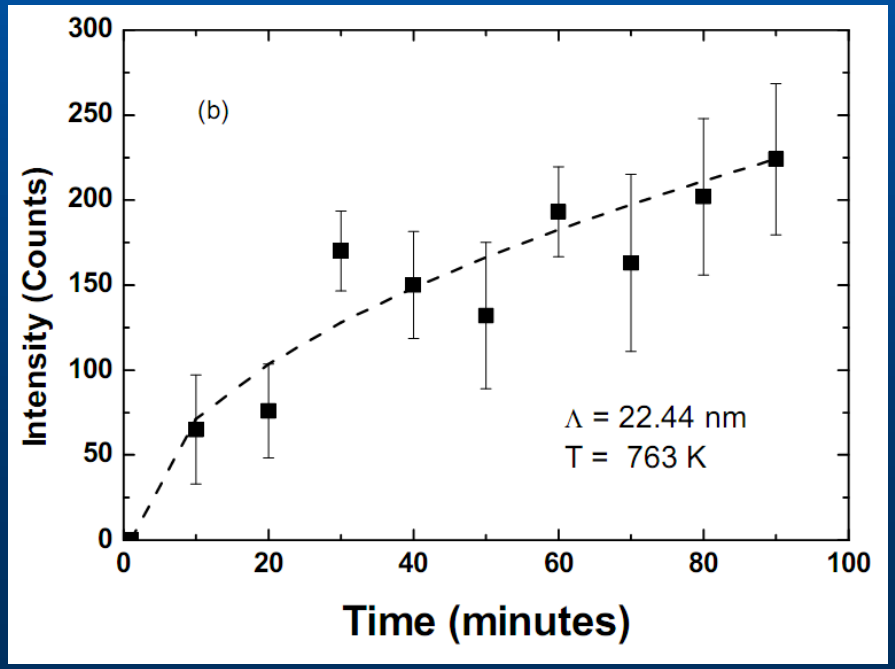




- Small Period Ru/Al-Multilayers -



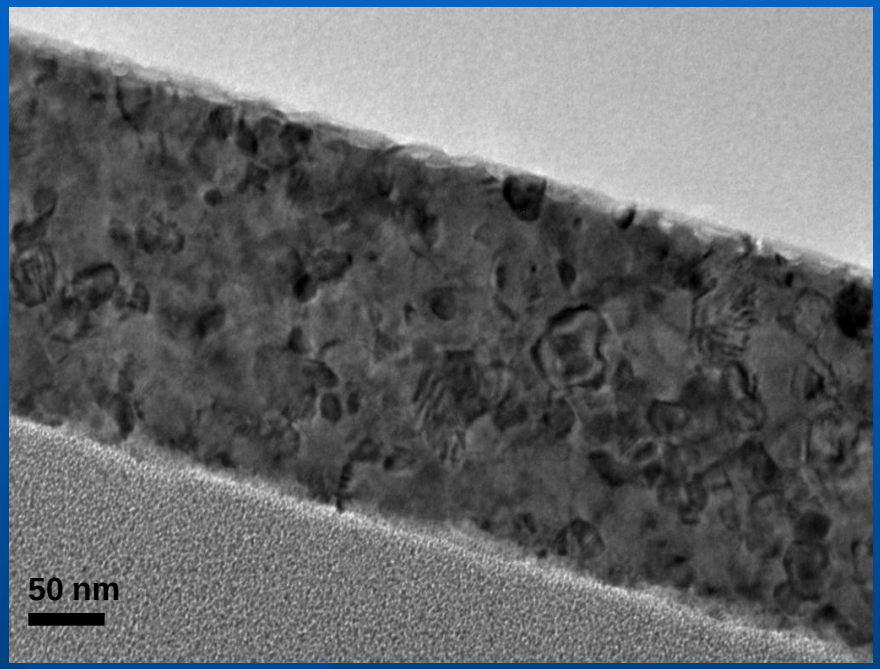
RuAl (100) peak with time at 763K

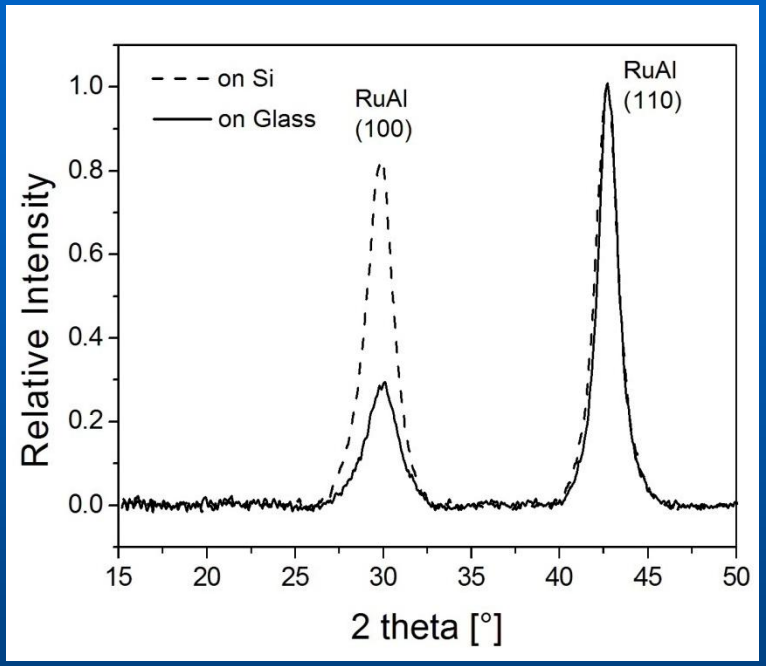


Diffusion-controlled growth of the RuAl phase!

Zotov et al., J Appl Phys (submitted)

- Microstructural Characterization-





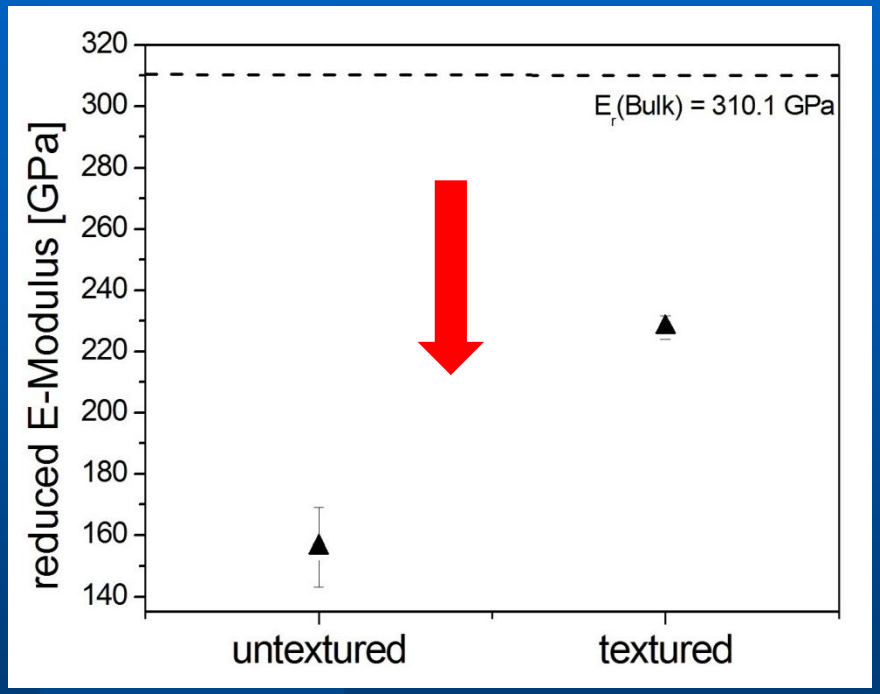
- ✓Granular grain morphology
- ✓ single-phase microstructure
- ✓ no multilayer structure

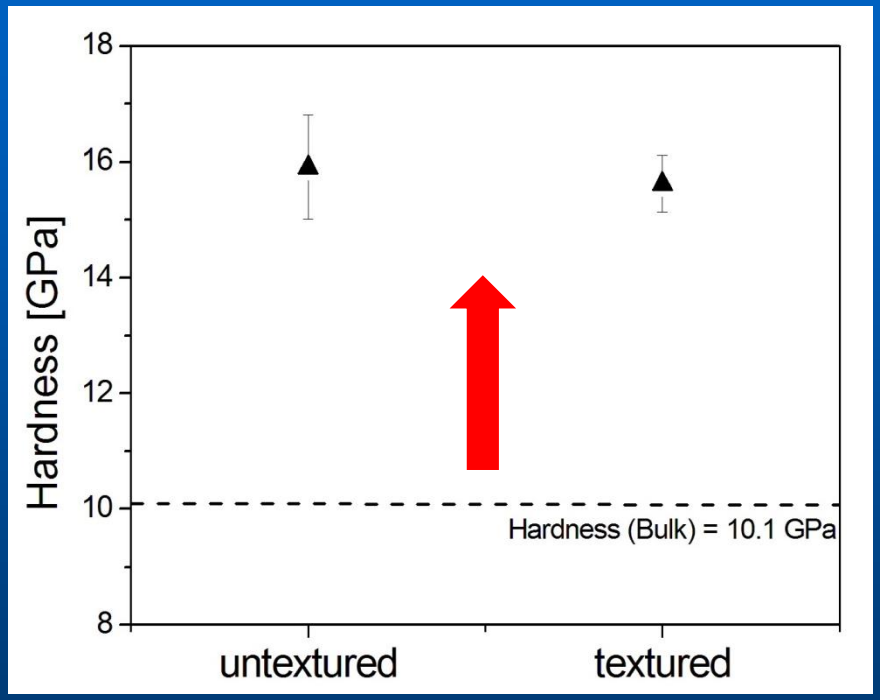
Outline

- Motivation
- Thin-Film Synthesis
- Mechanical Characterization
- Cyclic Oxidation Behaviour

- Mechanical Properties -

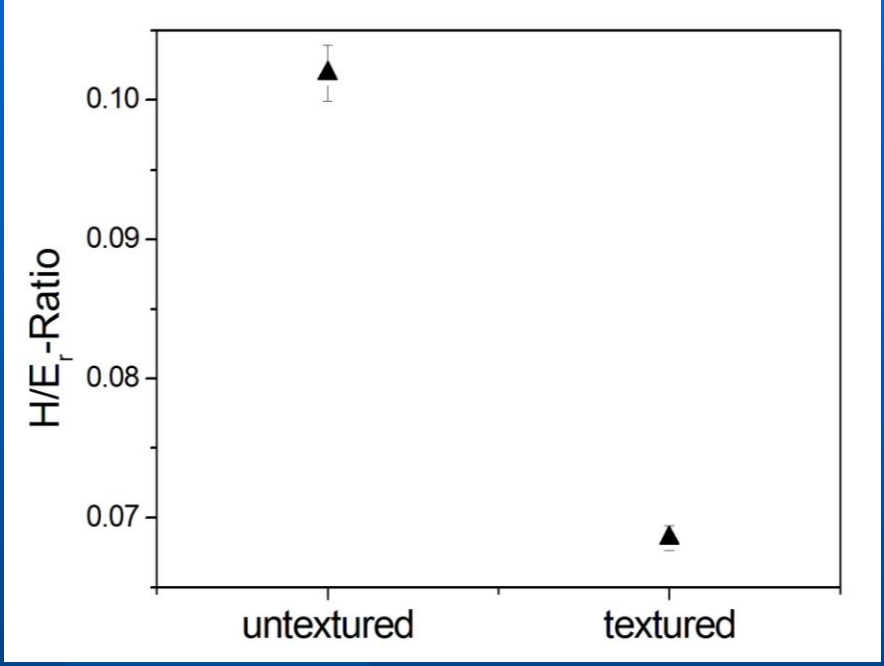
Influence of Texture





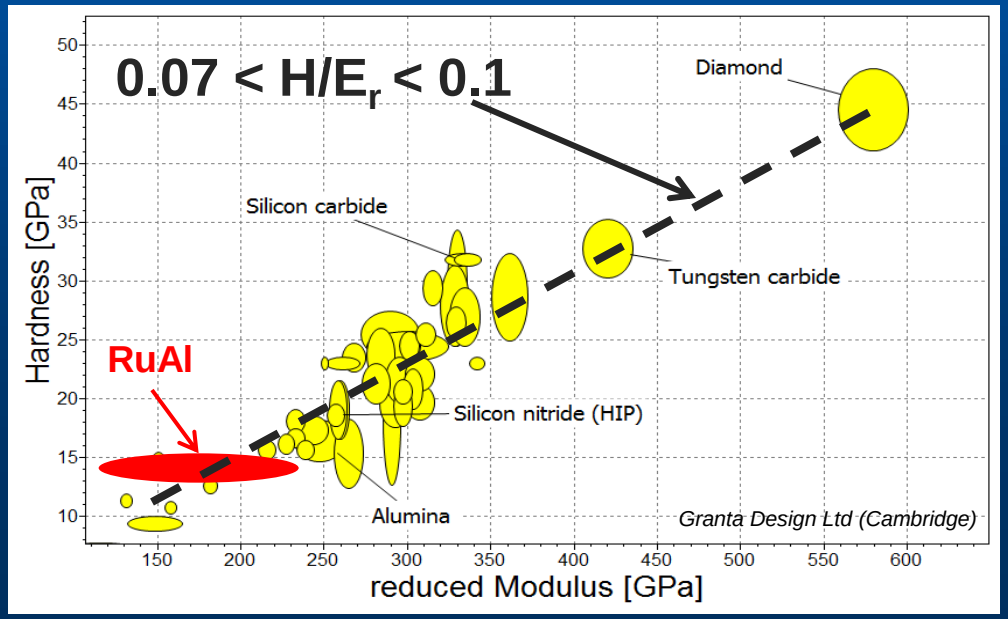
- ✓ Compared to bulk RuAl, H values are increased and E_r values are decreased
- ✓ Texture influences only elasticity of RuAl thin films

- Wear Properties -



It is expectable that RuAl thin films show similar wear properties compared to typical wear protective materials like SiC, WC or diamond

Needed for Protective Working Layers

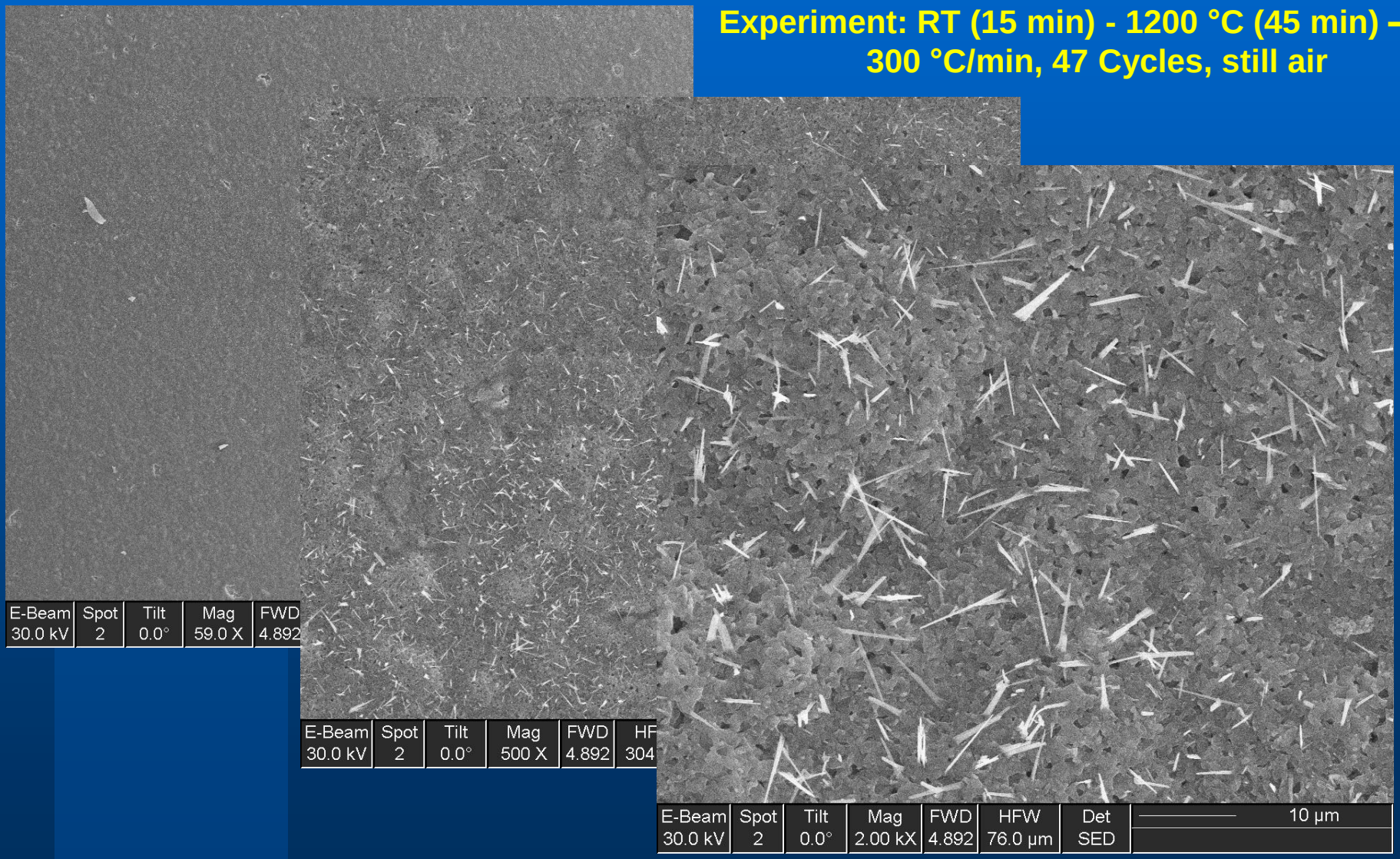


Outline

- Motivation
- Thin-Film Synthesis
- Mechanical Characterization
- Cyclic Oxidation Behaviour

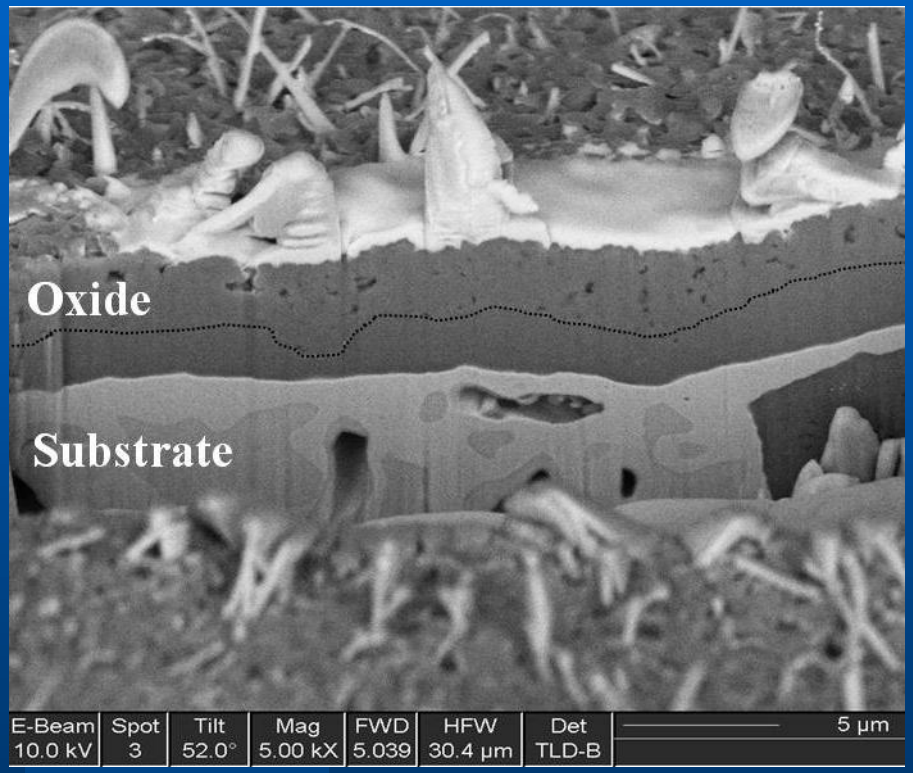
- Scale Morphology -

Experiment: RT (15 min) - 1200 °C (45 min) – RT
300 °C/min, 47 Cycles, still air

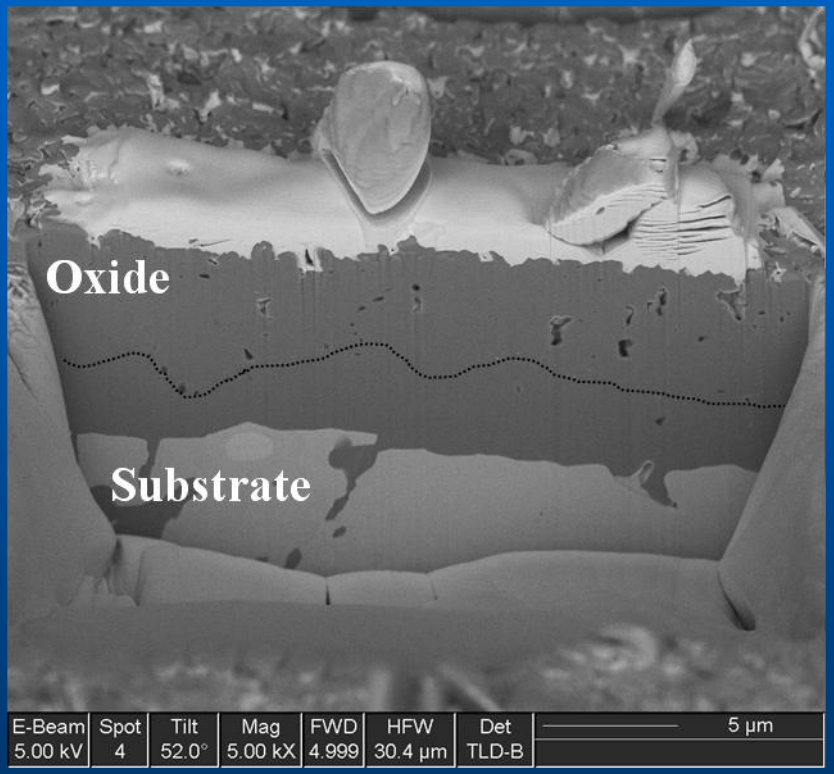


- Scale Morphology -

10 Cycles



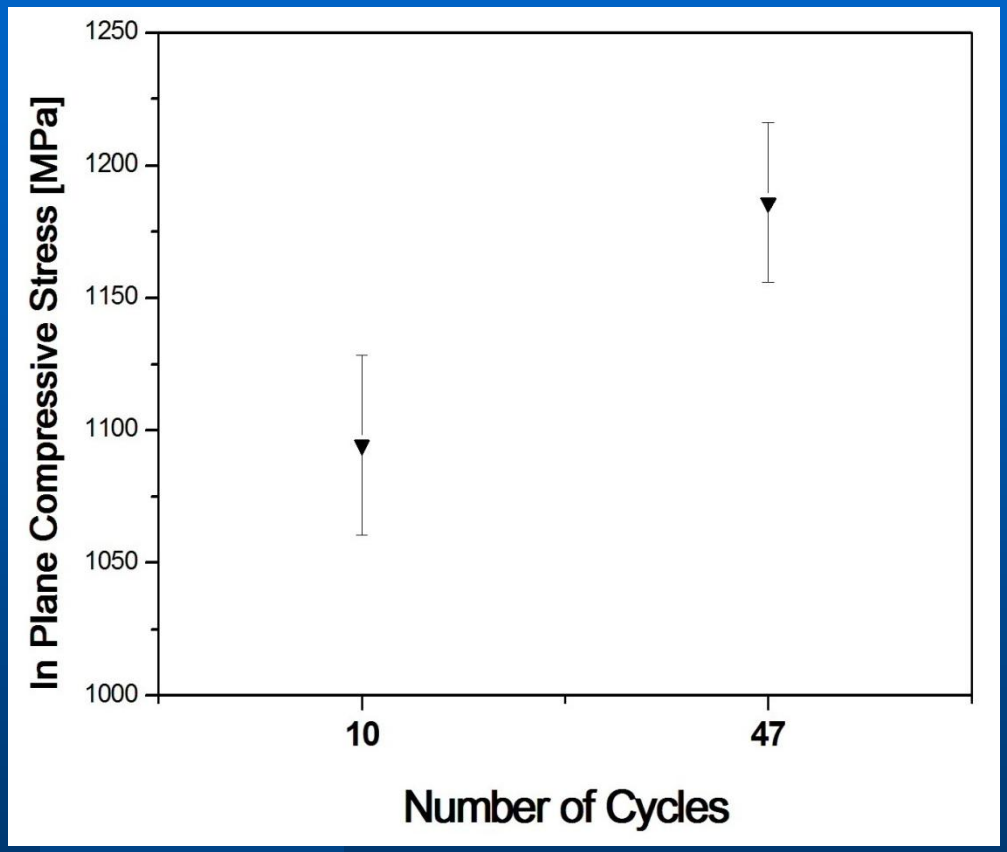
47 Cycles



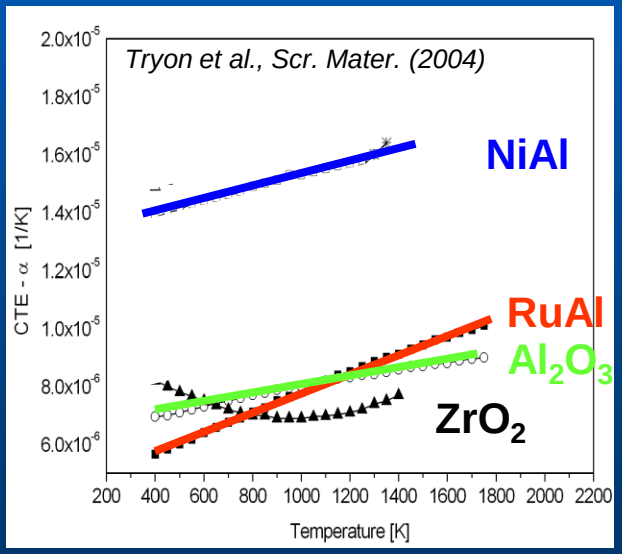
- ✓ double grained scale microstructure
- ✓ no cracks through the scale
- ✓ no interfacial cracking

} **Stress State ?**

- Stress State of the Scale -



- ✓ compressive stresses !
- ✓ low magnitudes!
- ✓ slight increase with oxidation time



Growth effects dominate the stress developement!

- Conclusion -

- Thin Film Synthesis
  - ✓Small period Ru/Al multilayers: **Direct** formation of B2-RuAl
  - ✓Possiblity to synthesize RuAl-Thin-Films with thicknesses from several nm to tens of µm

- Mechanical Characterization
  - ✓ Maximum hardness of ≈ 16 GPa
  - ✓ Texture affects only elasticity
  - ✓ H/E-ratio of RuAl-thin films comparable to typical wear protective materials

- Cyclic Oxidation Behaviour
  - ✓ Neither scale nor interfacial cracking
  - ✓ Low In Plane Pressure Stresses (≈ 1 GPa)
  - ✓Stress state positively influences the mechanical stability of the oxide