SiAlON Materials Development at Kennametal

Hot –Section Materials Development for Advanced Microturbines:
RFP No. 3400020692

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Outline

- Introduction: Current State
- Advanced Sialon Phase Dependence
- Advanced Sialon Characteristics
- Sialon Development and Microturbine

Introduction: Sialon State of the Art.

- α and β are the two polymorphs of Si3N4
- Each polymorph forms a solid solution
  - β -sialon $Si_{6-z}Al_zO_zN_{8-z}$
  - α -sialon $M_xSi_{12-(m+n)}Al_{(m+n)}O_nN_{16-n}$

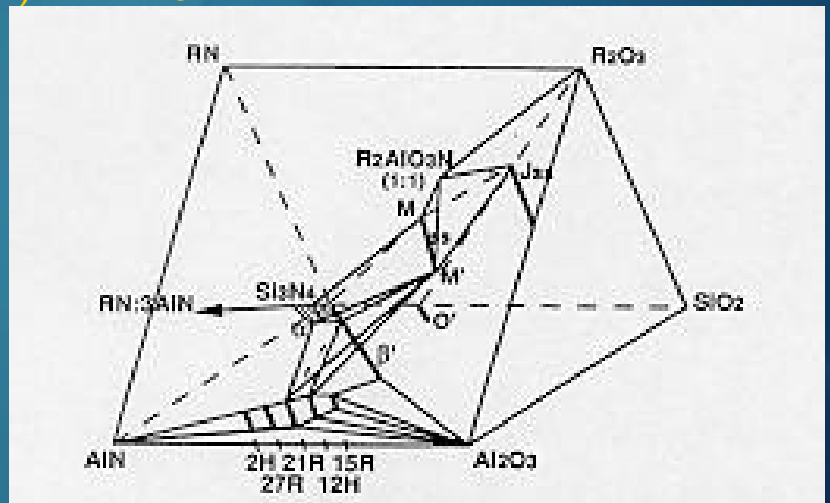
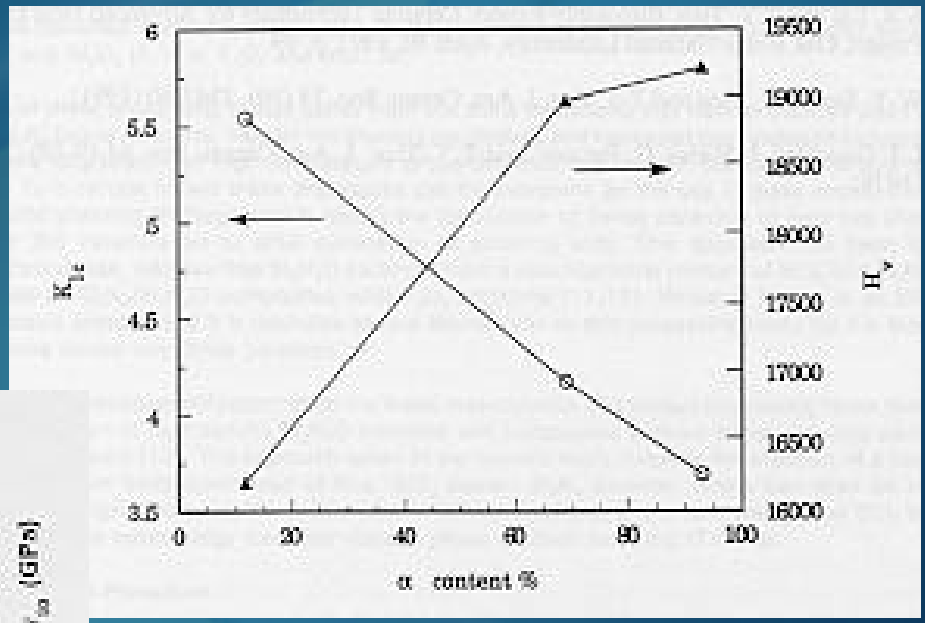
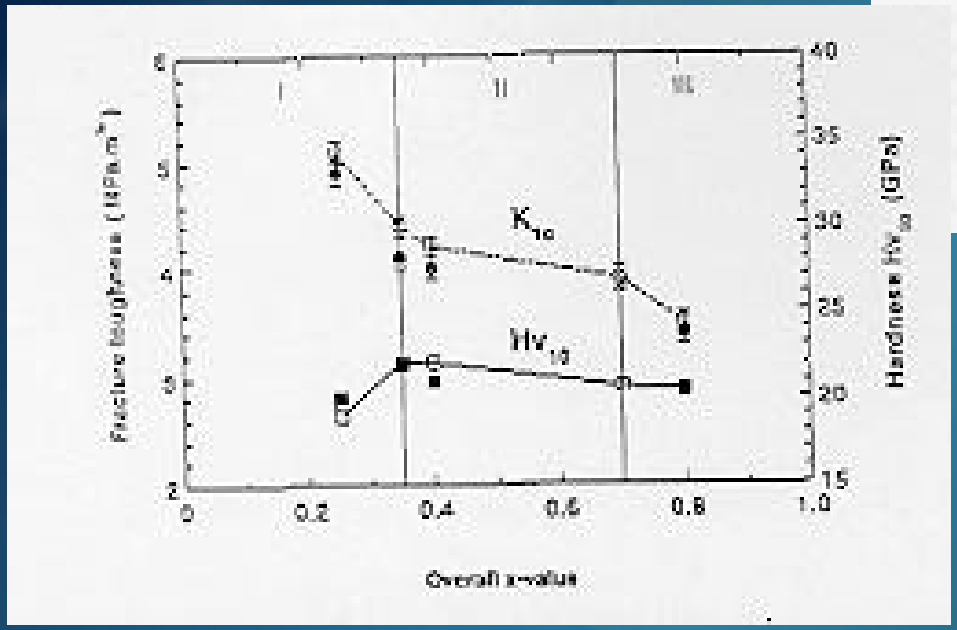


Fig. 5. Phase relations of M(R) with neighboring phases in R–Si–Al–O–N (R = Nd, Sm) system.[45]

Introduction: Fracture Toughness Decreases with increasing α-sialon



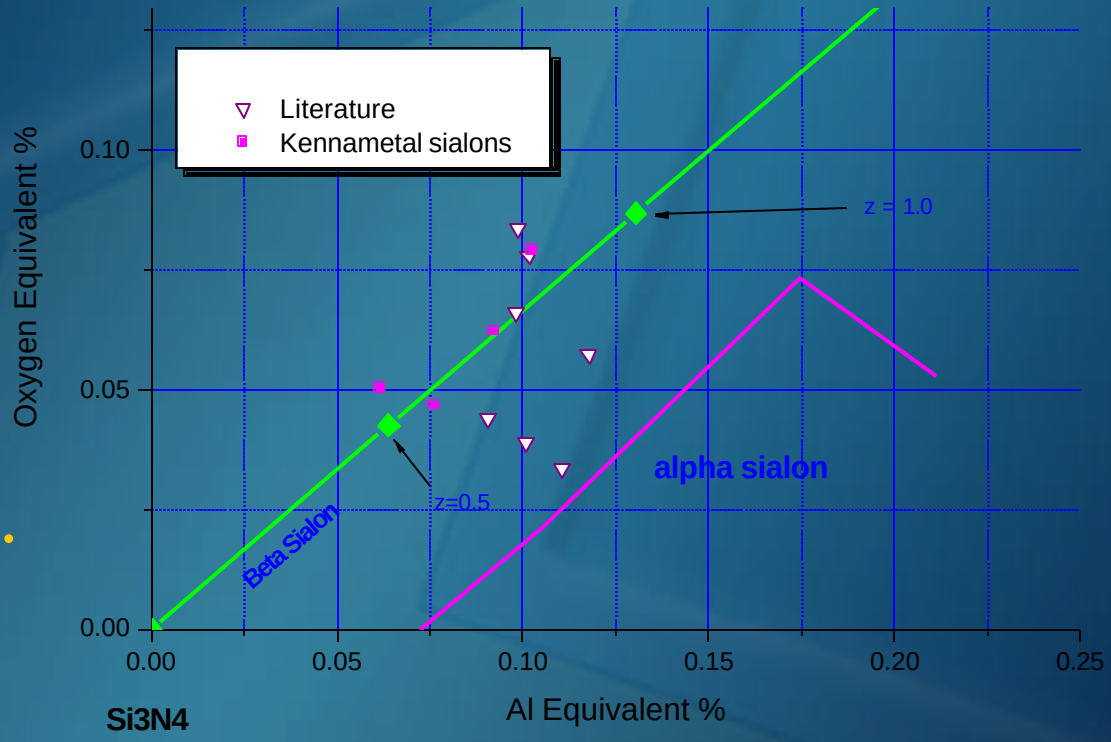


S. Boskovic, K. Lee, T. Tien "Reaction Sinering of b-Si3N4/a'-Sialon Ceramics, Silicon Nitride Ceramics Scientific and Technological Advances, Materials Research Soc. V287

Z. Shen, T. Ekstrom, M. Nygren,Ytterbium-stabilized α-sialon, J. Appl. Phys. 29(1996)

Advanced Sialon Phase Dependence

- Sialon improvements begin with difference in compositional phase dependence.

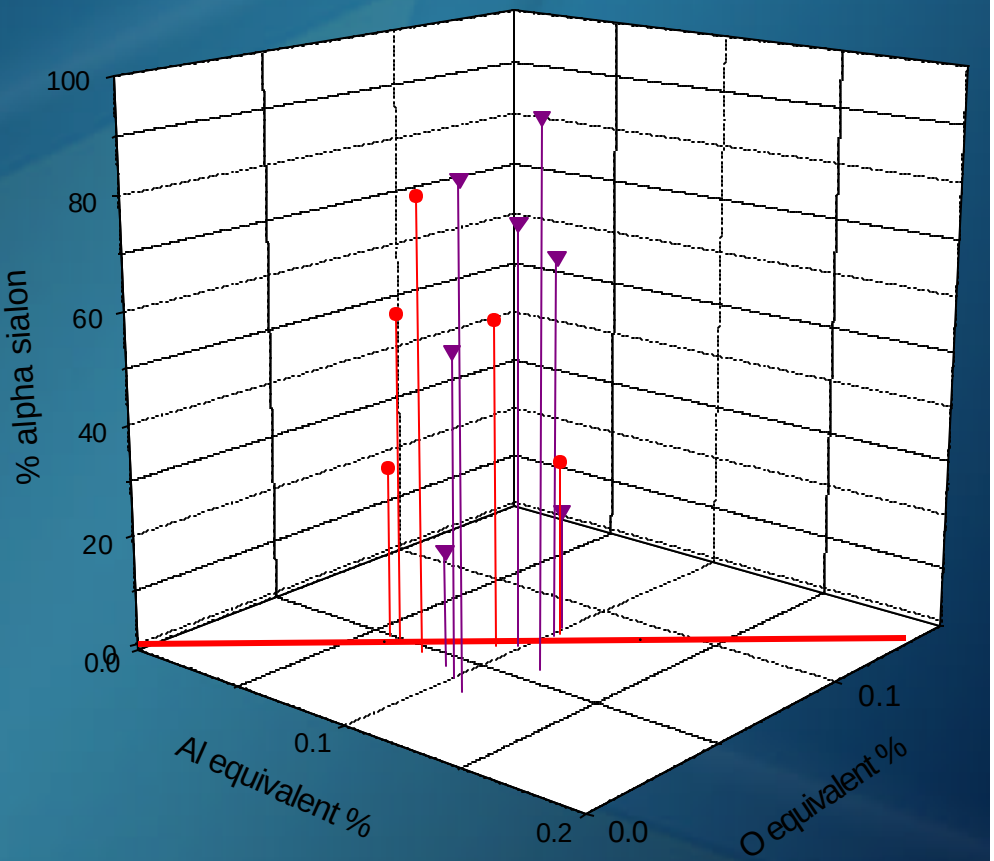


Silicon nitride corner of the Sialon behavior diagram showing compositions from Literature and Kennametal.

L. K. L. Falk, Z.J. Shen, T. Ekstrom, "Microstructural Stability of Duplex a-b Sialon Ceramics", J. European Cer. Soc. (17) 1997

Advanced Sialon Composites

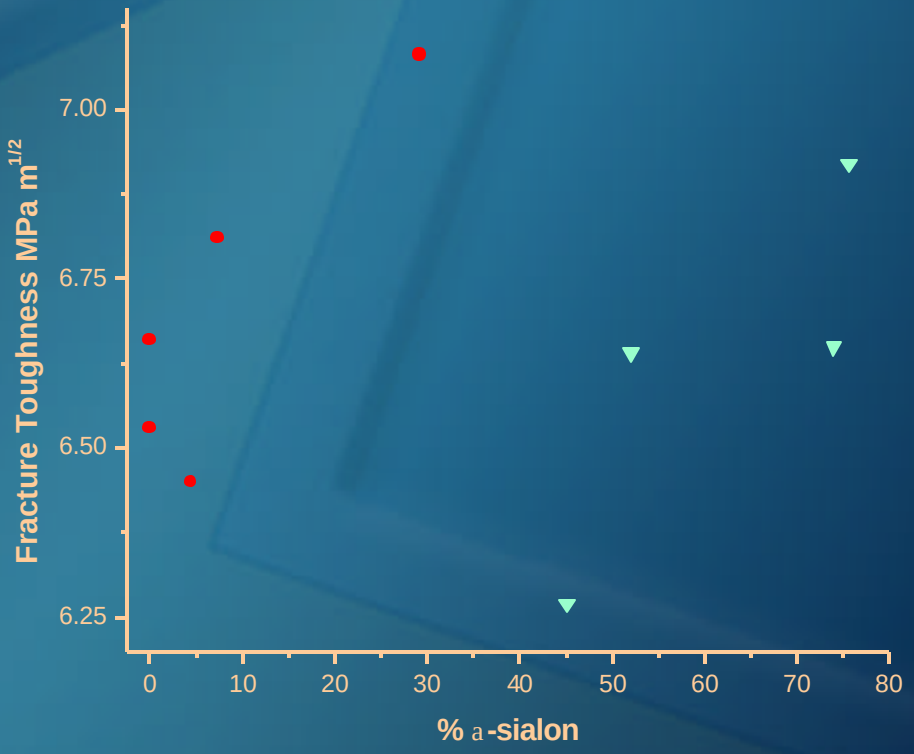
- Two methods in current state of art to control α sialon phase
  - Composition
  - Rare Earth type
- New phase dependence contributes to
  - Combined high hardness and toughness
  - High Strength
  - Microstructural engineering flexibility



In figure the Kennametal sialons(red) develop high α sialon content with less rare earth and compositions falling close to β sialon phase

Advanced Sialon Characteristics

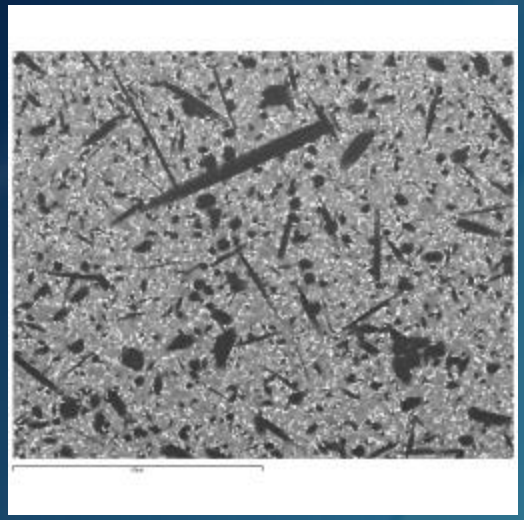
- Toughness Increasing with alpha Sialon
- Trend similar for two compositions with different alpha ranges
- Important for wide range of final α sialon content



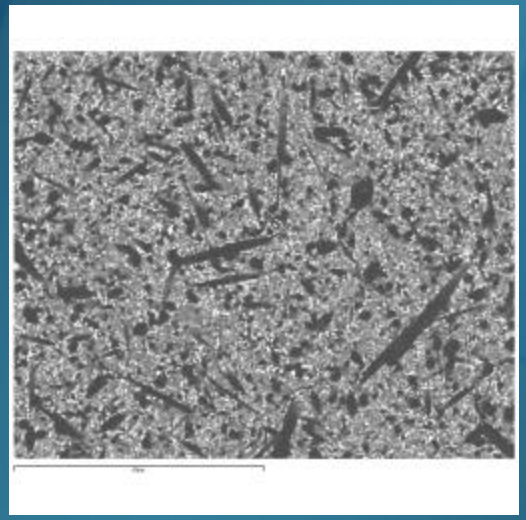
Toughness as function of α sialon

Advanced Sialon Characteristics

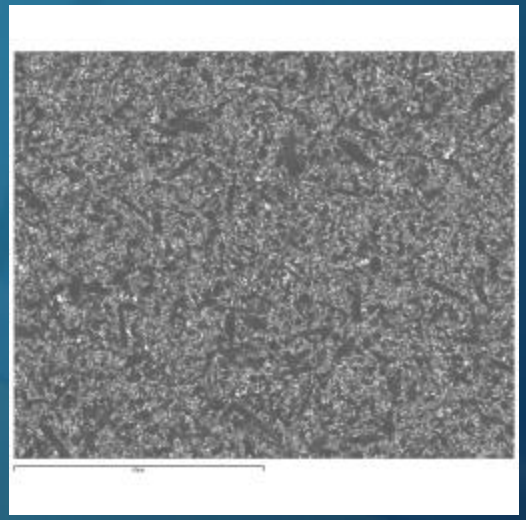
- Photomicrographs illustrate ability to control α/β ratio at fixed composition.
- At 69% α sialon the β sialon grows into the α sialon matrix developing large high aspect ratio grains



69% α-sialon
H_{vn} 18.72 GPa
K_{Ic} 7.82 MPa $m^{1/2}$



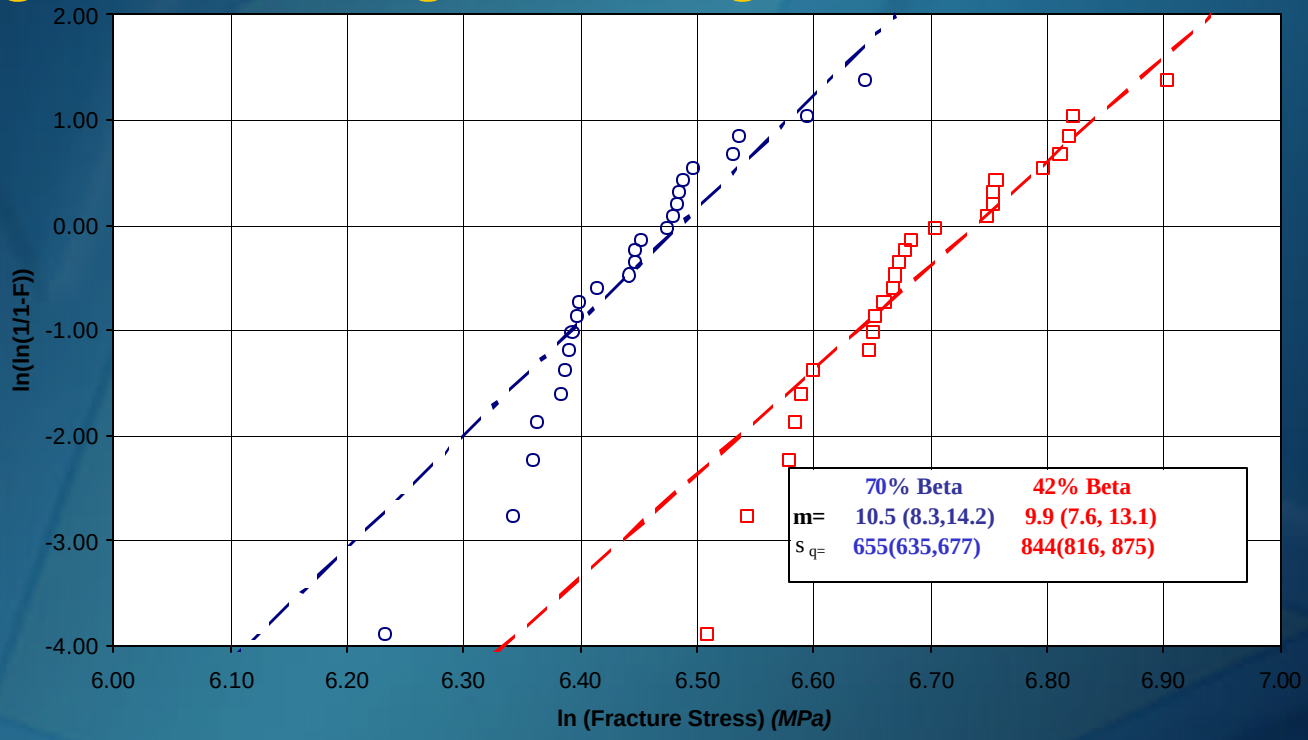
50% α-sialon
H_{vn} 17.59 GPa
K_{Ic} 6.98 MPa $m^{1/2}$



0% α-sialon
H_{vn} 16.26 GPa
K_{Ic} 6.53 MPa $m^{1/2}$

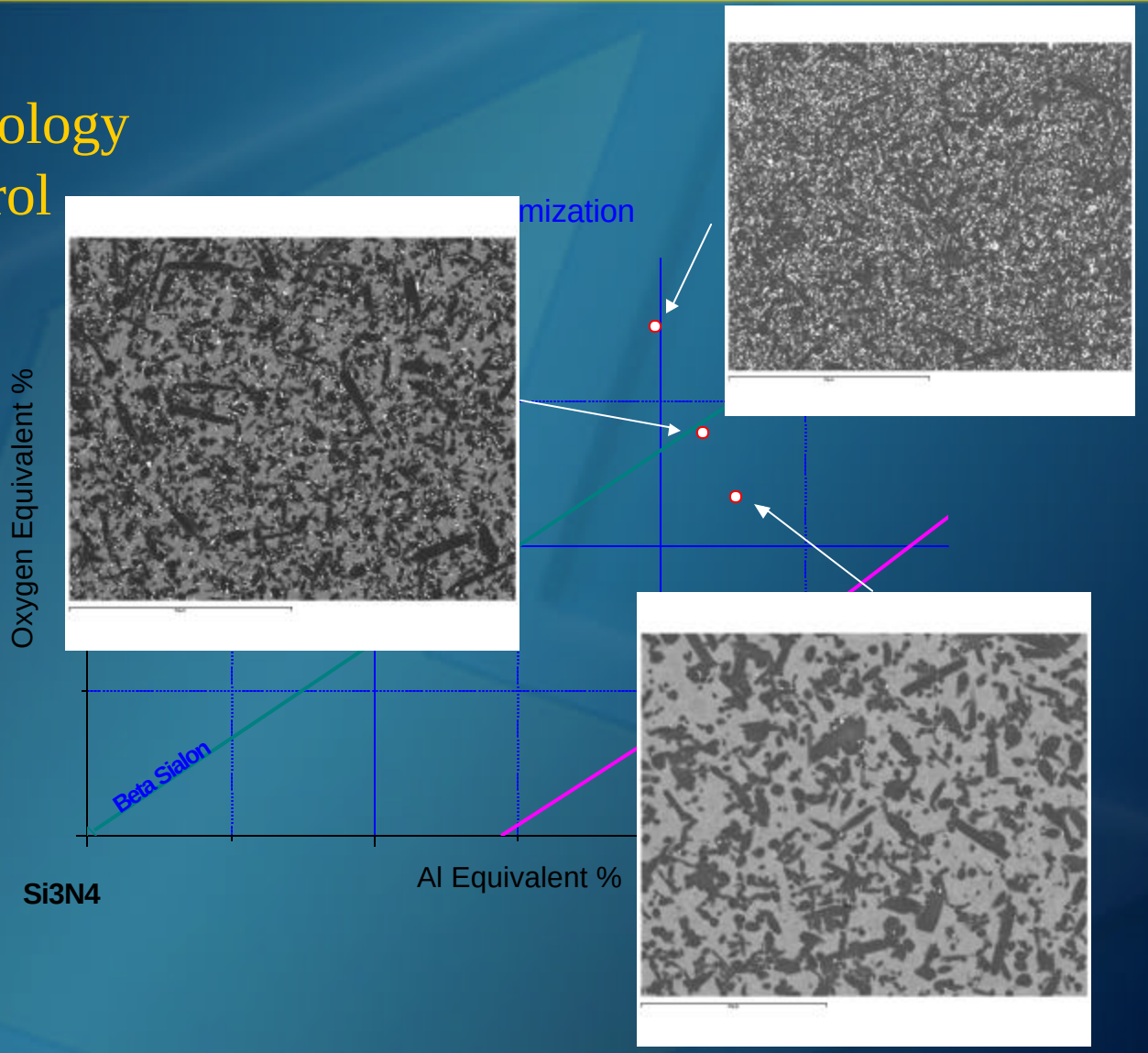
Advanced Sialon Characteristics

- Weibull distribution for a 70% β sialon and 42% β sialon, overall compositions are equivalent.
  - The high α sialon has greater strength.

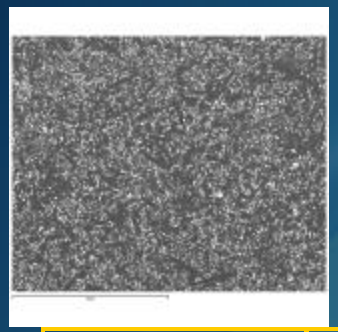


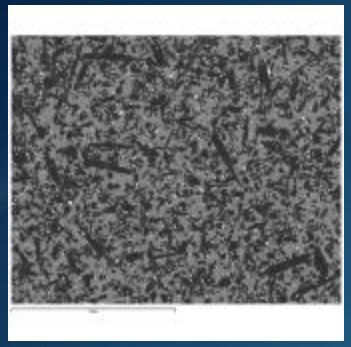
Advanced Sialon Characteristics

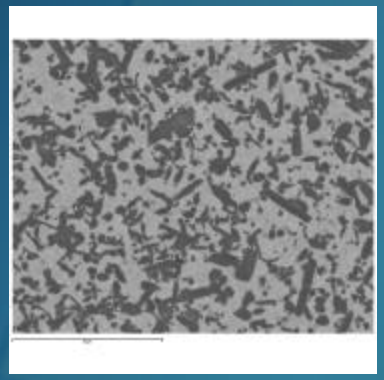
- New materials technology enables greater control over microstructure



Advanced Sialon Characteristics





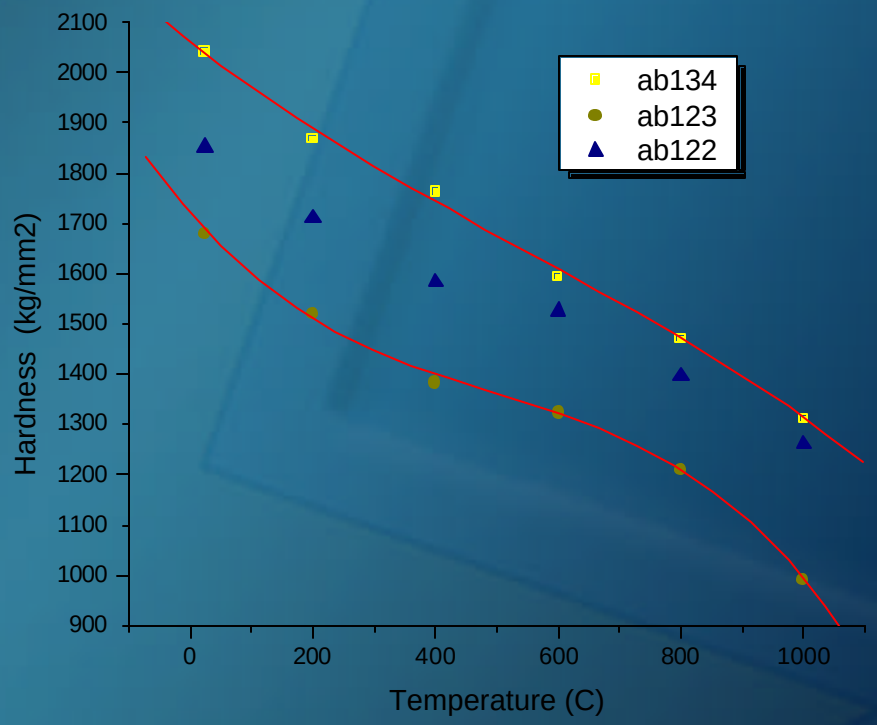


- Property Summary for the Three Sialons

	Hvn (GPa)		Kic (MPa m1/2		Glass	alpha'
Compsition	avg.	st dev	avg.	st dev	vol. %	w /o
ab134	16.59	0.16	6.44	0.19	5.4	0
ab123	18.61	0.41	6.38	0.38	1.4	40.8
ab122	20.40	0.29	5.59	0.22	0.15	57.3

Advanced Sialon Characteristics

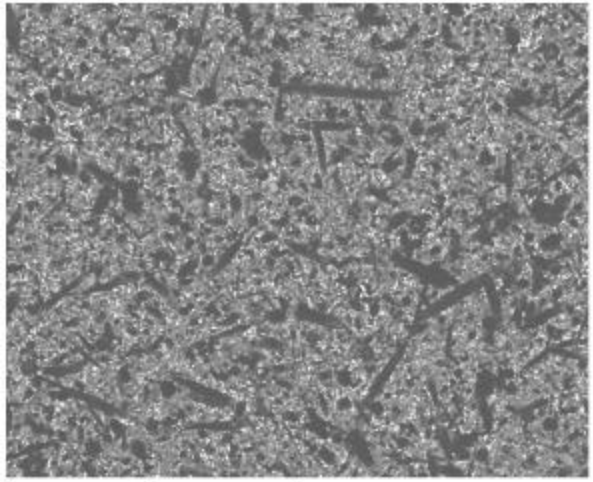
- Hot Hardness
  - Increased hardness with temperature desirable for metal cutting
  - Hardness decrease with alpha content and vol % glass.



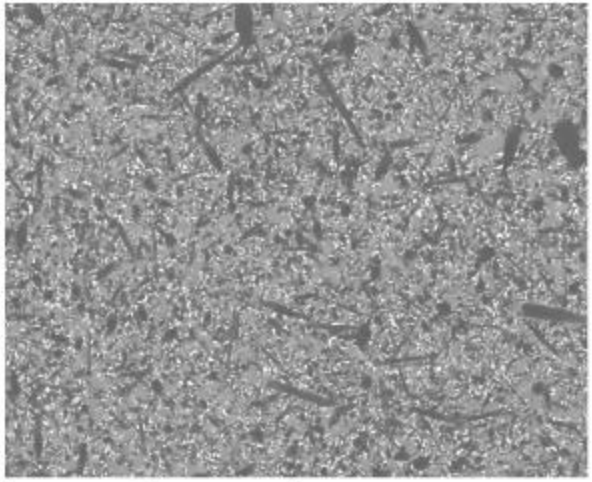
New Metal Cutting Products

- Designing sialons to meet application needs
  - Three products

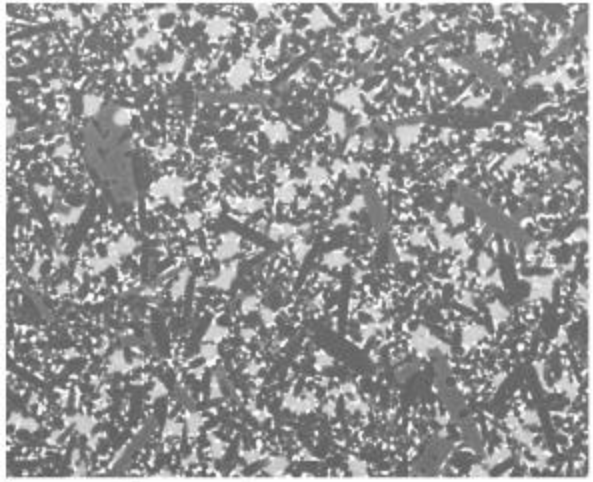
Sialon with high toughness
Low α sialon (10 –20%)
Application: Gray Cast Iron



Ky1540
Sialon with high toughness
Moderate α sialon (30-35%)
Application: Super alloys



Sialon moderate toughness
Moderate α sialon (20-30%), unique three sialon phase
Application: Milling super alloys
and PH SS.

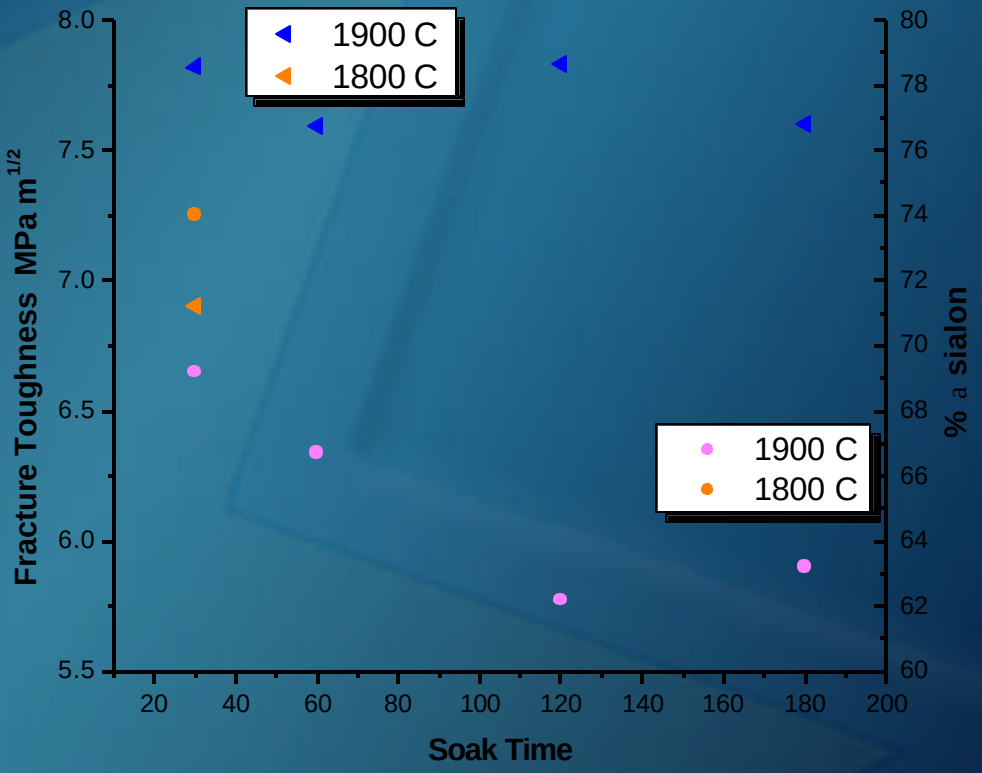


Sialon Development and Microturbines

- Sialon development driven by metal cutting
  - High hardness, strength, and toughness
  - Fine grain microstructure
- Materials engineering for Microturbines
  - Grain Growth/ Crystallization to optimize
    - Strength, Toughness
    - Fatigue Behavior
    - Oxidation Resistance

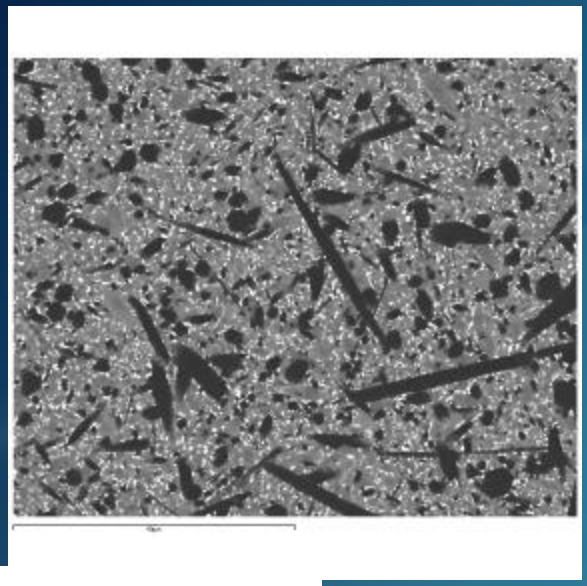
Enhance Toughness through grain growth

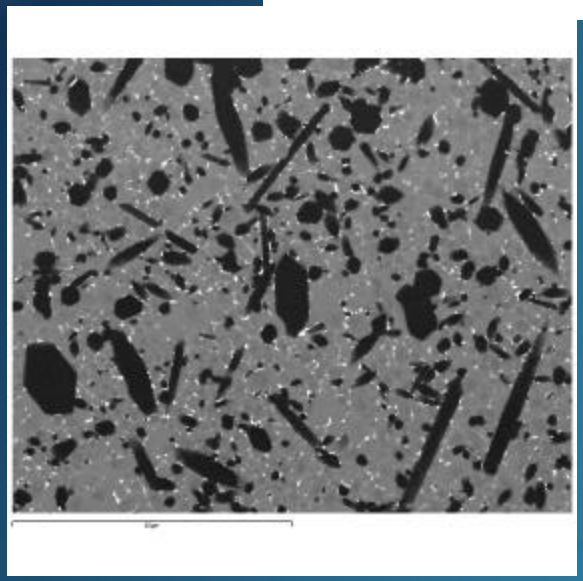
- Expected significant α to β transformation.
- Found phase mixtures stable, significant grain growth.

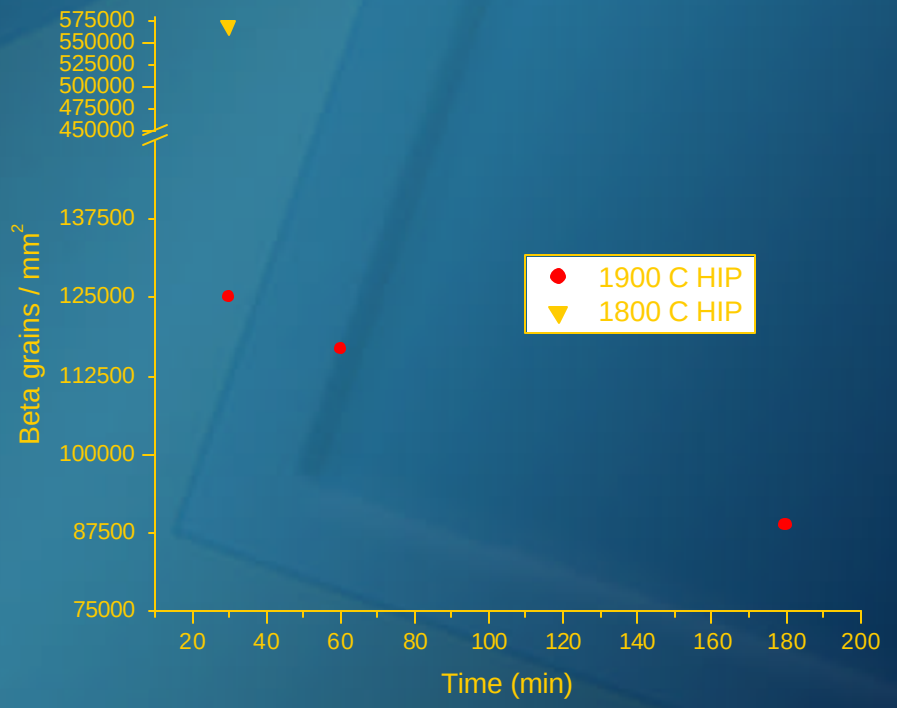


Final Microstructure affected by composition

Example of two different sialons after 1900 C for 180 minutes







Plot of β sialon grain area density with time

Sialon Material Advances

- Sialons designed for metal cutting
  - High toughness, strength and hardness
  - Unique ability to engineer microstructure
- Sialons as Microturbine hot section components.
  - Optimize α/β ratio and glass distribution
  - Oxidation resistance
  - Compatibility with EBC