

HIGH TEMPERATURE CERAMIC FIBER DEVELOPMENT AND TRENDS

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# High Temperature Ceramic Fiber Development and Trends

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# **Introduction**

## **Nextel™ industrial fibers (Nextel 312, 440, 550)**

- based on  $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ - $\text{B}_2\text{O}_3$  system
- textiles for flame barrier/thermal insulation

## **Nextel™ composite fibers (Nextel 610, 650, 720)**

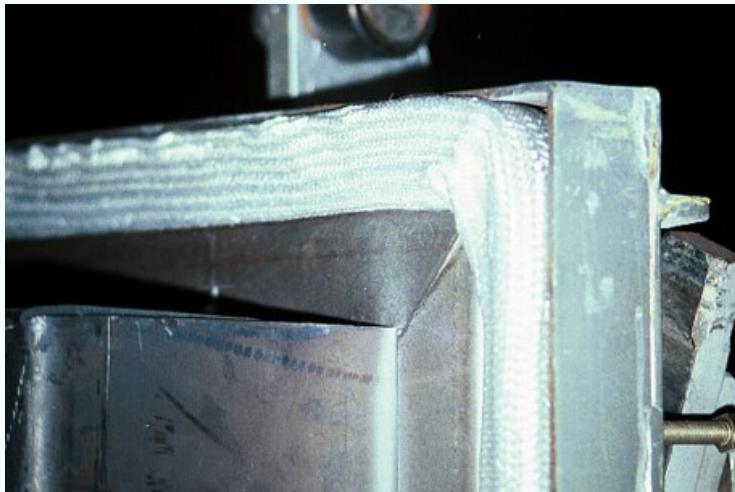
- based on  $\alpha\text{-Al}_2\text{O}_3$ ,
- improved stability, high temperature properties
- composite reinforcement

## **New high temperature fibers**

- YAG
- advanced mullite

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# **Nextel™ Furnace Door Seals**



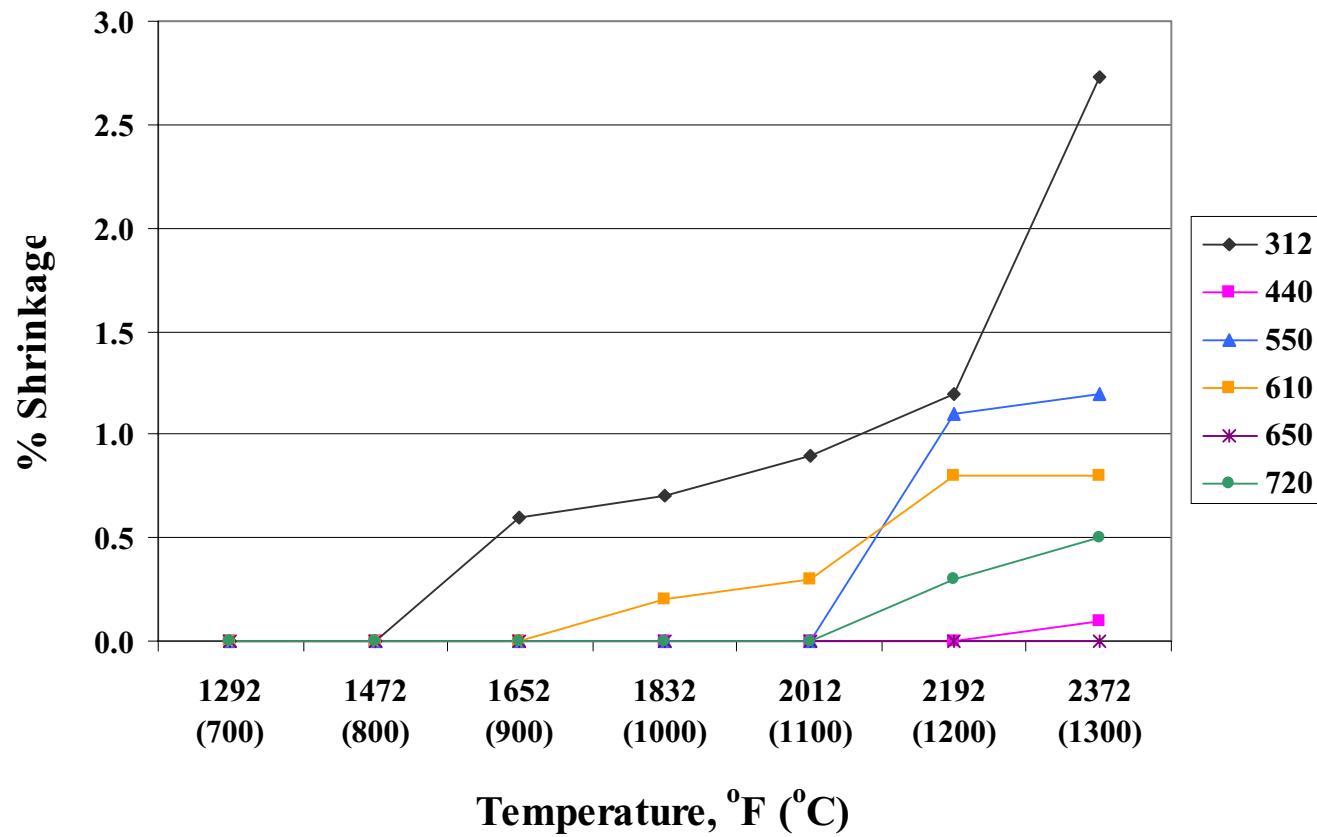
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## Nextel™ Industrial Fibers

<b>Property</b>		<b>Nextel™ 312</b>	<b>Nextel™ 440</b>	<b>Nextel™ 550</b>
<b>Chemical Composition</b>	wt. %	62 Al <sub>2</sub> O <sub>3</sub> 24 SiO <sub>2</sub> 14 B <sub>2</sub> O <sub>3</sub>	70 Al <sub>2</sub> O <sub>3</sub> 28 SiO <sub>2</sub> 2 B <sub>2</sub> O <sub>3</sub>	73 Al <sub>2</sub> O <sub>3</sub> 27 SiO <sub>2</sub>
<b>Crystal Phase</b>		9Al <sub>2</sub> O <sub>3</sub> ·2B <sub>2</sub> O <sub>3</sub> + Amorph.	γ-Al <sub>2</sub> O <sub>3</sub> + Amorph. SiO <sub>2</sub>	γ-Al <sub>2</sub> O <sub>3</sub> + Amorph. SiO <sub>2</sub>
<b>Tensile Strength (25.4 mm gauge)</b>	MPa (Ksi)	1700 (250)	2000 (300)	2000 (300)
<b>Elastic Modulus</b>	GPa (Gsi)	150 (22)	190 (28)	193 (28)
<b>Density</b>	g/cc	2.7	3.05	3.03
<b>Roving Denier: Filament Count</b>		600: 420 900: 420 1800: 780	700: 420 1000: 420 2000: 780	700: 420 1000: 420 2000: 780
<b>Thermal Expansion (100-1100°C)</b>	ppm/°C	3 (25-500°C)	5.3	5.3

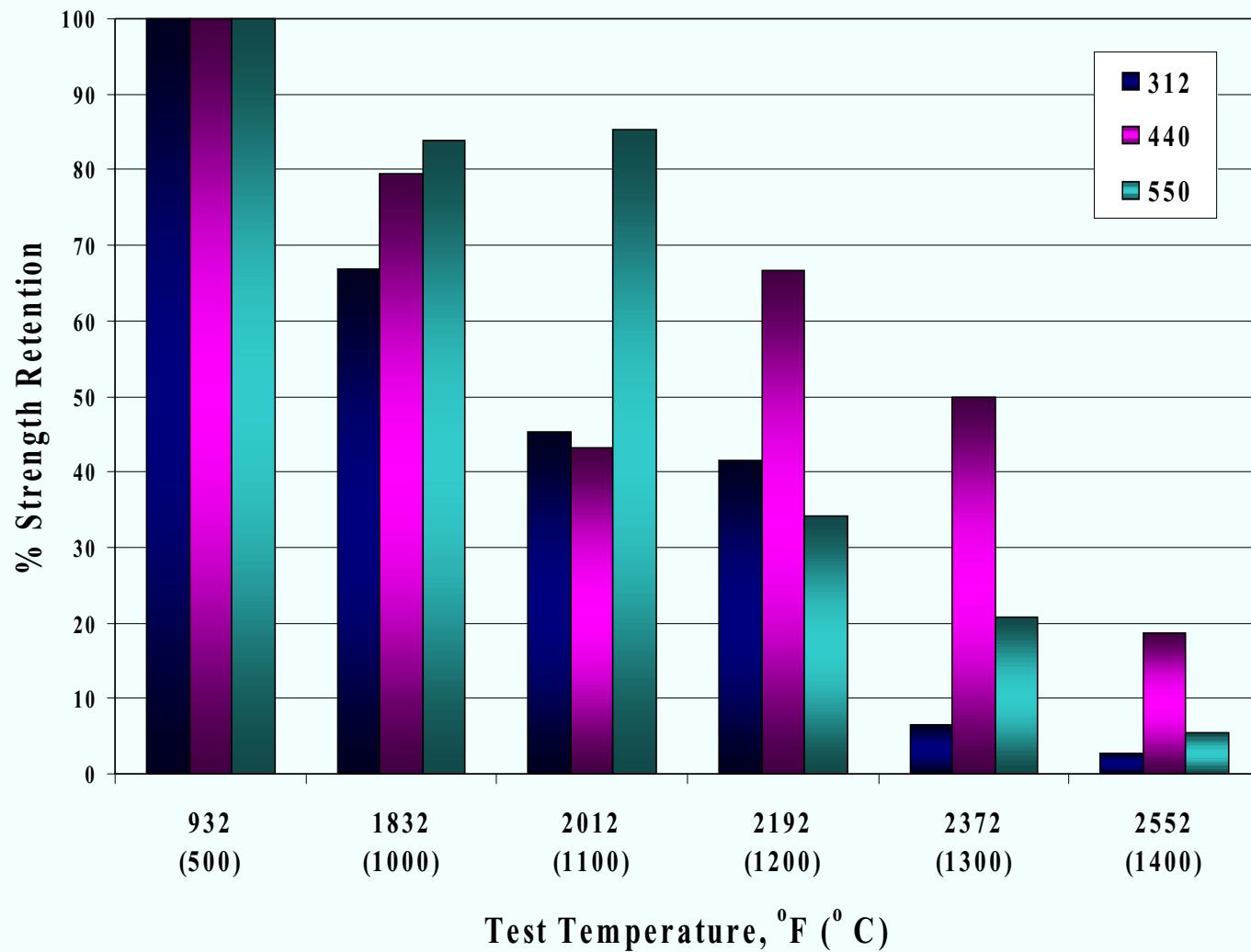
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# Nextel™ Shrinkage vs. Temperature



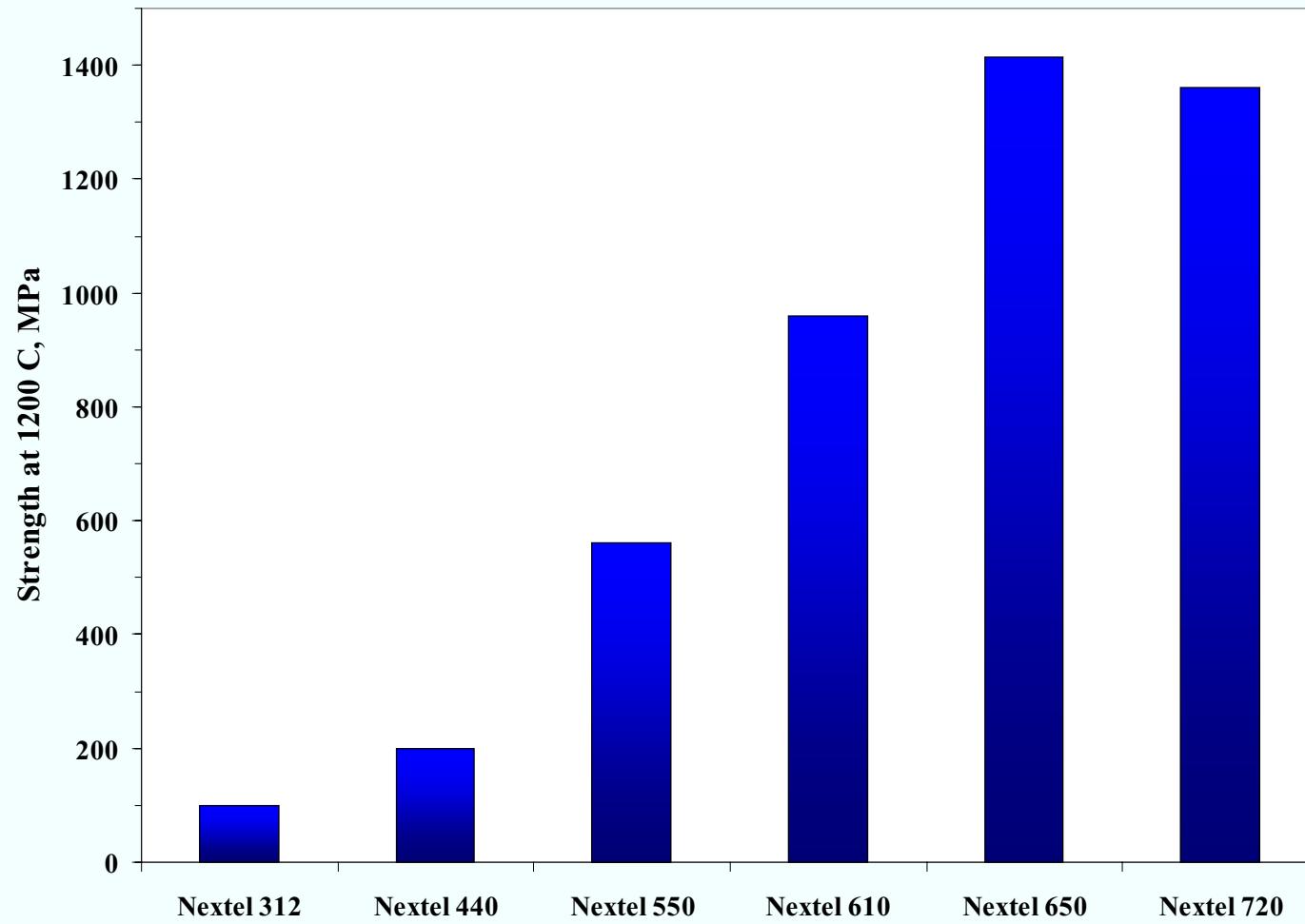
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## Nextel™ Industrial Rovings: Strength Retention after 100hr thermal aging



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# High Temperature Strength of Nextel™ Fibers is Increasing



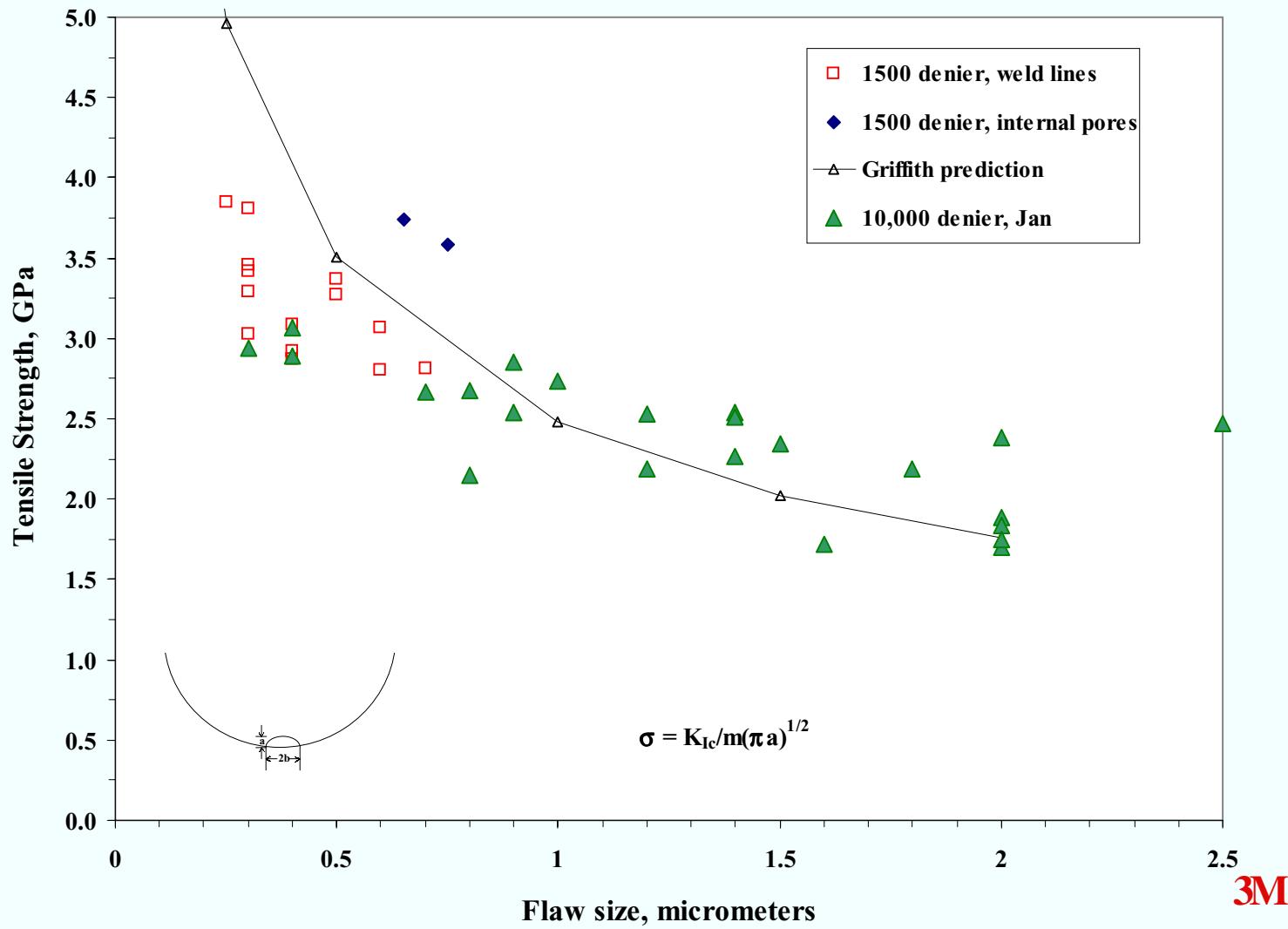
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## Nextel™ Composite Fibers

<b>Property</b>		<b>Nextel™ 610</b>	<b>Nextel™ 650</b>	<b>Nextel™ 720</b>
<b>Chemical Composition</b>	wt. %	>99 Al <sub>2</sub> O <sub>3</sub>	89 Al <sub>2</sub> O <sub>3</sub> 10 ZrO <sub>2</sub> 1 Y <sub>2</sub> O <sub>3</sub>	85 Al <sub>2</sub> O <sub>3</sub> 15 SiO <sub>2</sub>
<b>Crystal Phases</b>		α-Al <sub>2</sub> O <sub>3</sub>	α-Al <sub>2</sub> O <sub>3</sub> + cubic ZrO <sub>2</sub>	α-Al <sub>2</sub> O <sub>3</sub> + mullite
<b>Tensile Strength (25.4 mm gauge)</b>	GPa (Ksi)	3.3 (470)	2.5 (360)	2.1 (300)
<b>Tensile Modulus</b>	GPa (Msi)	373 (55)	358 (52)	260 (38)
<b>Density</b>	g/cc	3.9	4.1	3.4
<b>Thermal Expansion (100-1100°C)</b>	ppm/ °C	7.9	8.0	6.0
<b>Max Use Temperature (1% strain/ 69 MPa/1000 hr)</b>	°C	1000°C	1080°C	1150°C
<b>Roving Denier: Filament Count</b>		1500: 420 3000: 780 10000: 2600	3000: 780	1500: 420 3000: 780

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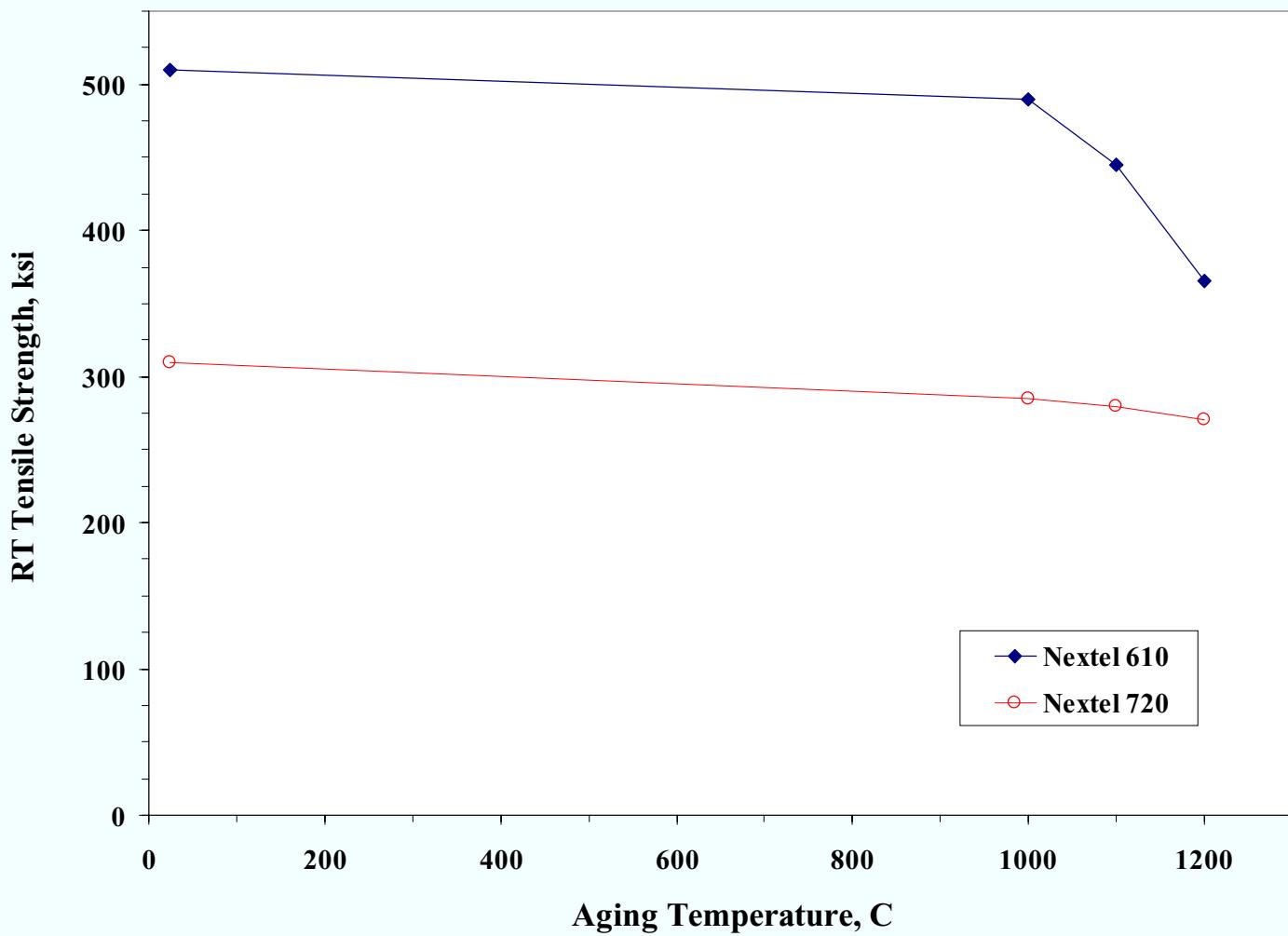
## The strength of Nextel 610 fiber is inversely proportional to flaw size



## **Nextel 720 fiber was developed for high temperature composite reinforcement**

- 85%  $\text{Al}_2\text{O}_3$  - 15%  $\text{SiO}_2$  composition intermediate between alumina and alumina-silica fibers
- Interpenetrating  $\alpha\text{-Al}_2\text{O}_3$ -mullite microstructure reduce grain growth, degradation at high temperature
- Large (0.5  $\mu\text{m}$ ) grains of mullite provide excellent creep resistance and hot strength
- Lower thermal expansion, modulus reduce thermal stresses

**Nextel™ composite fibers retain  
good strength after 1000 hrs at 1200°C**



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## **Summary of Nextel fiber attributes**

- Nextel™ 312:** Lowest cost, best textile properties
- Nextel™ 440:** Good strength retention > 1200°C, good textile properties
- Nextel™ 550:** Better chemical resistance, good strength to 1100 °C
- Nextel™ 610:** Highest strength, high modulus, excellent chemical stability
- Nextel™ 650:** High strength, better creep resistance, less shrinkage
- Nextel™ 720:** Best creep resistance, high temperature strength retention

# **Summary**

- Family of Nextel fibers available for both industrial and composite applications
- Composite fibers represent new opportunities in high temperature capability
- Opportunities exist for further improvements in fiber temperature performance
  - Nextel 650 fiber was recently developed for applications at 1100°C in corrosive environments
  - YAG fibers under development