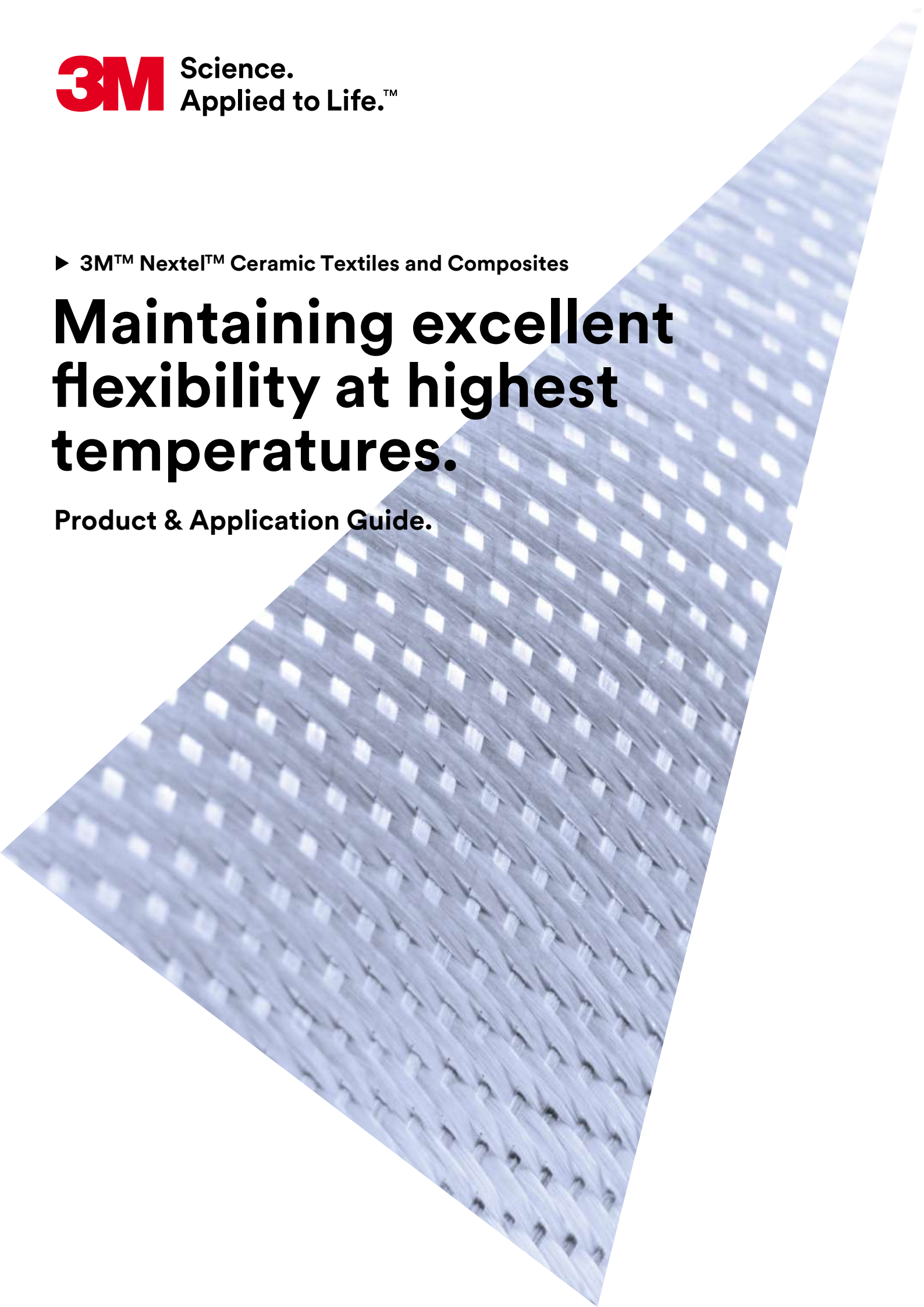


3M Science.
Applied to Life.™

► 3M™ Nextel™ Ceramic Textiles and Composites

Maintaining excellent flexibility at highest temperatures.

Product & Application Guide.

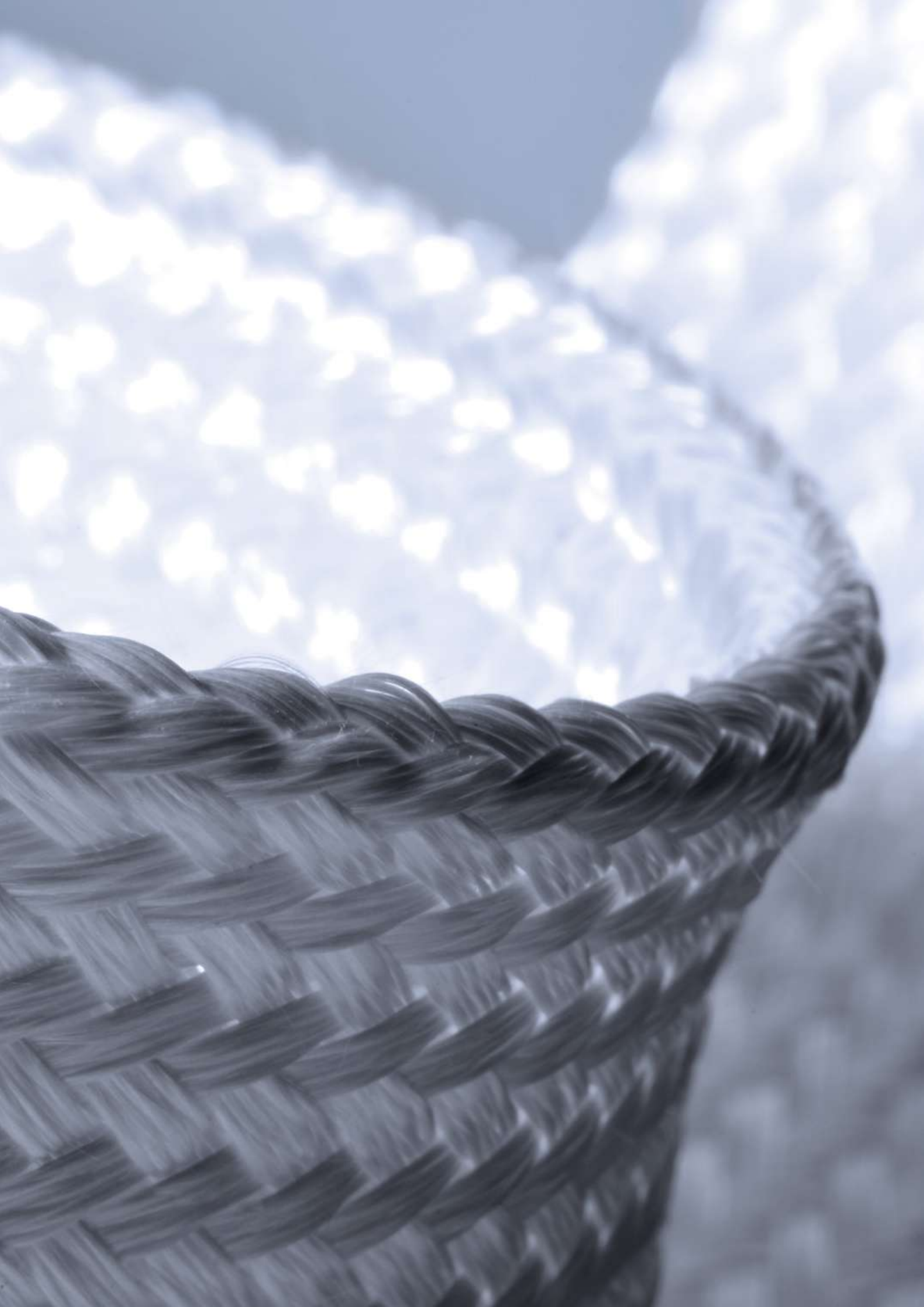


3M™ Nextel™ Ceramic Textiles

Solutions for high temperature applications.

Nextel Ceramic Textiles are made of continuous polycrystalline metal oxide fibres with a filament diameter of 10 to 12 μ , based on sol-gel technology. Their main advantages include low shrinkage and excellent dimensional stability, low thermal conductivity as well as non-porous and non-hygroscopic characteristics. These high-performance materials are designed to meet demanding thermal, mechanical, and electrical performance requirements. They retain their flexibility even at continuous temperatures of up to 1,370 °C. Due to the continuous form, high strength, and flexibility of the metal oxide fibres, they can be processed using conventional textile technology such as weaving and braiding. Nextel Ceramic Textiles are semi-finished products offered in the form of rovings, yarns, sewing threads, fabrics, tapes, and braided sleeveings.

Nextel Ceramic Textiles are used in a variety of applications, ranging from industrial, petrochemical, aviation, and outer space applications to the development of continuous-fibre reinforced composite materials.





3M™ Nextel™ Ceramic Textiles.

**Maintain excellent flexibility
even after continuous exposure
to temperatures up to 1,370 °C.**

Thermal Insulation Properties.

3M™ Nextel™ Ceramic Textiles feature both excellent resistance to thermal shock and low thermal conductivity and can be fabricated into excellent high temperature thermal insulations.

Thermal Mechanical Properties.

Nextel Ceramic Textiles retain greater strength and flexibility at higher temperatures than other refractory textile materials.

Electrical Properties.

Nextel Ceramic Textiles' high electrical resistance at elevated temperatures make it an excellent choice for high temperature electrical insulation applications.

Low Shrinkage.

Nextel Ceramic Textiles exhibit very low shrinkage, providing excellent dimensional stability.

Non-Hygroscopic.

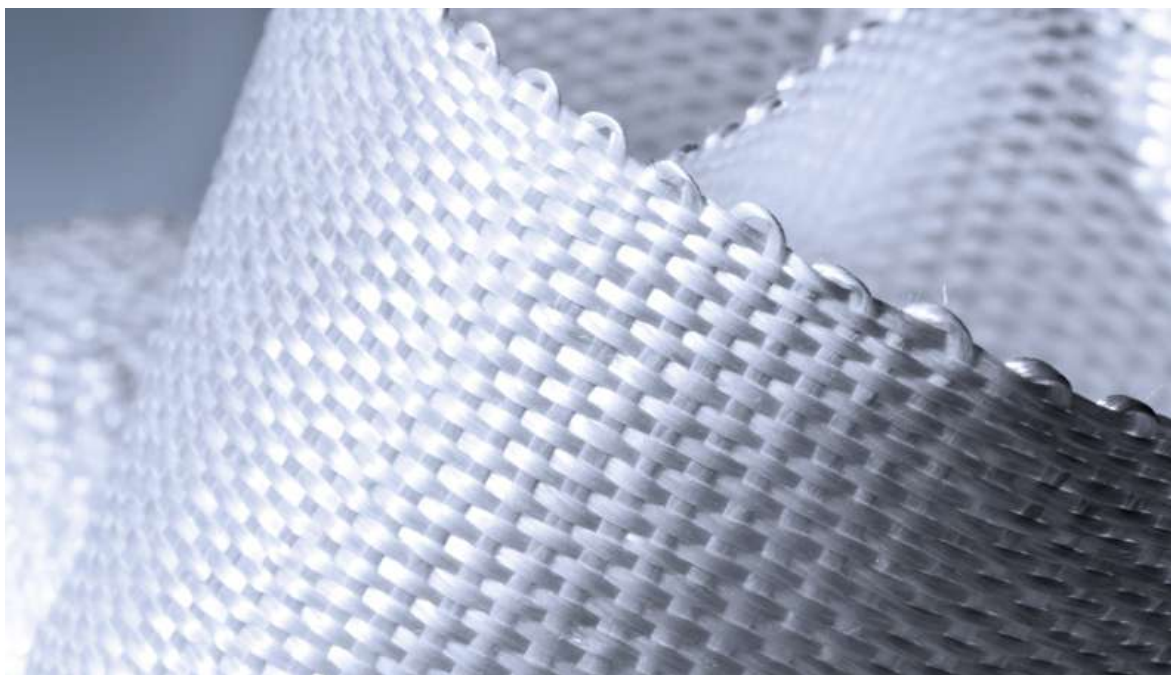
The smooth, non-porous surface of Nextel Ceramic Textiles only gains 0.08 % of its weight after 2 hours exposure to 100 % humidity.



Typical Properties.

Property	Units	Nextel 312	Nextel 440	Nextel 610	Nextel 720
Use Temperature*	°C	1204	1371	1204	1204
Filament Diameter	µm	10-12	10-12	10-12	10-12
Crystal Size	nm	< 500	< 500	< 500	< 500
Crystal Type		9 Al ₂ O ₃ : 2 B ₂ O ₃ + amorph. SiO ₂	gamma Al ₂ O ₃ + mullit + amorph. SiO ₂	alpha Al ₂ O ₃	alpha Al ₂ O ₃ + mullit
Density	g/cm ³	2.70	3.05	3.88	3.40
Filament Tensile Strength (25, 4 mm gauge)	MPa ksi	1700 250	2000 290	2930 425	2100 300
Filament Tensile Modulus	GPa msi	150 22	190 27	373 54	260 38
Surface Area	m ² /g	< 0.2	< 0.2	< 0.2	< 0.2
Chemical Composition	Weight %	62 Al ₂ O ₃ 24 SiO ₂ 14 B ₂ O ₃	70 Al ₂ O ₃ 28 SiO ₂ 2 B ₂ O ₃	> 99 Al ₂ O ₃	85 Al ₂ O ₃ 15 SiO ₂
Thermal Expansion (100-1100 °C)	ppm/°C	3 (25-500 °C)	5.3	7.9	6.0
Dielectric Constant	(at 9,375 Ghz)	5.2	5.7	~ 9.0	~ 5.8
Refractive Index		1.570	1.616	1.735	1.667

*Application dependent



Manufacturing Process.

Sol-Gel

High viscosity mixture of metal compounds in water

**1.**

Spinneret

Unit with a large amount of small holes, where the sol-gel is pressed through

**2.**

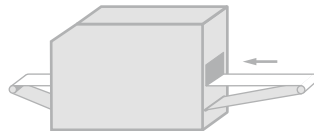
Drying Unit

Evaporation of water to come to a fibre material with a high solid content

3.

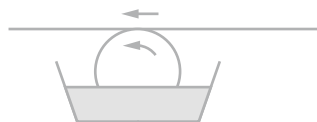
Firing Furnance

Crystallization of the ceramic fibres by controlled firing

**4.**

Sizing


Prevents fuzzing, reinforces fibre stability, and provides processability

**5.**

3M™ Nextel™ Roving

Base material for further converting to plied yarns, woven fabrics, sewing threads, braided sleeveings, woven tapes, or direct customer use

**6.**



3M™ Nextel™ Ceramic Textiles and Composites.

Application Overview.



Industrial Applications.

Steel Industry.

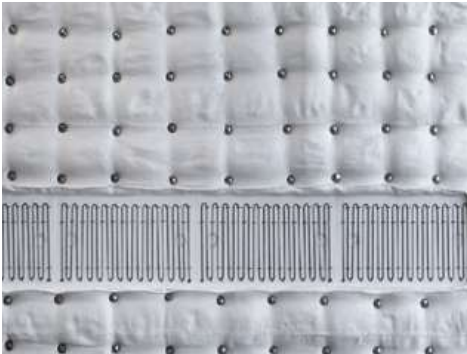
Heat Shield:

The ceramic fabrics, woven tapes, and braided sleeveings can be sewn and converted into an endless number of forms, including heat shields to protect specific areas, pads for assisting the transportation of high-temperature material, ropes for use as gasket material, or even as ties for securing an object within a high-temperature location.



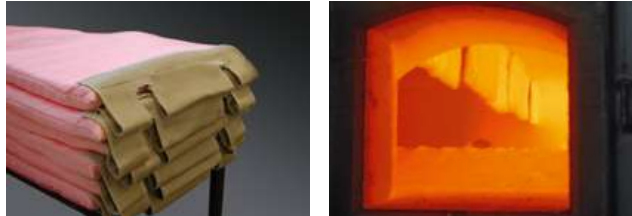
Furnace Lining:

3M™ Nextel™ Ceramic Fabrics can help resolve shedding problems associated with soft-refractory furnace interiors. The furnace lining application represented here shows how ceramic fabric can be fastened to furnace walls and ceilings, helping to reduce dusting and improve product quality. The higher temperature capabilities of Nextel Ceramic Fabrics could extend the duration and viability of the interior insulation.



Zone Divider:

Textile separator with Nextel Ceramic Fabrics for 1,370 °C in heat treating furnaces.



▶ 02

Electrical Insulation.

Covering for Thermocouple Wires:

Nextel Ceramic Yarns for compensation cables are useful for electrical applications because of their low conductivity characteristics. As a covering for thermocouple wire, the ceramic textile is insulating the wiring and electronic components as well as offering heat protection.



▶ 03

Cables for High Temperature Applications:

Flexible high temperature resistant cables are covered with Nextel Yarns used in the electric engineering industry, in lighting technology, and in electrical heating technology.



▶ 04

Industrial Applications.

Ceramic Industry.

Furnace Lining:

3M™ Nextel™ Ceramic Fabrics prevent the erosion of ceramic bulk fibre modules. This helps to reduce dust, which contaminates products such as sanitary ware and is dangerous to operators if they breathe it in. Erosion also means high maintenance costs and shutdown time.



Petrochemical Industry.

Internal and External Tube Seals:

Nextel Ceramic Textiles can be used in high temperature resistant flexible tube sealing for tube passings in roofs, floors, and walls for all types of process heaters and furnace reformers in the petrochemical industry.



▶ 05



Expansion Joints:

The manufacture of expansion joints with Nextel Ceramic Fabrics, e.g. for the use in ammonia reformers, is also possible.



▶ 02



▶ 05

Heat Shields:

Another application for Nextel Ceramic Fabrics is on radiant coils to help decrease the formation of coke and reduce premature aging of the tube skin furnace.



▶ 05

Aviation Applications.

3M™ Nextel™ Ceramic Textiles are successfully used in several **Boeing*** and **Airbus**** aircrafts. Potential applications are fan cowl door insulators, struts, thrust reversers, and firewalls around engines.

Silicone Coatings:

Can easily be applied to Nextel Fabrics, helping to protect against impact from environmental factors.



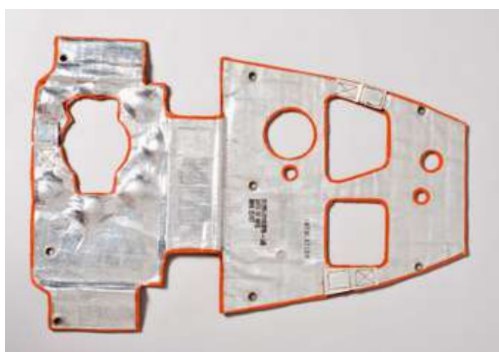
FAA Firewall Test:

According to FAA fireproofing regulations, commercial engine cowlings must be capable to withstand a flame of 1,093 °C for 15 minutes without flame penetration.



Firewalls:

Nextel Ceramic Textiles are key elements in firewalls.





Outer Space Applications.

3M™ Nextel™ Ceramic Textiles have flown in space as:

- ▶ Micrometeorite shield
- ▶ Whipple shield
- ▶ Door seals
- ▶ Gaskets
- ▶ Shuttle tiles
- ▶ Booster access doors
- ▶ Exit cone

Nextel Ceramic Textiles have been used by NASA and other aerospace manufacturers to achieve their goals of performance and value. Examples include various space-shuttle applications such as incorporation in the under-body tiles, gap fillers, gaskets, and seals. These lightweight and durable fabrics allow design engineers to meet or exceed their specifications.

Shuttle re-entry criterion is 1,093 °C for 9 minutes

Shuttle launch criterion is 1,648 °C for 2 - 3 minutes

Micrometeorite shield is used as impact protection from outerspace debris



Outer Space Applications.

Delta II Rocket:

In the Delta II rocket, Nextel Ceramic Fabrics were sewn into blankets to protect the liquid fueled engine from the plume of the solid propellant boosters. Easily incorporated into blankets or other configurations, Nextel Ceramic Fabrics can solve many problems.



SHEFEX (Sharp Edge Flight Experiment):

WHIPOX^{®***} reinforced with Nextel Ceramic Textiles and used as re-usable thermal production system SHEFEX (Sharp Edge Flight Experiment) displays a low weight and resistance to extreme temperatures (re-entry with 2,400 m/sec. at 1,600 °C).



▶ 06

Stuffed Whipple Shield:

The Stuffed Whipple Shield protects the spacecraft against collisions with micro-meteorites. The shield, produced at NASA Marshall Space Center in Huntsville, AL, and the Johnson Space Center in Houston, TX, contains Nextel Ceramic Fabrics. Nextel Ceramic Textiles were shown to be a key component in the development of this lightweight improvement on conventional shielding.



Nextel Braided Sleeveings were used to **protect pressurized gas lines** against the heat and flames resulting from the rocket plume.



Nextel Ceramic Fabric is a key component in the development of strong, **lightweight space debris shields**, for use on the Space Station Laboratory Habitation and other U.S. manned (e.g. ISS) and unmanned missions (e.g. Stardust Mission).

International Journal of Impact Engineering, Vol. 17, Enhanced Meteoroid and Orbital Debris Shielding, E. L. Christiansen, J. L. Crews, J. E. Williamsen, J. H. Robinson, A. M. Nolen

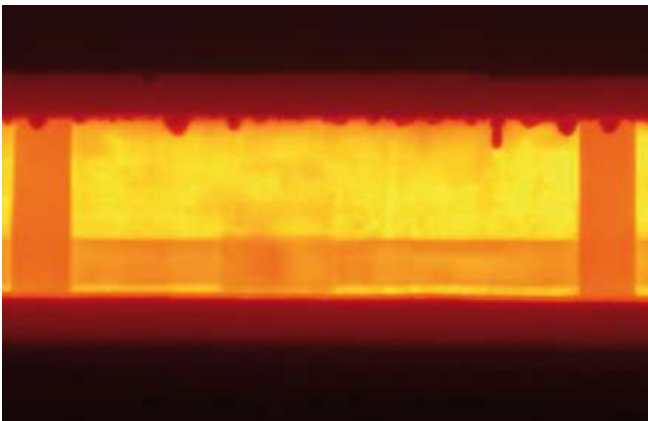


Composite Applications.

Ceramic Matrix Composites (CMC).

3M™ Nextel™ Ceramic Fibres reinforce oxide ceramics

and enable the production of high-temperature, thin walled, thermal shock and oxidation resistant Ceramic Matrix Composites (CMC). This high performance material can be used in numerous applications in industrial furnaces, for the production of kiln furniture and in the field of burner technologies.



Lift gate

in a sinter metal production furnace with H₂/N₂-atmosphere at 1,300 °C.

▶ 07

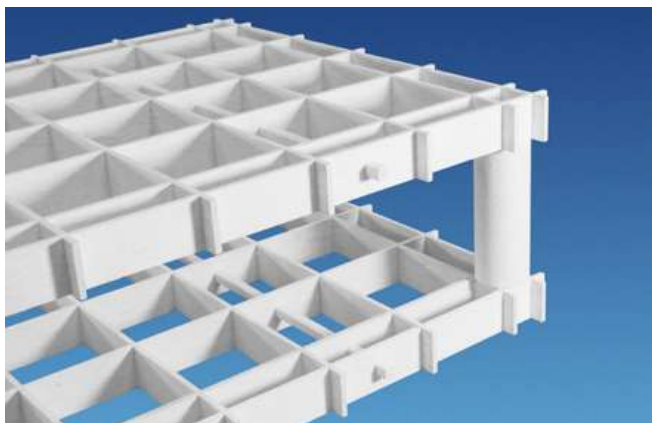


Furnace door

casing to prevent the erosion of bulk fibre insulation material.

▶ 08

Heavy duty charge carriers
for heat treatment of metals in oxidizing atmospheres.



► 09

Lightweight support structure
non-corrosive and thermal shock resistant.



► 09

Insulation segments
made of ceramics matrix composites (CMC).



► 10

Protective tubes and kiln rollers
with low thermal capacity and good thermal heat permeability.



► 09

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Composite Applications.

Polymer Matrix Composites (PMC).

Polymer Matrix Composites reinforced with 3M™ Nextel™ 610 Ceramic Textiles are designed for applications requiring strength and stiffness combined with electrical non-conductivity and electromagnetic transparency, such as structural aircraft components, rotor blades, and radomes.

Features

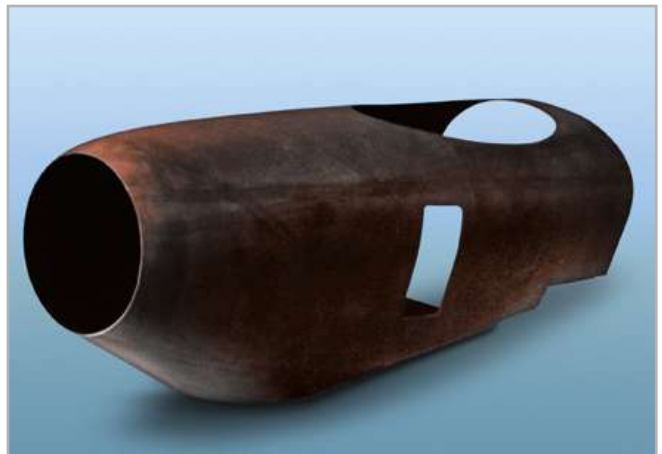
- ▶ Very high compressive strength
- ▶ Electrically non-conductive
- ▶ Electromagnetically transparent
- ▶ CTE similar to titanium
- ▶ Thermal conductivity higher than glass

Applications

- ▶ Structural aircraft components
- ▶ Rotor blades
- ▶ Radomes
- ▶ Electrical insulation

Nextel 610 Ceramic Textiles can be used in the manufacture of high-performance polymer composites suitable for lightweight, high-strength components such as aircraft radomes.

Other applications for PMC reinforced with Nextel Ceramic Textiles are aircraft panels or structural components in engines, ducting, or firewalls.



Metal Matrix Composites (MMC).

Metal Matrix Composites reinforced with Nextel 610 Ceramic Textiles

enable the production of high performance components or parts which are half the weight of steel or cast iron, but with all of the strength and stiffness. Whether a completely new geometry is needed, or improvements to an existing design are required, MMCs can be created to benefit the system. Based on current performance specifications, a new solution can be designed that may have a different shape, a significant weight reduction, or better performance. Alternatively, MMCs can be designed to replace an existing component, like an interchangeable part, in order to improve on existing performance specifications, while decreasing weight and possibly improving strength or stiffness.



Important Notice

All information set forth herein is based on our present state of knowledge and is intended to provide general notes regarding products and their uses. It should not therefore be construed as a guarantee of specific properties of the products described or their suitability for a particular application. Because conditions of product use are outside 3M's control and vary widely, user must evaluate and determine whether a 3M product will be suitable for user's intended application before using it. The quality of our products is warranted under our General Terms and Conditions of Sale as now are or hereafter may be in force.

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