A unique fiber for harsh filtration of fluids

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ABSTRACT *Many filtration applications require a high-performance fiber with good thermal, chemical, and textile properties. Ryton fiber has this unique combination of properties. Physical properties including tenacity and elongation were measured after exposing fiber samples to various acidic and caustic environments at elevated temperatures. These data were compared with physical data obtained by exposing other high-performance fibers to the same conditions. Used as a fiber bag material in harsh baghouse environments, the new fiber results in high fabric strength retention and longer bag life. Other applications also take advantage of the fiber's unique balance of properties.*

KEYWORDS
Air pollution control
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Nonwovens
Physical properties
Polyphenylene sulfide
Synthetic fibers

In many industrial settings in which nonwoven or woven fabrics are used, conditions require a fabric with a balance of good thermal, chemical, and textile properties. Ryton® sulfar polyphenylene sulfide (PPS) fiber is a readily available, high-performance fiber with a unique combination of these properties. It is an ideal fiber for nonwoven and woven fabrics intended for use in harsh industrial environments.

Background

Most "new" man-made fibers produced in the past 10 years have been physical or chemical variants of fibers already known or in production. The PPS fiber is outside the current classes of fibers recognized by the Federal Trade Commission. Accordingly, in July 1986, the Federal Trade Commission granted a new generic name, "sulfar," for this class of fibers. "Sulfar" is described as a fiber-forming substance containing "a long-chain synthetic polysulfide with at least 85% of the sulfide linkages attached directly to two aromatic rings."

Polyphenylene sulfide resins have been produced commercially since 1973. In the polymerization, as shown in **Fig. 1**, paradichlorobenzene and sodium sulfide are allowed to react in a polar solvent at elevated temperatures to form the aromatic sulfide polymer, polyphenylene sulfide (*1*). In this form, the polymer is a light tan, free-flowing powder.

Since the preliminary work leading to the first patent, many improvements have been made in the polymerization process; these are described in the subsequent patents and in other publications (*2*). The resins have become recognized as unique engineering thermoplastics and are now being used in injection molding and coating applications. They demonstrate good dimensional stability, inherent flame retardancy, thermal stability, chemical resistance, and excellent electrical resistance.

It was soon recognized that a synthetic fiber made from these resins would be a unique and potentially useful material. After thorough research and evaluation, a linear, high-molecular-weight polymer suitable for melt spinning was developed using conventional melt spinning equipment (*3*). The spun fiber is drawn at elevated temperatures and is converted into staple fiber using conventional crimping and cutting techniques. Sulfar fiber became available in commercial quantities in 1983, but it was available initially in staple form only. It is now available in multifilament form and monofilament form.

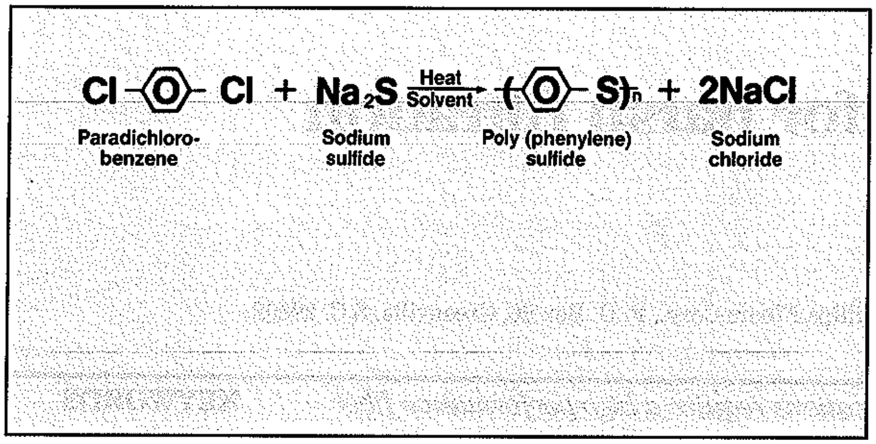
Sulfar fiber possesses the following properties for specialty nonwoven and woven purposes:

- Good physical properties
- Outstanding thermal resistance
- Excellent chemical resistance
- Flame retardancy
- Good electrical properties.

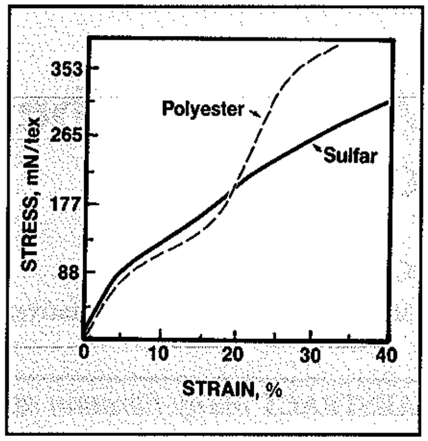
Possible uses for the fiber in nonwoven and woven fabrics include:

- Woven and nonwoven filter fabrics for liquid and gas filtration
- Filter bags for filtration of flue gas from coal-fired boilers
- Papermakers' felts
- Electrolysis membranes
- High-performance composites with glass, Kevlar®, or carbon fiber
- Rubber reinforcement
- Gaskets and packings

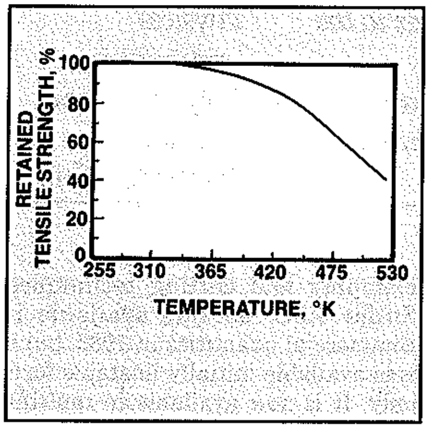
1. Chemistry of the polymerization of sulfar fiber



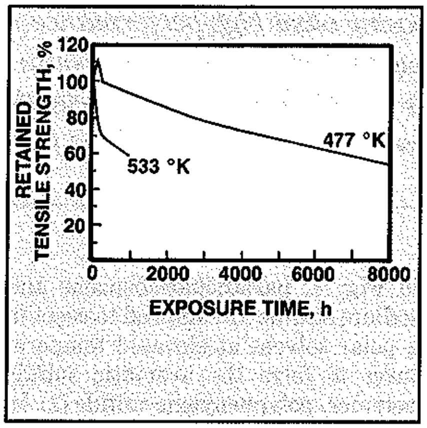
2. Stress-strain curves of sulfar and polyester staple fiber



3. Tensile strength retained at elevated temperatures



4. Strength retention after exposure in air at high temperatures



I. Typical physical properties

Tenacity, mN/tex	310
Elongation, %	40
Modulus,[a] mN/tex	1415
Elastic recovery, %	
2% extension	100
5% extension	96
10% extension	86
Dry shrinkage,[b] %	4
Moisture regain, %	0.6
Specific gravity	1.37
Melting point, °K	558
Heat setting temp., °K	450-550

[a]At 10% extension. [b]At 403° K.

- Electric insulation
- Wet- and dry-laid fabrics.

Most of our company's experience with the fiber has been in filter bags for the filtration of flue gases from coal-fired boilers and incinerators.

Fiber properties

Physical properties

Typical physical properties of sulfar staple fiber are shown in **Table I.** The properties are in the range of most textile fibers. The fiber has a tenacity of 310 mN/tex and an elongation-to-break of 40%. The specific gravity is similar to that of polyester. One of the more attractive properties is its low moisture regain of 0.6%.

The stress-strain curves for sulfar and polyester are shown in **Fig. 2.** Based on the similarity of these curves, one should not be surprised that sulfar performs similar to polyester in conventional carding and needlepunch nonwoven processes. Sulfar also processes well in normal spun processing. Yarns and fabrics exhibit physical properties similar to polyester.

The 4% shrinkage permits control of fabric porosity and density by finishing techniques. The use of the proper heat setting can reduce the shrinkage of a finished nonwoven to under 1%. Its thermoplastic nature adds greatly to its versatility, permitting nonwoven fabrics to be glazed, fusion-bonded, and molded.

Thermal resistance

The fiber exhibits good high-temperature stability. Thermal stability can be demonstrated in several different ways. One method is to measure tensile strength retention as a function of temperature in an Instron environmental test chamber. Results from this testing are shown in **Fig. 3** for temperatures up to 522°K. In this test, sulfar retained over 60% of its strength at 477°K and 40% of its strength at 522°K. Elongation-to-break remained essentially unchanged up to 522°K.

Figure 4 shows perhaps a more severe test. In this test, the fiber was exposed to constant temperature for a prolonged period of time. It still retained 60% of its tensile strength after exposure for 8000 h at 477°K. At 533°K, the loss of strength is more rapid, as expected, with 60% tensile strength retention being reached in the first 1000 h.

Table II compares this fiber to other filter fabrics at 505°K. The nonwoven filter fabrics were exposed for up to five weeks during this test. All of the products showed some loss of strength, but the Nomex®, polybenzimidazole (PBI), Huyglas®, and sulfar fabrics all retained 60% of their strength after five

II. Fabric strength retained after exposure in an oven at 505°K

Fiber type	Strength retained, % 24 h	2 weeks	3 weeks	5 weeks
Nomex	100	100	98	95
PBI	100	98	100	79
Huyglas	80	88	93	79
PPS	95	70	93	61
Polyester	29	27	23	19
Acrylic	3	1	...	...
Polypropylene	Melted	...	...	...

*In nonwoven filter fabric.

III. Chemical resistance: tensile strength retained after exposure to various chemicals (360°K for 1 week)

Chemical	Strength retained, %
Acids	
48% sulfuric acid	100
10% hydrochloric acid	100
Conc. hydrochloric acid*	100
Conc. phosphoric acid	95
Acetic acid	100
Formic acid	100
Alkalis	
10% sodium hydroxide	100
30% sodium hydroxide	100
Organic solvents	
Acetone*	100
Carbon tetrachloride*	100
Chloroform*	100
Ethylene dichloride*	100
Perchlorethylene*	100
Toluene	75–90
Xylene (mixed)	100
Oxidizing agents	
10% nitric acid	75
Conc. nitric acid	0
50% chromic acid	0–10
5% sodium hypochlorite	20
Conc. sulfuric acid	10
Br_2 (free bromine)	0

*Fiber exposed at boiling point of chemical for one week.

weeks. These data indicate that these four materials could survive limited exposure to temperatures as high as 505°K in air.

Chemical resistance

One of the major benefits of sulfar fibers is their ability to retain physical properties in the presence of harsh chemical environments. **Table III** shows tensile strength retention in various acids, alkalis, organic solvents, and oxidizing agents. The exposure lasted one week at elevated temperatures. The retained strength of the fiber, when exposed to normal acids and alkalis, is essentially unchanged. Organic solvents such as carbon tetrachloride, toluene, and perchlorethylene have practically no effect on retained strength. However, strong oxidizing agents and elevated temperatures cause thermal oxidation, resulting in loss of strength.

Free bromine can also attack PPS fiber. In general practice, however, it is difficult for the free bromine radical to reach the baghouse. In one industrial situation, a photographic film was being burned in an incinerator to salvage the silver from the film. PPS filter bags were used as a trial in this installation. Free bromine, available in the system, quickly attacked the filter bag, causing early failure of the bags. Subsequent laboratory work has shown both PPS and Nomex are totally dissolved by bromine gas after 24 h of exposure at ambient temperature.

Table IV compares the strength retention of nonwoven fabrics made from Nomex, PBI, Huyglas, sulfar, polyester, acrylic, and polypropylene in 50% sulfuric acid and in 10% sodium hydroxide at 366°K. After two weeks of exposure in H_2SO_4, only the sulfar and polypropylene fabrics showed no evidence of degradation. Exposing the same fabrics to 10% NaOH under similar conditions gave similar results.

In **Table V**, Nomex, sulfar, and P-84 strength retentions are compared at 366°K for one week in 10% nitric acid, 50% sulfuric acid, 10% hydrochloric acid, 25% sodium hydroxide, and 5.5% sodium hypochlorite. Only nitric acid and sodium hypochlorite affected the PPS.

Flame retardancy

In a NASA study reported by Kourtides and Parker (*4*), 12 thermoplastics were classified according to fire safety for aircraft interiors. Sulfar ranked as number one in fire safety. Sulfar has a limiting oxygen index of 34 or 35, which means it is classified as nonflammable, and sulfar will not combust under normal atmospheric conditions (*5*).

Electrical properties

Sulfar fiber has excellent electrical insulation properties, which suit it for a broad range of electrical applications. The dielectric constant, dissipation factor, and volume resistivity are summarized in **Table VI**.

Applications

The combination of physical properties, thermal resistance, chemical resistance, and good processability offer many opportunities for sulfar fibers in high-performance nonwovens and wovens markets.

High-temperature filtration

A major established use for filter fabrics is in baghouses for coal-fired boilers and incinerators. Sulfar has been successfully used in pulse-jet baghouses since the late 1970s. Since then, the bulk of our experience in high-temperature filtration has involved needled fabrics designed for a high air-to-cloth ratio for use in pulse-jet processes. In our early experience, a PTFE (polytetrafluoroethylene) scrim proved highly successful in developing sulfar filter felt. Experience is being gained rapidly with the use of 100% sulfar filter felts. Scrim made of spun and/or continuous-filament sulfar has been used success-

IV. Fabric strength retained after exposure to 50% H_2SO_4 at 366°K and to 10% NaOH at 366°K

Fiber type*	Strength retained, % 24 h	1 week	2 weeks
	50% H_2SO_4		
Nomex	16	Degraded	...
PBI	87	78	82
Huyglas	5	1	1
PPS	100	100	100
Polyester	30	Degraded	...
Acrylic	79	Degraded	...
Polypropylene	100	100	100
	10% NaOH		
Nomex	16	Degraded	...
PBI	40	18	10
Huyglas	Degraded	...	...
PPS	100	100	100
Polyester	Dissolved	...	...
Acrylic	Dissolved	...	...
Polypropylene	100	100	100

*In nonwoven filter fabric.

V. Chemical resistances after exposure to various chemicals (1 week at 366°K)

	10% HNO_3	50% H_2SO_4	10% HCl	25% NaOH	5.5% NaOCl
PPS	54	114	119	112	18
Nomex	D	D	D	D	8
P-84	D	20	D	D	D

D = dissolved or decomposed to zero strength.

fully in a number of filter felt applications.

It is difficult to filter fly ash from coal-fired boilers and industrial and utility plants because of high temperature and harsh conditions within the flue gas chamber. Bag life is also influenced by abrasion created by periodic cleaning cycles. Needled fabric prepared from sulfar fiber is one of the few materials capable of long-term exposure in conditions of high temperature and high acid where abrasion of this type is common.

Conditions under which sulfar seems well suited for high-temperature filtration are:

- The flue gas temperature is 465°K or less.
- Sulfur is present in the fuel.
- Water is present in the system.
- The oxygen content of the flue gas is 15% or less.

Temperature requirements in many boiler applications demand a fiber that will withstand high temperatures. Ryton, Nomex, and PTFE are fibers that meet this requirement.

Since SO_2 and SO_3 are normally present in the flue gas of coal-fired boilers, the operator of a filter bag unit must be aware of the number of times the acid dewpoint is reached. At the dewpoint, water vapor condenses with SO_2 and SO_3 gasses, and sulfuric acid is formed. Some baghouses are even operated below the acid dewpoint. Not only are acids generated constantly under such conditions, but good filtration is inhibited because of the possible accumulation of moisture on the filter surface. As noted in Tables IV and V, some fibers are adversely affected by sulfuric acid.

VI. Typical electrical properties

Dielectric constant	
At 1 kHz	3.1-3.3
At 1 MHz	3.1-3.3
Dissipation factor	
At 1 kHz	0.003-0.005
At 1 MHz	0.005-0.009
Volume resistivity, ohm • cm	$2.2\text{-}4.2 \times 10^{16}$

Other applications

Its good stability in harsh chemical and thermal environments and its ease of processing make sulfar an attractive fiber for purposes besides high-temperature flue gas filtration. Sulfar could be used in liquid filtration for hot corrosive chemicals because it is resistant to solvents, acids, and alkalis at high temperatures. These filters could be of nonwoven or woven construction.

The fiber could be used in specialty papers for electrical insulation. The electrical resistance coupled with low moisture regain and temperature resistance should make it attractive.

The fibers are being evaluated in high-performance composites with carbon fiber, glass, and Kevlar to take advantage of its thermoplastic properties.

The fiber has potential in the papermaker's felt market in staple form in the wet end of the process. Sulfar monofilaments are already used in belts in the dry end. These applications take advantage of the thermal and chemical resistance.□

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