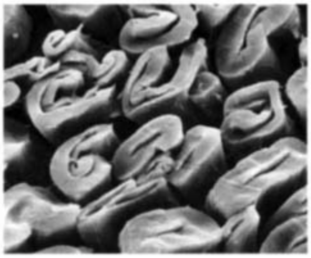
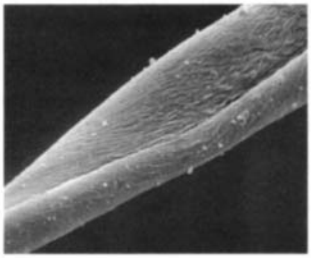
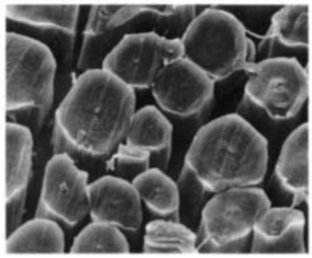
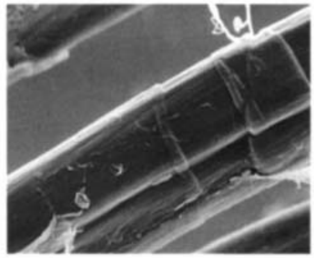
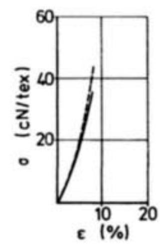
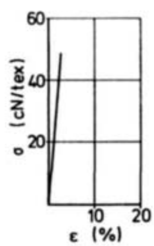
11 Fiber Tables

The first fiber table appeared in the 1950s as "Man-made Fiber Table" in the US journal "Textile World". In 1960 the Deutsche Forschungsinstitut für Textilindustrie (German Research Institute for the Textile Industry) translated the table into German. Fourné supplemented this with further fiber types, and generated a Fiber Table, which appeared in his book "Synthetische Fasern" (Synthetic Fibers) in 1964. This fiber table was revised once more in 1975 by E. Kleinhansl of the above German Research Institute in Denkendorf and was published in "TEXTIL PRAXIS". With their permission, these tables have been further supplemented, revised and published in this book. Part of this (new) information can be found in Table 1.1. Additionally, new SEM photographs of fibers have been included, as have additional force/elongation curves due to Latzke and Fourné, as well as research work done by the Fraunhofer Institute.

In view of the many, different sources and—arising from this—the variations in describing certain properties or their characteristics, the data can only be compared within certain limits. This is not only particularly true for given qualitative properties, but also for quantitative properties which are derived from a multitude of polymer- and production modifications. These very variations, however, enable "tailor-made" fibers and yarns to be produced.

Comments on the Fiber Tables

1) Pure polyurethane does not appear in the Fiber Tables, as it is not produced as fiber commercially.
2) The properties are strongly dependent on the polymer blending ratio and the spinning conditions.
3) When PVA is cited, the reference is to insoluble PVA yarn.
4) The linear density-based tenacity at maximum force is based on German Standard DIN 53815.
5) The titer-based tensile force is obtained by extrapolating the tangent of the quasi-linear region of the force/elongation curve up to an elongation of $\varepsilon = 100\%$
6) Minimum reaction time in medium: 3 min.
7) Oxygen content of an oxygen/nitrogen atmosphere in which the fiber continues to burn.
8) Yarn tenacity as % of the original tenacity, after treatment for a long time.
9) Values are for yarns exposed to sunlight in Florida for 12 months.
10) Results are based on resistance to decomposition, mold and rotting.
11) Selected examples, incomplete: only soluble when solution takes place within 30 min; insoluble when fiber only swells, becomes lumpy or disintegrates. Acids and bases are concentrated.
12) Fiber types selected from information provided by the manufacturer or from knowledge of the market. Where data is incomplete, this is due to lack of samples in the market or because production has ceased.
13) The long-term temperature resistance is not clearly defined. Often it is taken to mean the temperature at which the sample experiences a 20% reduction in tenacity when exposed for 1000 h.
14) Sketched from an image converter screen.

	Natural fibers	
	Cotton (CO)	Flax/Linen (LI)
Microphotographs of cross-section and longitudinal view	 	 
Force/elongation diagram		
Produced as	Cellulose/fiber	Cellulose/long fiber
Fineness (titer) dtex	1...1.6...2...4	Elementary: 1...7 tech. 10–40
Length mm	10...25...32...60	Elementary: 10–40 tech. 45–80
Sold as	Staple	Staple
Density g/cm³	1.50...1.54	1.43...1.52
Force/elongation properties: Tenacity in standard atmosphere cN/tex (daN/mm²)	20...50 (35...70)	30...55 (45...80)
Wet (as % of dry strength) (8)	100...110	105...120 (tech. fiber)
Loop strength %	65...70	20...40
Knot strength %	60...100	
Elongation at max. force %	6...10	1.5...4.0
Wet (as % of dry elongation)	100...110	110...125
Elongation at break %	6...10	1.5...4.0

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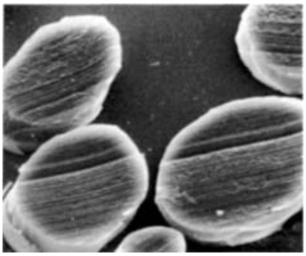
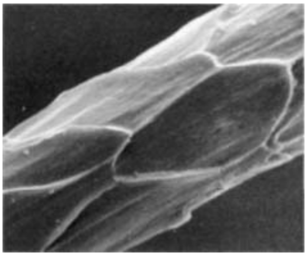
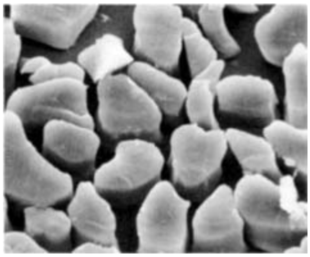
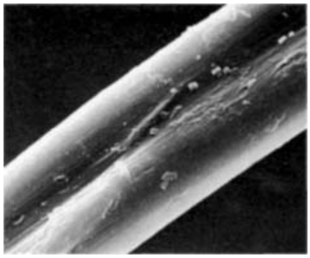
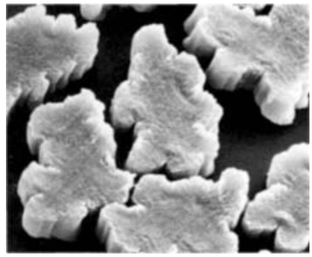
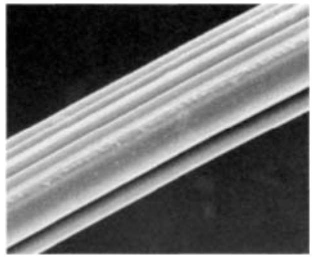
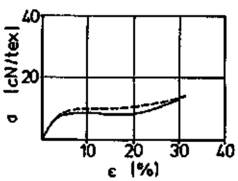
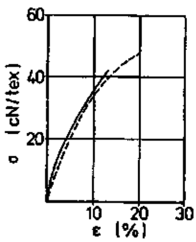
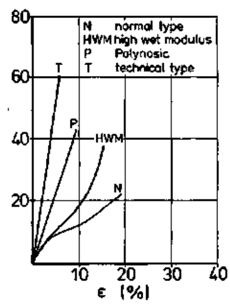
Natural fibers		Chemical fibers
Wool (WO)	Silk (mulberry) SE	Viscose (VI)
 	 	 
		
Keratin/staple	Fibroin/yarn	Viscose (cellulose hydrate)
2...50 (acc. to source) 50...350 (acc. to source) Staple 1.32	1...4 — Filament yarn 1.37 (raw)/1.25 (boiled-off) 1.52	N/H/T: 1.3–22; P: 1.3–3.6 38–200 Staple, filament yarn, tow 1.52
 10...16 (13–21) 70...90 75...85 80...85 25...50 110...140 25...50	 25...50 (30...60) 75...95 60...80 80...85 10...30 120...200 10...30	N H P T 18...35 35...45 40...75 (25...55) (55...70) (60...125) 40...70 70...80 20...60 15...20 30...70 30...70 25...65 15...30 8...18 7...15 100...130 120...150 150...200 —

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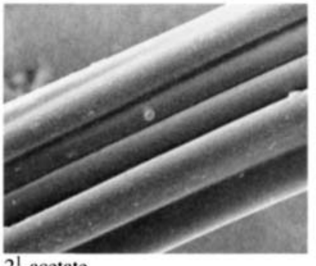
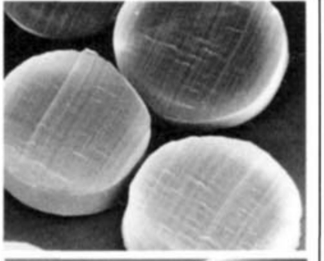
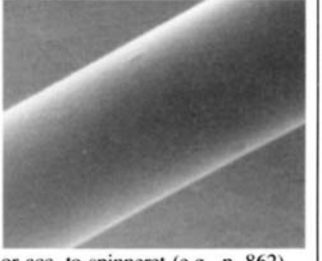
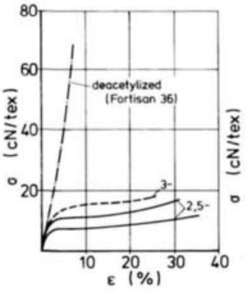
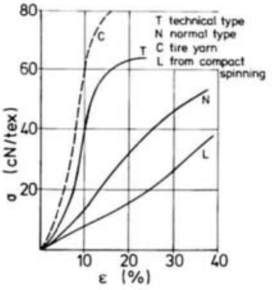
	Chemical fibers	Fibers from polycondensation polymers	
	Acetate ($2\frac{1}{2}$) CA)/ Triacetate (CT)	Polyamide 6 (e.g. Perlon®) (PA6) Polyamide 66 (Nylon) (PA66) (if different from PA6)	
Microphotographs of cross-section and longitudinal view	For triacetate, see p. 862  $2\frac{1}{2}$ acetate	  or acc. to spinneret (e.g., p. 862)	
Force/elongation diagram			
Produced as	Solution spinning	Melt spinning	
Fineness (titer) dtex	2…10	1.4…22, 30…300	< 2 mm ∅
Length mm	40…120	38…200; continuous filament	
Sold as	staple, filament yarn	staple, filament yarn, tow.	Monofil
Density g/cm³	1.29…1.33	1.14	
Force/elongation properties		N	T
Tenacity in standard atmosphere cN/tex (daN/mm²)	10…15 (13…20)	40…60 (45…70)	(60…90 (70…100)
Wet (as % of dry strength)	50…80	80…90	80…90
Loop strength %	70…90	65…85	70…79
Knot strength %	80…90	80…90	60…70
Elongation at max. force %	20…40	20…60	15…25
Wet (as % of dry elongation)	120…150	105…125	
Elongation at break %			

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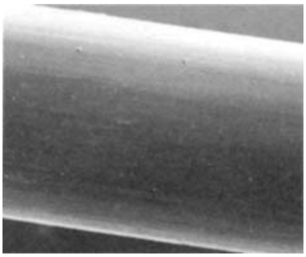
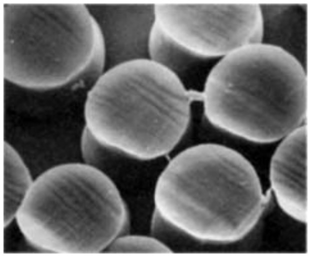
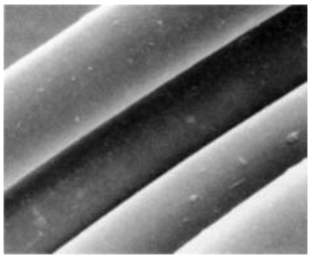
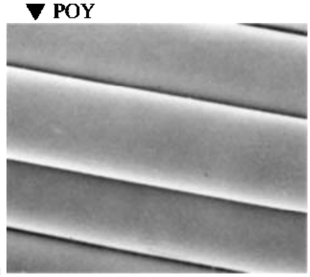
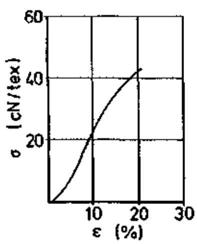
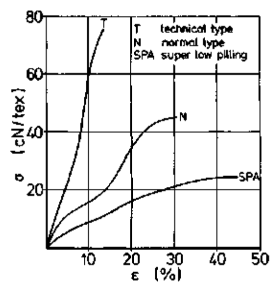
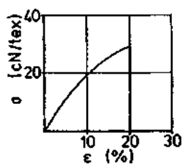
Fibers from polycondensation polymers		
Polyamide 11 (PA11) (Rilsan)	Polyester (PES) Polyethylene terephthalate (PET)	Polyester (PES) Polybutylene terephthalate (PBT)
	 	▼ POY 
Round or acc. to spinneret hole	or acc. to spinneret hole	Round or acc. to spinneret; e.g., trilobal for BCF
		
Melt spun	Melt spun	Melt spun
3...7 0.1...2 mm ∅ continuous filament Filament yarn Monofil 1.04...1.05	0.6...44 0.08...2 mm ∅ 38...200; continuous filament Staple; filament yarn Tow Monofil 1.36...1.38	3...9, 12...20 38...200; continuous filament Staple, filament yarn 1.3...1.35
 45...68/47...70 100 — 75 15...40	N T 25...60(35...90) 70...95(95...130) 95...100 30...95 80...95 70...95 70...80 40...70 15...50 8...20 100...105	 25...35 95...100 24...40

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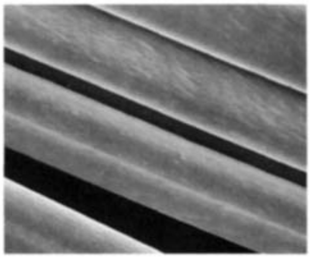
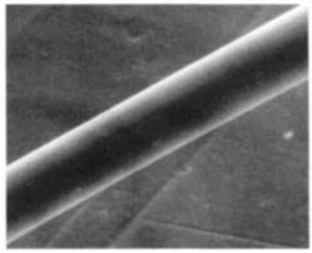
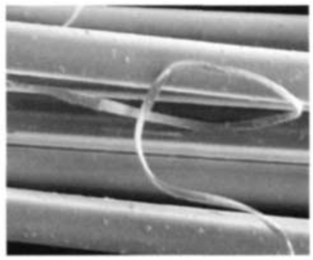
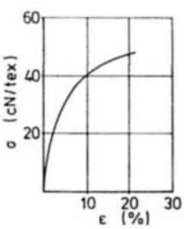
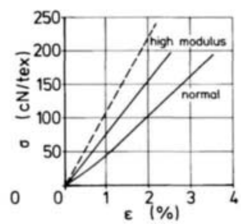
	Fibers from polycondensation polymers	
	meta-Aramid (m-AR) (aromatic PA)	para-Aramid (p-AR) (aromatic PA)
Microphotographs of cross-section and longitudinal view	 Nomex	  above: Twaron; below: Kevlar
Force/elongation diagram		
Produced as	Solution spun	Solution spun
Fineness (titer) dtex	1.6...12	1.1...1.3
Length mm	38...120	38...120
Sold as	Staple, filament yarn, Tow	Staple, filament yarn, Short cut staple
Density g/cm^3	1.38	1.44...1.45
Force/elongation properties: Tenacity in standard atmosphere cN/tex (daN/mm^2)	44...53/60...75	170...270/250...400
Wet (as % of dry strength)	75...80	100
Loop strength %	95	50...80
Knot strength %		
Elongation at max. force %	15...30	2...5
Wet (as % of dry elongation)	60...80	not known
Elongation at break %		

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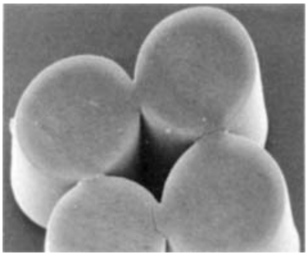
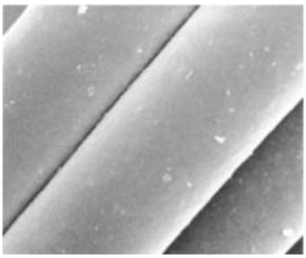
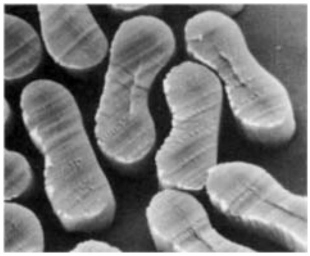
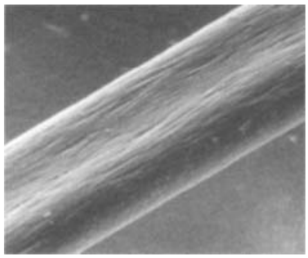
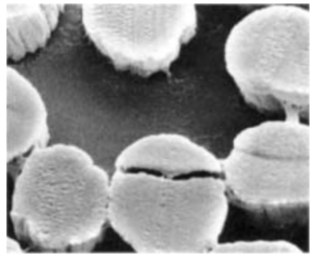
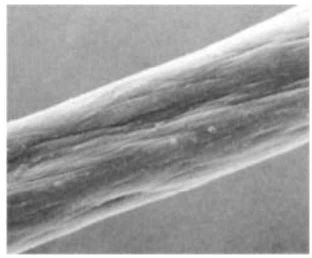
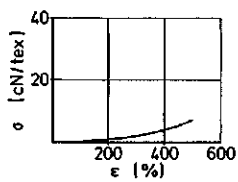
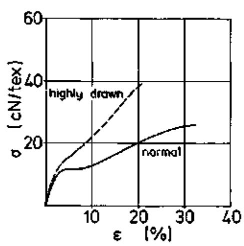
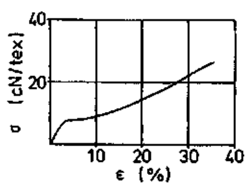
Fibers from polycondensation polymers	**Fibers from polymerisates**	
Elastane (EL) (Spandex); also polyurethane (PUR) (1)	Polyacrylonitrile (PAN)	Modacrylic (MAC) (2)
  Very variable; depends on manufacturing process; fused, with voids	with ≥ 85% acrylonitrile (dry spun). T: technical, 100% ACN  	with < 85% ACN  
		
Solution spun, wet or dry	Solution spun, wet or dry	
30...500 Continuous filament Filament yarn	0.6...25 38...200 Staple, continuous filament yarn, tow 1.14...1.18	1.5...26; 30...60 for artificial hair 38...200 Staple, tow 1.30...1.42
(depends on spinneret hole cross-section) 4...12/8...15 75...100 not known not known 400...800 100	T: 35...45/40...55 20...35/23...40 80...95 30...70 (T: 60) 70...80 20...70 (T: 20...40) 80...95	 10...25/13...40 80...100 50...70 ca. 80 25...50 80...100

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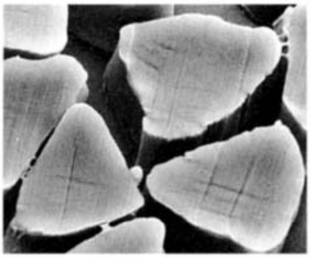
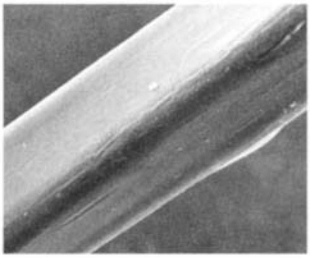
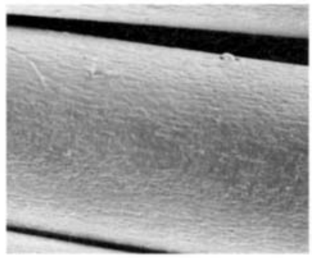
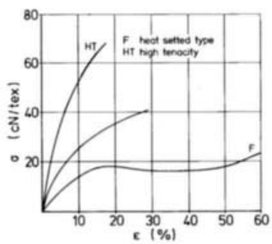
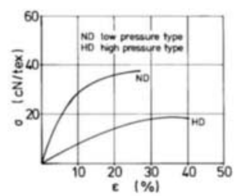
	Fibers from polymerisertes	
	Polypropylene (PP)	Polyethylene (PE)
Microphotographs of cross-section and longitudinal view	  or acc. to spinneret	N: low-, H: high pressure  or acc. to spinneret; also tapes
Force/elongation diagram		
Produced as	Melt spun	Melt spun
Fineness (titer) dtex Length mm Sold as Density g/cm^3	1.5...40 (...300) 38...200, Staple, filament yarn, tow, Monofils 0.90	10...25 38...200, filament yarn, Staple, filament yarn N: 0.95...0.96; H: 0.92...0.94
Force/elongation properties		N / H
Tenacity in standard atmosphere cN/tex (daN/mm^2)	T: up to 85 15...60 (13...55) F: 15...30	N: 32...65 / H: 34...70
Wet (as % of dry strength)	100	N: 100 / H: 100
Loop strength %	85–95	N: 70...90 / H: 80–100
Knot strength %	70...90	N: 10...45 / H: 20...60
Elongation at max. force %	15...200; F: 70...300	100
Wet (as % of dry elongation)	100	
Elongation at break %		

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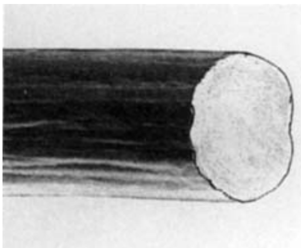
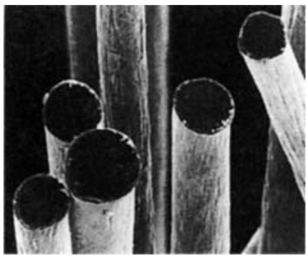
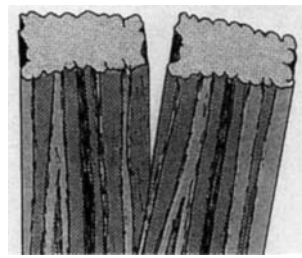
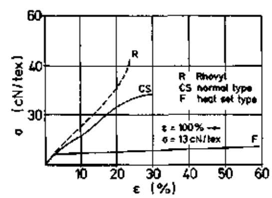
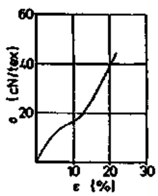
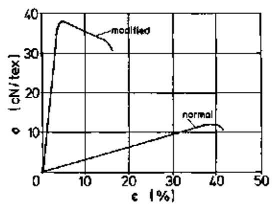
Fibers from polymerisates		
Polyvinylchloride (PVC)	Polyvinylalcohol (PVAL), Vinal A: water soluble, B: water insoluble (3)	Fluorofiber Polytetrafluoroethylene (PTFE)
	  both wet spun	 peeled (14)
		
Mostly solution spun; also melt spun		Suspension dry-spun/sintered
1.5...20; 30...60 artificial hair 38...200 Staple, filament yarn, tow C: 1.35...1.42; D: 1.65...1.75	1.5...10 38...200 Staple, filament yarn, tow 1.26...1.31	5...9 / 10...25 — — Staple, filament Staple, yarn, tow / Filament yarn 2.1 / 2.1
C / D 20...30 / 10...25 100 / 100 60...90 / 45...65 65 10...35 / 10...40, slowly spun 100...200	 20...65/25...80 65...85 35...80 45...75 10...30 120...140	8...14/ 16...28 not bleached / 5...12/ 10...26 60% bleached / drawn 4 times 100 / 100 60...90 / not known 75...90 18...75 not bleached / 25...50 undrawn 8 drawn 100 / 100

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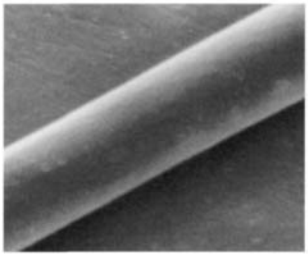
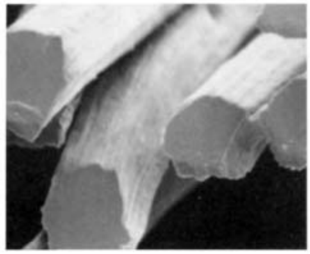
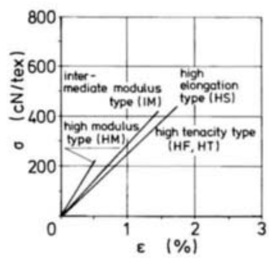
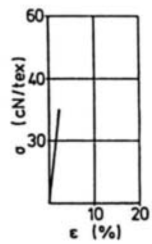
	Inorganic fibers from PAN	**Fibers from metal**
	Carbon fiber (CF)	X12CrNi 18. 8 (and higher) alloys
Microphotographs of cross-section and longitudinal view	 round	 mainly round; multi-stage drawn through dies
Force/elongation diagram		
Produced as	Carbonized or graphitized yarns	Monofilament
Fineness (titer) dtex	∅ 5...12 µm	∅ 4 µm and 8...12 µm
Length mm		variable
Sold as	Staple, filament yarn, short cut staple	Staple, filament yarn, non-wovens
Density g/cm^3	1.7...1.9	7.9
Force/elongation properties: Tenacity in standard atmosphere cN/tex (daN/mm^2)	110...280 (200...500)	22...29 (175...225)
Wet (as % of dry strength)	100	100
Loop strength %	0	65...75 (filament yarn)
Knot strength %	0	60...90
Elongation at max. force %	0.4...2	1...2
Wet (as % of dry elongation)	100	100 (filament yarn)
Elongation at break %		

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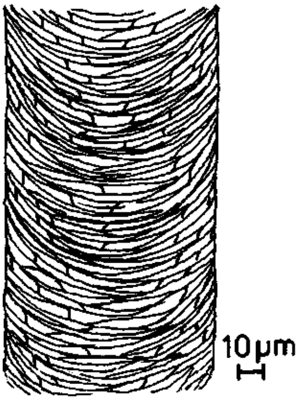
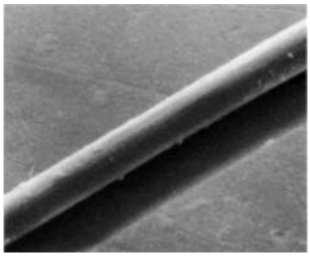
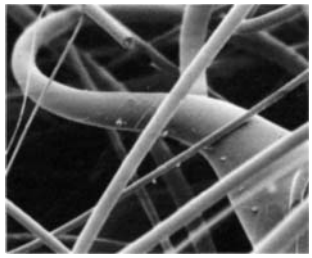
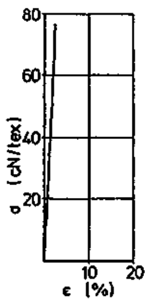
Fibers from non-metallic elements	**(special) Glass fibers**	**Ceramic fibers**
Boron		
 (14)		
		
Staple	Filament yarn, staple	Filament yarn, staple
∅ ca. 100 µm Staple 2.6	∅ 5…15 µm Continuous filament or 6…80 Filament yarn, staple 2.45…2.60	∅ 3…15 µm Continuous filament or 6…80 Filament yarn, staple Zircon oxide: 5.6…5.9 Aluminum oxide: 3.25
10…13 (280…350) 0.5…0.9	70…120 (175…300) 100% (90…80% when in daily use) 15…30 10…25 2…5 100	1.5…6 (40…150) 1…3

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		Natural fibers	
		Cotton (CO)	Flax/Linen (LI)
Force/elongation properties	Elastic modulus (5) cN/tex	300...600	800...1000 (tech. yarn)
	Tenacity at specified elongation		
	– at $\varepsilon=2\%$	6...8	6...8
	– at $\varepsilon=5\%$	15...20	15...20
	– at $\varepsilon=10\%$	—	—
	Torsional modulus cN/dtex (daN/mm^2)	16	8...10
	Transverse brittleness (angle °)	53...56	48...52
	Degree of elasticity at ε % (as % of total elongation)		
	– at $\varepsilon=2\%$	75	
	– at $\varepsilon=5\%$	45	not known
	– at $\varepsilon=10\%$	—	
Moisture effect	Moisture absorption		
	– at 21 °C/65% RH %	7...11	8...10
	– at 24 °C/95% RH %	14...18	up to 20
	Water retention %	45...50	50...55
	Electrostatic charge		
	– at 21 °C/65% RH	low	low
	– at 24 °C/25% RH	low	low
	Specific electrical resistance $\Omega \cdot cm$	$10^6 \ldots 10^8$	$10^8 \ldots 10^{11}$
Thermal properties	Temperature °C		
	– Glass transition	—	—
	– Heat setting/ironing	–/180..320	–/215...240
	– Dyeing/softening	120...150/–	260...320/–
	– Melting/decomposition	–/400	–/not known
	– Self-ignition	400	not known
	– Carbonization	430	320
	Shrinkage %		
	– in water, 95 °C	not known	not known
	– in hot air, 150 °C	not known	not known
	– in hot air, 190 °C	not known	not known
	Specific heat $kJ/kg \cdot K$	1.3	1.4
	Heat of fusion kJ/kg	—	—
	Thermal conductivity $J/m \cdot s \cdot K$	0.3...0.5	0.3
	Burning behavior of fiber		
	– before ignition	does not melt	does not melt
	– in the ignition flame	ignites	ignites
	– on removal of the flame	continues burning rapidly	continues burning rapidly
	– odor	burnt paper	burnt paper
	– residue	gray-white ash	yellow-gray ash
	LOI index (7)%	19	not known

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Natural fibers		Chemical fibers			
Wool (WO)	Silk (mulberry) (SE)	Viscose (VI)			
		N	H	P	T
150...300	700..1100	200...300	650...750		
4...7	11...14	5...10			
7...12	20...22	8...12	18...25		25...50
8...13	30	12...18	30...35		40...70
8...10	15...23				
48...52	51				
95...99	95	70...95			
60...70	70	40...60			
45...50	—	not known			
15...17	9...11	11...14			
25...30	20...40 (boiled off)	26...28			
40...45	40...45 (boiled off)	N: 85...120; H/P/T: 65...75			
low	low	low			
average	average	low			
$10^{8}...10^{11}$	$10^{8}...10^{10}$	$10^{6}...10^{9}$			
—	—	—			
–/160...170	–/140...165	–/150...180			
120...140/–	120/–	120...140/–			
–/not known	–/170...180	–/175...205			
590...600	not known	420			
not known	not known	—			
not known	not known	0.5...10			
not known	not known	not known			
not known	not known	not known			
1.3...1.6	1.4...1.5	1.3...1.5			
–	–	–			
0.2	0.2...0.4	0.3...0.6			
	as for wool				
does not melt		does not melt			
ignites		ignites			
continues burning slowly		continues burning quickly			
burnt horn		burnt paper			
carbon residue		gray-white ash			
25		20			

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		Chemical fibers	Fibers from polycondensation polymers	
		Acetate (2½) (CA)/ triacetate (CT)	Polyamide 6 (e.g. Perlon ®) (PA6) Polyamide 66 (Nylon) (PA66) (if different from PA6)	
Force/elongation properties			N	T
	Elastic modulus cN/tex	200...350	50...300	600...900
	Tenacity at specified elongation			
	– at $\varepsilon=2\%$	5	1...4	4...5
	– at $\varepsilon=5\%$	8	3...8	10...20
	– at $\varepsilon=10\%$	9	5...20	25...75
	Torsional modulus cN/dtex (daN/mm^2)	6...8	3	7 (12)
	Transverse brittleness (angle °)	44...50	27...41	
	Degree of elasticity at ε % (as % of total elongation)			
	– at $\varepsilon=2\%$	90...95	95...100	
	– at $\varepsilon=5\%$	CA: 40...60/CT: 55...70	95...100	90...95
	– at $\varepsilon=10\%$	not known	90...95	83...90
Moisture effect	Moisture absorption			
	– at 21 °C/65% RH %	CA: 6...7/CT: 2...5	3.5...4.5	
	– at 24 °C/95% RH %	CA: 13...15/CT: 8...10	6...9	
	Water retention %	CA: 20...28/CT: 10...17	10...15	
	Electrostatic charge			
	– at 21 °C/65% RH	low	average } much lower in antistatic types	
	– at 24 °C/25% RH	average	high } much lower in antistatic types	
	Specific electrical resistance Ω·cm	CA: $10^9...10^{12}$/CT: 10^{14}	$10^9...10^{11}$ ($10^9...10^{12}$)	
Thermal properties	Temperature °C	CA CT		
	– Glass transition	not known 170...180	40...42	
	– Heat setting/ironing	180...220/180 180...220/220...250	185...190/150 (220...225/180...200)	
	– Dyeing/softening	120/190 130/190...250	120...160/185...190 (120/200...225)	
	– Melting/decomposition	250/280 300/300	215...220/–(255...260/–)	
	– Self-ignition	475 480	510...530 (530)	
	– Carbonization	— —	— (–)	
	Shrinkage %			
	– in water, 95 °C	not known 5...20	1...15	
	– in hot air, 150 °C	not known not known	1...15	
	– in hot air, 190 °C	4...5 0.5...2	2...18	
	Specific heat kJ/kg·K	1.3...1.5 1.5	1.5...2.0	
	Heat of fusion kJ/kg	—		
	Thermal conductivity J/m·s·K	0.3 0.3	0.2...0.3	
	Burning behavior of fiber			
	– before ignition	melts	melts, drips, shrinks	
	– in the ignition flame	ignites	ignites	
	– on removal of the flame	burns further	burns on hesitantly	
	– odor	pungent, acidic	aromatic, amine odor	
	– residue	dark lumps	dark ball	
	LOI index %	18...19	20	

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Fibers from polycondensation polymers		
Polyamide 11 (PA 11) (Rilsan)	Polyester (PES) Polyethylene terephthalate (PET)	Polyester (PES) Polybutylene terephthalate (PBT)
	N T	
45...50/450	250...400 700...1200	
	4...12 10...18	
	9...16 35...45	
	10...23 50...65	
	6.5 11 (12)	
36...44	30...49 47...48	
100	90...98	
100	70...90	
not known	50...80	
0.9...1.3	0.2...0.5	0.2...0.5
	0.8...1.0	
3	3...5	
	average	average
	high	
	$10^{11}\ldots10^{14}$	
40...50	72...75	
	180...230/150...200	
120/120	120...180/230...240	
ca. 190	254...260/–	224/not known
	510	
	—	
	0.5...8	N: 3...4; BCF 1
	2...15	
	3...20	
	1.1...1.4	
	0.2...0.3	
Similar to PA 6	melts, drips, shrinks	
	ignites	
	burns on hesitantly	
	aromatic	
	dark ball	
	21...22	

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		Fibers from polycondensation polymers	
		meta-Aramids (m-AR) (aromatic PA)	para-Aramids (p-AR)
Force/elongation properties	Elastic modulus cN/tex	750...1450	8000...10000
	Tenacity at specified elongation – at $\varepsilon=2\%$ – at $\varepsilon=5\%$ – at $\varepsilon=10\%$		
	Torsional modulus cN/dtex (daN/mm²)		
	Transverse brittleness (angle °)		
	Degree of elasticity at ε % (as % of total elongation) – at $\varepsilon=2\%$ – at $\varepsilon=5\%$ – at $\varepsilon=10\%$	not known	not known
Moisture effect	Moisture absorption – at 21 °C/65% RH % – at 24 °C/95% RH %	 4.5...5 6.5...7	 3...4 4...7
	Water retention %	12...17	7
	Electrostatic charge – at 21 °C/65% RH – at 24 °C/25% RH	not known	not known
	Specific electrical resistance **Ω · cm**	not known	not known
Thermal properties	Temperature °C – Glass transition – Heat setting/ironing – Dyeing/softening – Melting/decomposition – Self-ignition – Carbonization	 280...290 — –/– –/ > 370 675 350	 300 –/– –/550 — —
	Shrinkage % – in water, 95 °C – in hot air, 150 °C – in hot air, 190 °C	 1.5 0.1 0.5	 0.1 0.1 0.1
	Specific heat kJ/kg · K Heat of fusion kJ/kg Thermal conductivity J/m · s · K	1.2 — 0.13	1.4 — not known
	Burning behavior of fiber – before ignition – in the ignition flame – on removal of the flame – odor – residue	 does not melt ignites and carbonizes self-extinguishing not known carbonized fiber; dripping is reduced in mixtures	 does not melt ignites extinguishes after 10..15 s undefinable dark residue
	LOI index %	28	29

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Fibers from polycondensation polymers	Fibers from polymerisates	
Elastane (EL) (Spandex) also polyurethane (PUR)	Polyacrylonitrile (PAN)	Modacrylic (MAC)
0.3…0.7 (…1.2) 0.04 at 300%: 93…98	300…500 5…12 10…20 10…30 10 45…60 90…95 50…90 55…80	100…450 4…10 8…20 10…25 95…99 85…98 55…95
 0.15…1.5 0.5…1.5 7…11 not known 	 1.0…2.0 2…5 5…12 $10^{8}…10^{14}$	 0.5…4 1…6 10…20 $10^{12}…10^{13}$
–60…–20 (soft segments) 180…200/150…180 190/160 –/230 not known —	30…75 in water, 50…100 dry –/150…180 140/200 –/250 510…560 —	85…95 10…110/not known 120/130…200 130…170/170 650…700 250…350
up to 15 5…10 not known	N: 0.5…5 high shrinkage type: 20…40 — —	0.2…5 130 °C: 5…30 —
not known — 0.15	1.2…1.5 — 0.2	not known not known
 shrinks and melts ignites continues burning undefinable dark residue not known	 shrinks strongly on contact with flame ignites continues burning aromatic, pungent hard, dark residue 18	 not uniform self-extinguishing 27

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		Fibers from addition polymers			
		Polypropylene (PP)		Polyethylene (PE)	
Force/elongation properties		Filament yarn	Staple	N	H
	Elastic modulus cN/tex	300…500	50…250	N	H
	Tenacity at specified elongation			150…500	20…200
	– at $\varepsilon=2\%$	7…9	4…6	7…15	1…5
	– at $\varepsilon=5\%$	13…15	8…12	15…30	2…8
	– at $\varepsilon=10\%$	20…30	12…18	25…30	3…15
	Torsional modulus cN/dtex (daN/mm^2)			0.5	
	Transverse brittleness (angle °)				
	Degree of elasticity at ε % (as % of total elongation)				
	– at $\varepsilon=2\%$	90…95	95…100	95…100	
	– at $\varepsilon=5\%$	85…90	90…95	90…95	
	– at $\varepsilon=10\%$	80…85	85…90	80…90	
Moisture effect	Moisture absorption				
	– at 21 °C/65% RH %	0		0	
	– at 24 °C/95% RH %	0		0	
	Water retention %	not known		not known	
	Electrostatic charge				
	– at 21 °C/65% RH	average		high	
	– at 24 °C/25% RH	average		high	
	Specific electrical resistance $\Omega \cdot cm$	$> 10^{13}$		$10^{13} \ldots 10^{17}$	
Thermal properties	Temperature °C				
	– Glass transition	–5…–10		N: –35; H –80	
	– Heat setting/ironing	not known/130		not known	
	– Dyeing/softening	120/150…160		N: 105…120; H: 70…90	
	– Melting/decomposition	160…175/–		N: 125…135/–; H: 105…120/–	
	– Self-ignition	430…450		not known	
	– Carbonization	—			
	Shrinkage %				
	– in water, 95 °C	0…5		N: 5…10; H: 40…60	
	– in hot air, 150 °C	30…50		—	
	– in hot air, 190 °C	—		—	
	Specific heat $kJ/kg \cdot K$	1.6…2.0		1.4…2.0	
	Heat of fusion kJ/kg				
	Thermal conductivity $J/m \cdot s \cdot K$	0.1…0.3		0.2…0.4	
	Burning behavior of fiber				
	– before ignition	as for PE		shrinks and melts	
	– in the ignition flame			ignites	
	– on removal of the flame			burns slowly	
	– odor			undefinable	
	– residue			dark ball	
	LOI index %	19		not known	

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Fibers from addition polymers		
Polyvinylchloride (PVC)	Polyvinylalcohol (PVAL), Vinal A: water soluble, B: water insoluble	Fluorofibers Polytetrafluoroethylene (PTFE)
C D		
200…400	300…600	35…200 not bleached 50…460
4…8	4…6	bleached, reduced drawn
5…9	8…12	1..3 1
8…12	12…18	2…7 2
6…7	9…15	4…13 4
27…55		2…3 < 12
70…90 not known	60…80	not known not known
60…65	40…60	
not known	30…50	
0…0.2	3.5…5	0 0
0…1	not known	0 not known
25…35	4…6	not known not known
average	low	not known not known
high	average	
$10^{12}…10^{14}$		10^{18}
C: 70; CS: 100; D: not known	75…130	30 not known
	90…98/not known	not known/not known
not known/65…70;		
not known/125…130	110/210 dry	180/327 not known/327
D: not known/90…150	60…120 wet	
C, CS: –/160…200; D: 180	–/240…260	327/– 327/–
not known	not known	not known not known
not known	–	not known not known
		zero-strength: 310
Starts to shrink (C, D): 60…80	B: 2…3; A: forms gels	2 not known
30%: C: 85…95; CS 180	not known	not known not known
	not known	177 °C: 3
		177 °C: 100 h 11
		288 °C: 100 h 24
0.8…1.3	not known	1.0 1.1
0.2	not known	0.23 0.23
		Does not melt;
		poisonous fumes
shrinks rapidly, with partial melting	shrinks	evolve not known
does not ignite	ignites	as per 2.
C: CS: does not burn	continues burning	
pungent	undefinable	
Dark lumps	carbon residue	
37; 45	20	not known 95

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		Inorganic fibers from PAN	Fibers from metal
		Carbon fiber (CF)	X12CrNi 18.8 (and higher) alloys
Force/elongation properties	Elastic modulus cN/tex Tenacity at specified elongation – at ε=2% – at ε=5% – at ε=10% Torsional modulus cN/dtex (daN/mm²) Transverse brittleness (angle °) Degree of elasticity at ε % (as % of total elongation) – at ε=2% – at ε=5% – at ε=10%	200…500 kN/mm² — —	1500…2600 75…95 100
Moisture effect	Moisture absorption – at 21 °C/65% RH % – at 24 °C/95% RH % Water retention % Electrostatic charge – at 21 °C/65% RH – at 24 °C/25% RH Specific electrical resistance Ω·cm	 1 1 not known — 10^{-3}	 0 0 not known – 0.7×10^{-4}
Thermal properties	Temperature °C – Glass transition – Heat setting/ironing – Dyeing/softening – Melting/decomposition – Self-ignition – Carbonization	 Resistant to > 2000 °C in inert gas: Oxidation begins in air at ca. 400 °C	 Glows at: 980–1010 Sinters at: 1050 ca. 600/– 1400…1450/– —
	Shrinkage % – in water, 95 °C – in hot air, 150 °C – in hot air, 190 °C	 —	 — — —
	Specific heat kJ/kg·K Heat of fusion kJ/kg Thermal conductivity J/m·s·K	0.7 — 15…120	0.46 15.0
	Burning behavior of fiber – before ignition – in the ignition flame – on removal of the flame – odor – residue LOI index %	not known > 60	Does not burn glows —

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Fibers from non-metallic elements	(Special) glass fibers	Ceramic fibers
Boron		
1500/38 000…40 000 700/1900	2800…3400 Tenacity/elongation curve without flow zone 160 (4000) 85…88 100	260/7000 87…89
0 0 not known $10^{5} \ldots 10^{6}$	0 0.3 not known average high $10^{12} \ldots 10^{15}$	~0
ca. 2300/–	Softens at: 805…960 Glows at: 650…810 Melts above softening point	900
— — —	— — —	
	0.7…0.8 0.8…1.0	
Ignites in air at ca. 700 °C Burns to boron trioxide	Does not burn —	Does not burn —

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		Natural fibers	
		Cotton (CO)	Flax/linen (LI)
Properties in use	Creasing – dry – on boiling Fibrillation Pilling	 high high low low	 high high high low
Resistance to	Acids (1000 h at 20 °C/ 10 h at 100 °C) – phosphoric acid (10%) – nitric acid (1%) – hydrochloric acid (1%) – sulfuric acid (1%)	 60...80/0...20 60...80/0...20 60...80/0...20 60...80/0...20 average resistance	 More resistant than cotton
	Alkali (1000 h at 20 °C/ 10 h at 100 °C) – ammonia (1%) – sodium hydroxide (1%) – soda solution (1%)	 90...100/90...100 80...90/80...90 90...100/90...100 good resistance, but is attacked by 10% sodium hydroxide	
	Light (in %) – behind glass – direct weathering Thermal treatment (Temp. in °C/duration in h) Tenacity at break (%) – hot air – steam	 20...30 0...20 120/100/40...60 120/1/80...100	 not known
	Bacteria and fungus (biological resistance)	unbleached: low	unbleached: low bleached: good
Dyeing and bleaching	Solubility (11) (k = cold, h = boiling, hot)	Sulfuric acid: k/h ammoniacal copper oxide	Sulfuric acid: k/h
	Dyestuffs	Mordant (also diazotization and coupling), developing, vat, sulfur, reactive, oxidation, pigment, basic	as for cotton, but vat dyestuffs should only be used under special conditions
	Bleaching agents	Sodium chlorite Sodium hypochlorite Peroxide	Sodium chlorite (peroxide may result in damage)

Natural fibers		Chemical fibers
Wool (WO)	Silk (mulberry) (SE)	Viscose (VI)
low	very high	N: very high; P: high
—	—	N: very high; P: high
low	low	N: low; P: high
low	—	low
	somewhat lower resistance than wool	
90...100/20...60 90...100/0...20 90...100/90...100 90...100/20...60 average to satisfactory resistance; attacked by concentrated acids		similar to cotton: average resistance
90...100/90...100 0...20/0...20 80...90/0...20 average resistance, but destroyed by alkalis		similar to cotton: good resistance; dissolved by 10% sodium hydroxide P: resistant to mercerizing H: resistant to mercerizing when mixed with 50% cotton if certain precautions are taken
0...20	0...20	0...30
0...20	0...20	0
120/100/60...80	120/100/60...80	120/100/20...40 resp. 65/8/70–85
120/1/50...80	120/1/70...90	120/1/80–95
not moth-proof; good resistance to rotting	when not bleached: low	low
Sulfuric, nitric, phosphoric and hydrochloric acid: h	Sulfuric, phosphoric and hydrochloric: k/h	Sulfuric: k/h; nitric, phosphoric and hydrochloric: h
potash lye	potash lye, formic acid	
Acid, mordant, basic, vat, reactive dyes	Acid (also chrome- and chrome complex), mordant, basic, vat, reactive dyes developing	Mordant, cationic, sulfur, vat, developing, reactive dyes
Peroxide, sulfur dioxide	Peroxide, sulfur dioxide	Chlorite, hypochlorite

		Chemical fibers	Fibers from polycondensation polymers
		Acetate ($2\frac{1}{2}$) (CA)/ Triyacetate (CT)	Polyamide 6 (e.g. Perlon ®) (PA6) Polyamide 66 (Nylon) (PA66) (if different from PA6)
Properties in use	Creasing – dry – on boiling Fibrillation Pilling	CA / CT low / average average / average low / low low / low	 low (better than PA6) high low low
Resistance to	Acids (1000 h at 20 °C/ 10 h at 100 °C) in %) – phosphoric acid (10%) – nitric acid (1%) – hydrochloric acid (1%) – sulfuric acid (1%)	 90...100/90...100 80...90/0...20 60...80/90...100 80...90/80...90 average resistance (CA and CT)	 90...100/90...100 90...100/90...100 90...100/90...100 90...100/90...100 Good resistance, but attacked by conc. acids
	Alkali (1000 h at 20 °C/ 10 h at 100 °C) – ammonia (1%) – sodium hydroxide (1%) – soda solution (1%)	 60...80/70...90 0...20/40...60 60...80/60...80	 90...100/90...100 90...100/90...100 90...100/90...100 Good resistance, but attacked by 10% sodium hydroxide
	Light (in %) – behind glass – direct weathering	 20...45 (CA and CT) 0...25	 20...30 Delustered types are very susceptible; 5...15 improved by light stabilization
	Thermal treatment (Temp. in °C/duration in h) Tenacity at break (%) – hot air	 CA: 120/100/55...70 CT: 130/250/70...80	 120/100/60...80. Improved by light stabilization T: 80/1000/90...100
	– steam	CA: 120/1/40...60: CT not known	120/100/70...90
	Bacteria and fungus (biological resistance)	Good	Good to very good; contradictory reports concerning termite resistance
Dyeing and bleaching	Solubility (k = cold, h = boiling, hot)	CA, CT: sulfuric, nitric, phosphoric and hydrochloric: k/h; tetrachloroethane: h; acetone, o-chlorophenol, m-cresol, phenol, cyclohexanone, dioxan, DMF: k/h	Sulfuric, nitric, phosphoric, hydrochloric and formic acids: h; o-chlorophenol, m-cresol, phenol k/h; DMF: h PA66 is insoluble in DMF h
	Dyestuffs	CA: nitromethane: k; butyronitrile: h CT: methylene chloride: k/h	Acid (also metal complex and chrome), mordant, basic, vat, dispersion, reactive (the last restricted to differential dyeing types)
	Dyestuffs	CA: dispersion (results in brilliant color) CT: dispersion, acid (more difficult to dye than CA)	
	Bleaching agents	Peracetic acid, chlorite, hypochlorite	Sodium chlorite, sodium hypochlorite

Fibers from polycondensation polymers		
Polyamide 11 (PA11) (Rilsan)	Polyester (PES) Polyethylene terephthalate (PET)	Polyester (PES) Polybutylene terephthalate (PBT)
average strong — not known	low high–low with correct heat setting none; low with modified PET strong: low or none with modified PET	
Similar to PA6 good	90...100/90...100 90...100/90...100 90...100/90...100 90...100/90...100 good resistance; attacked by conc. acids; copolyester is less resistant	Similar to PET
Similar to PA6 good	90...100/90...100 90...100/90...100 90...100/90...100 good resistance, degraded by conc. alkalis; copolyester is less resistant	Similar to PET
Similar to PA6	60...80 (improved by stabilizers) 5...15	Similar to PET
	120/1000/90...100 resp. 180/100/60...70 120/100/70...90	
good	very good	Similar to PET
as for PA6	Sulfuric acid: k/h Potassium alkalis, tetrachloroethane, o-chlorophenol, m-cresol, phenol, o-dichloro benzene, DMF, TEG: h	Similar to PET
as for PA6	Dispersion, basic (for modified PET), also developing, oxidation, vat. With special equipment: (HT = high temperature, carrier, Thermosol). Dyeability increased or made easier by polymer modification.	can be dyed carrier-free at 100 °C. Dyestuffs as for PET
as for PA6	All typical bleaching agents	as for PET

		Fibers from polycondensation polymers	
		meta-Aramids (m-AR) (aromatic PA)	para-Aramids (p-AR)
Properties in use	Creasing – dry – on boiling Fibrillation Pilling	 — — — —	 — — — —
Resistance to	Acids (1000 h at 20 °C/ 10 h at 100 °C) – phosphoric acid (10%) – nitric acid (1%) – hydrochloric acid (1%) – sulfuric acid (1%)	 90...100/90...100 90...100/80...90 80...90/90...100 90...100/80...90 good to satisfactory: attacked by conc. acids	 good
	Alkali (1000 h at 20 °C/ 10 h at 100 °C) – ammonia (1%) – sodium hydroxide (1%) – soda solution (1%)	 90...100/90...100 not known/90...100 90...100/90...100 good to satisfactory resistance; attacked by hot, conc. alkalis.	 good
	Light (in %) – behind glass – direct weathering	Similar to PA66; 40 h in Fade-O-meter: 50% 50	 65...80 after 16 weeks not known
	Thermal treatment (Temp. in °C/duration in h) Tenacity at break (%) – hot air – steam	 180/1000/90...100 260/1000/60...70 150/1000/20...40	 good Loss of tenacity starts at 200...300 °C
	Bacteria and fungus (biological resistance)	very good	very good
Dyeing and bleaching	Solubility (k = cold, h = boiling, hot)	Sulfuric acid: k/h; Phosphoric acid, Potassium hydroxide: h; organic polar solvents + solubility agent (e.g., LiCl)	Sulfuric acid: h n-methyl pyrrolidone + 5% LiCl
	Dyestuffs	Spun dyed Own color: raw white	Own color: yellow
	Bleaching agents	Chlorite, hypochlorite: can only be bleached at room temperature	—

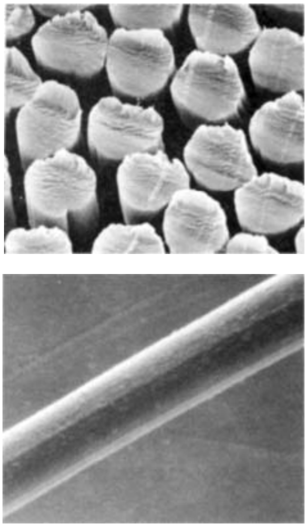
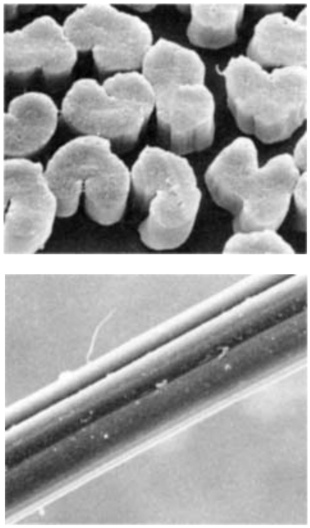
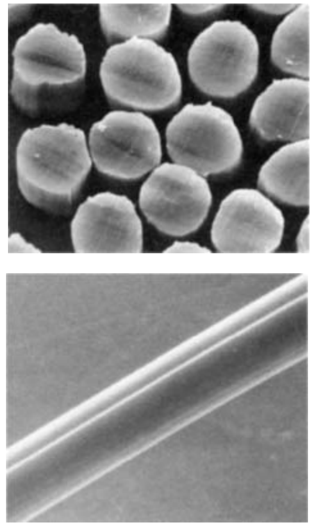
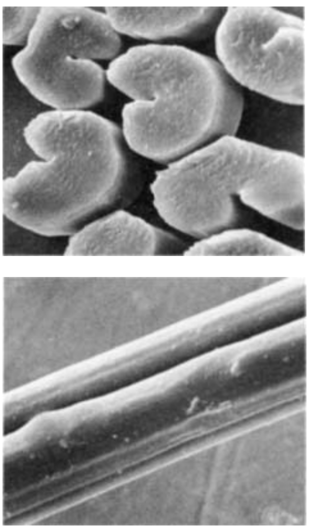
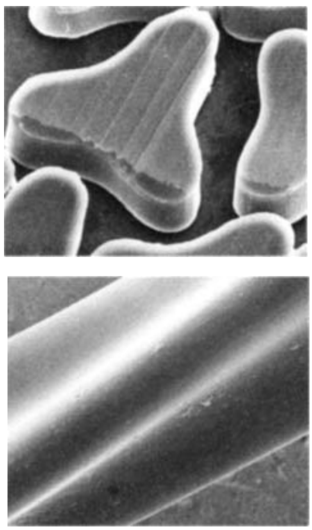
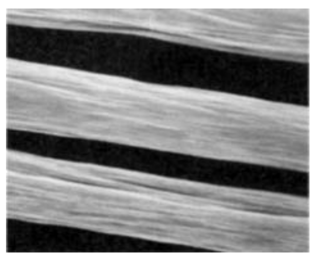
Fibers from polycondensation polymers	Fibers from addition polymers	
Elastane (EL) (Spandex) also polyurethane (PUR)	Polyacrylonitrile (PAN)	Modacrylic (MAC)
— — — —	average — not known average/strong	average — average/strong
90...100/not known 90...100/0...20 90...100/90...100 90...100/90...100 Polyetherdiol: satisfactory Polyesterdiol: less resistant	90...100/80...90 90...100/80...90 90...100/90...100 90...100/80...90 Good resistance. Soluble in conc. acids (except hydrochloric acid)	Good resistance. Attacked by conc. acids to various degrees, depending on type.
Polyetherdiol: at the upper limit Polyesterdiol: at the lower limit Resistant enough for typical cotton dyeing	90...100/90...100 90...100/60...80 90...100/90...100 Good resistance. Attacked by conc. alkalis, esp. by hot, 10% sodium hydroxide	Very good resistance
Sufficiently resistant for normal application	Very good resistance 60...80 50...60	Depending on type, can be very resistant
Has good resistance during thermal processing; can be heat set	120/1000/70...100 Fiber yellows T: 120/100/70...90	Depends on type, otherwise similar to PAN
Generally good. Polyesterdiol is somewhat poorer	Very good	Good to very good
Sulfuric acid: k/h; phosphoric, formic, sodium hydroxide, tetrachloroethane, chlorophenol, m-cresol, phenol, cyclohexanone, DMF, DMAC: h	Sulfuric, nitric acid: k/h; phosphoric acid, DMF, DMAC: h	Sulfuric acid, acetone, phenol, cyclohexanone, pyridine: h. DMF, DMAC: k/h
Acid, metal complex, chrome, dispersion; partly also: reactive, direct, vat, sulfur, napthalene	Basic, acid, dispersion, vat. T-PAN is difficult to dye, but can be improved by comonomers	Similar to PAN. Some types can also be dyed with mordant and development dyes
Dithionite, formaldehyde, sulfoxilate (reduction bleach), perborate, hydrogen peroxide or sodium hypochlorite (cold) when bleaching with cotton	Chlorite	Chlorite

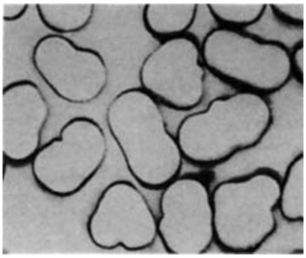
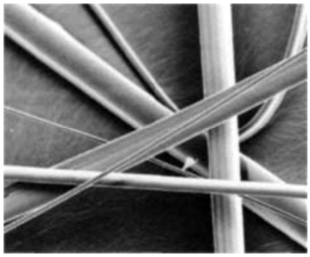
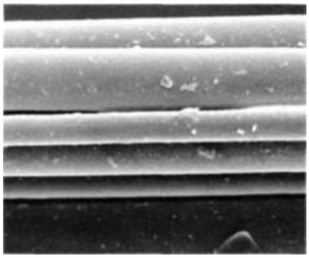
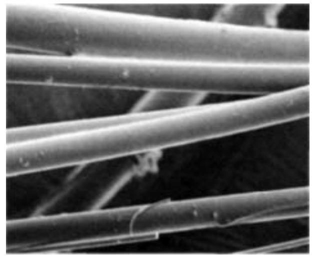
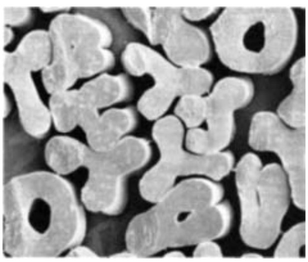
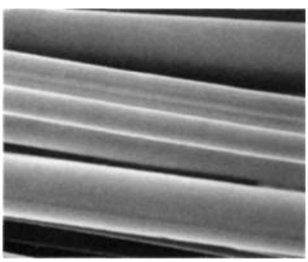
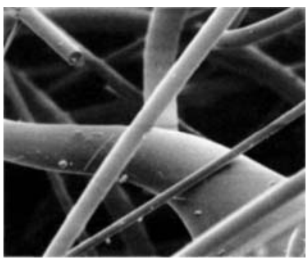
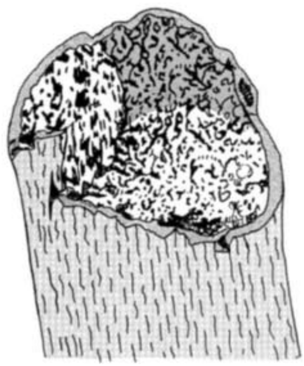
		Fibers from addition polymers	
		Polypropylene (PP)	Polyethylene (PE)
Properties in use	Creasing – dry – on boiling	 average high	 high —
	Fibrillation	strong	average
	Pilling	—	—
Resistance to	Acids (1000 h at 20 °C/ 10 h at 100 °C) – phosphoric acid (10%) – nitric acid (1%) – hydrochloric acid (1%) – sulfuric acid (1%)	Very good resistance. Attacked by conc. nitric acid	Very good resistance. Attacked by conc. nitric and conc. sulfuric acid
	Alkali (1000 h at 20 °C/ 10 h at 100 °C) – ammonia (1%) – sodium hydroxide (1%) – soda solution (1%)	Very good resistance. Attacked by hot, conc. alkalis.	Very good resistance. Attacked by hot, conc. alkalis.
	Light (in %) – behind glass – direct weathering	 0; 3 months: 0…20 0; 3 months: 0…10 Improved by stabilizers	 Very good resistance, provided it is not modified.
	Thermal treatment (Temp. in °C/duration in h) Tenacity at break (%) – hot air – steam	Large tenacity loss when subjected to $>120\,^\circ$C for a long time	Acceptable resistance for $>70\ldots90\,^\circ$C
	Bacteria and fungus (biological resistance)	Very good	Very good
Dyeing and bleaching	Solubility (k = cold, h = boiling, hot)	Sulfuric acid, trichloroethylene, toluene, xylene: h	Sulfuric acid, tetrachloroethylene, toluene: h; only H: tetrachloromethane, benzene, chloroform, trichloroethylene: h. H has much greater solubility than N.
	Dyestuffs	Weakly dyed by acid, metal complex, chrome, direct, soluble polymer dyes. Pigments are used for unmodified PP.	As for PP when modified. Otherwise can only be spun-dyed.
	Bleaching agents	Chlorite	Chlorite

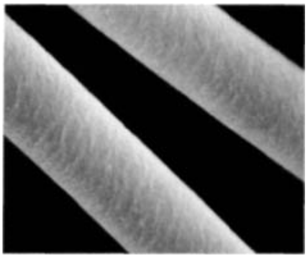
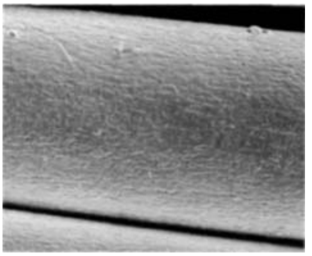
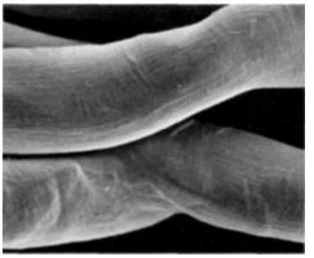
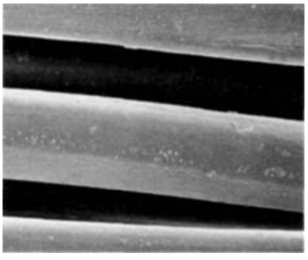
Fibers from addition polymers			
Polyvinylchloride (PVC)	Polyvinylalcohol (PVAL), Vinal A: water soluble, B: water insoluble	Flurofibers Polytetrafluoroethylene (PTFE)	
C, CS: low; D: unknown	high	not known	not known
—	very high		
—	not known	not known	not known
average	strong		
C, CS: very good resistance. Only attacked by hot, conc. nitric acid D: good resistance	Good resistance. Attacked by conc. acids	Very good resistance. Bleached by boiling, conc. mineral acids	not known
C; CS: Good resistance D: Attacked by conc. ammonia solution	Good resistance	Very good resistance	Very good resistance
C, CS: 0...90; D: 10...20	not known	100	very good
not known		100	
Low resistance because of	Average to acceptable	177/1000/90...100	temp up to 300 °C
low softening point	resistance. Shrinks strongly above 110 °C	288/1000/65...75	unknown
		Can be held for a short time up to 316 °C	not known
Very good	Very good	not known	
Sulfuric acid, ethylene chloride, tetrachloroethane, cyclohexanone, dioxan: h; DMF, o-chlorophenol: k/h; C is often soluble in chem. dry cleaning solvents; CS can be dry cleaned.	Sulfuric, nitric, phosphoric acids: k/h; potassium alkalis, m-cresol, phenol, DMF: h	Only solvent is perfluorated solution at 300 °C. No disintegration, swelling or lump formation in typical solvents	as left
Dispersion (esp. with carrier)	Dispersion, mordant, vat, development	No dyeing possible	No dyeing possible
		own color:	own color:
Basic, development for C/CS	Dark shades are difficult to dye.	dark brown (without bleach)	white
—	Chlorite	With 98% nitric acid at 316 °C for 1 h. Stepwise hot air treatment at 232 and 304 °C for ca. 2 days	

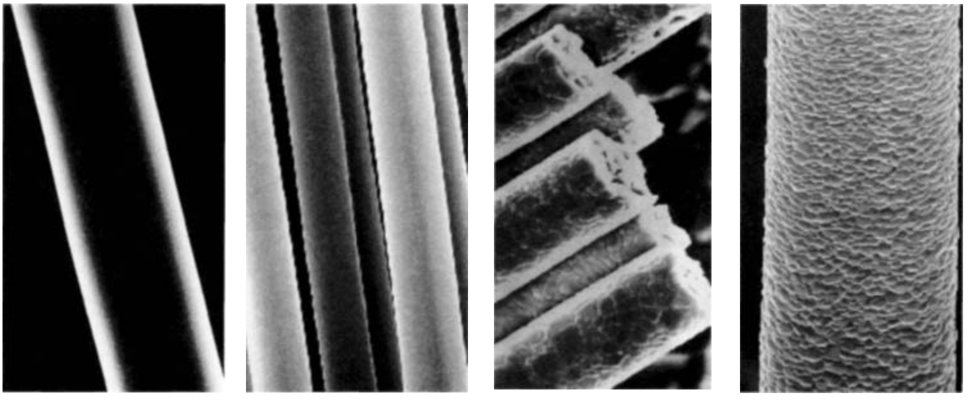
		Inorganic fibers from PAN	Fibers from metal
		Carbon fiber (CF)	X12CrNi18.8 (or higher) alloys
Properties in use	Creasing – dry – on boiling Fibrillation Pilling	 — — — —	 — — — —
Resistance to	Acids (1000 h at 20 °C/ 10 h at 100 °C) – phosphoric acid (10%) – nitric acid (1%) – hydrochloric acid (1%) – sulfuric acid (1%)	Very good resistance	Good resistance Good resistance Attacked by hydrochloric and sulfuric acid
	Alkali (1000 h at 20 °C/ 10 h at 100 °C) – ammonia (1%) – sodium hydroxide (1%) – soda solution (1%)		Good resistance
	Light (in %) – behind glass – direct weathering		Very good
	Thermal treatment (Temp. in °C/duration in h) Tenacity at break (%) – hot air – steam	Oxidation with tenacity loss above 400 °C	
	Bacteria and fungus (biological resistance)	Very good	
Dyeing and bleaching	Solubility (k = cold, h = boiling, hot)	Insoluble	Insoluble in normal solvents, but attacked by halogenated solvents
	Dyestuffs	—	Forms "shadows" with metal complex dyes.
	Bleaching agents	—	Oxide, peroxide. Damaged by chlorite

Fibers from non-metallic elements	(Special) glass fibers	Ceramic fibers
Boron		
—	—	—
—	—	—
—	—	—
—	—	—
Attacked by HNO_3, aqua regia	Attacked by inorganic acids, particularly hydrofluoric acid	Very good, except for fluorine-hydrogen compounds
Good resistance		Very good
—		Very good
		Very good, but varies acc. to type
	Very good	Very good
Conc. HNO_3, aqua regia	Hydroflouric acid	Hydroflouric acid
—	—	—
—	—	—

Additional SEM photographs of various man-made fibers		
		
Viscose (techn) (see p. 833)	Viscose (modal) (see p. 833)	Cupro
		
Triacetate (see p. 834)	PA6 trilobal (see p. 834)	PAN (wet spun) (Faserwerke Lingen) (see p. 837)

Additional SEM photographs of various man-made fibers		
	 	
PVA fiber (dry spun) (see p. 839)	Basalt, melt-spun at ca. 1320 °C. above: centrifugally-spun below: spun and wound at 3300 m/min	Glass: melt-blown (see p. 841)
 		
Polyimide P 84 (Lenzing AG)	Ceramic filaments Melt-blown (see p. 841)	PAN: porous fiber "Dunova" (Bayer AG) (14) (see p. 837)

Additional SEM photographs of various man-made fibers		
		
PE non-woven (Reifenhäuser) (see p. 838)	PE fiber (Hüls AG) (see p. 838)	PE from compact spinning plant (Rieter-Automatik) (see p. 838)
		
LLDPE from compact spinning plant (Barmag AG) (see p. 838)		



A B C D

A) SiO_2 filament spun by sol-gel process. Used for strengthening polymer matrices.
B) α-Al_2O_3 filament spun by sol-gel process and treated for 1 h at 1000 °C in air. Reinforcement fiber for ceramic and metallic composites.
C) Piezoelectric lead zircona titanate-PZT fibers spun by sol-gel process and sintered at 950 °C. Used for developing active or passive functional fibers for sensors, etc.
D) α-$AL_2O_3/Y_3Al_5O_{12}$ fiber (eutectic mixture) spun by sol-gel process and treated in air for 1 h at 1750 °C. Used for developing high-temperature stable reinforcement fibers.

The scanning electron microscope (SEM) photographs of inorganic fibers A to D were provided by the Fraunhofer Institute for Silicate Research in Würzburg, Germany.