4) PROPIEDADES DE POLÍMEROS SINTÉTICOS

Valores de Tg y Tm para Homopolímeros de Alta Masa Molar

Todos los polímeros sintéticos exhiben una Tg, pero sólo algunos polímeros exhiben también una Tm.

Reference: Polymer Properties

Thermal Transitions of Homopolymers: Glass Transition & Melting Point

Literature values for the glass transition temperature, (T_g), and melting temperature, (T_m), are given in Table I for the more common homopolymers. Polymers are listed by the repeating unit in the polymer chain. These polymers and corresponding monomers are available from Aldrich. Literature values for a given material can vary widely. The values reported in Table I have been taken from various sources and represent the most commonly reported numbers.[1] Several factors can influence the reported values, including molecular weight, molecular weight distribution, tacticity, thermal history, purity, and method of measurement.

Table I: Thermal Transitions of Homopolymers: Glass Transition (T_g) & Melting Point (T_m) Temperatures

Repeating Unit	T_g (°C)	T_m (°C)
Acenaphthylene	214	
Acetaldehyde	-32	165
4-Acetoxystyrene	116	
Acrylamide	165	
Acrylic acid	105	
Acrylonitrile, syndiotactic	125	319
Allyl glycidyl ether	-78	
Benzyl acrylate	6	
Benzyl methacrylate	54	
Bisphenol A-*alt*-epichlorohydrin	100	
Bisphenol A terephthalate	205	
Bisphenol carbonate	174	
Bisphenol F carbonate	147	
Bisphenol Z carbonate	175	
4-Bromostyrene	118	
cis-Butadiene	102	1
trans-Butadiene	-58	148
1-Butene	-24	171
N-tert-Butylacrylamide	128	
Butyl acrylate	-54	
sec-Butyl acrylate	-26	
tert-Butyl acrylate	43-107	193
2-*tert*-Butylaminoethyl methacrylate	33	
Butyl glydicyl ether	-79	
Butyl methacrylate	20	
tert-Butyl methacrylate	118	
4-*tert*-Butylstyrene	127	
tert-Butyl vinyl ether	88	250
Butyl vinyl ether	-55	64
ε-Caprolactone	-60	
Cellulose nitrate	53	
Cellulose tripropionate		
cis-Chlorobutadiene	-20	80
trans-Chlorobutadiene	-40	101
2-Chlorostyrene	119	
3-Chlorostyrene	90	
4-Chlorostyrene	110	
Chlorotrifluoroethylene	52	214
2-Cyanoethyl acrylate	4	
Cyclohexyl acrylate	19	
Cyclohexyl methacrylate	92	
Cyclohexyl vinyl ether	81	
2,6-Dichlorostyrene	167	
Diethylaminoethyl methacrylate	20	
N,N-Dimethylacrylamide	89	
Dimethylaminoethyl methacrylate	19	
2,6-Dimethyl-1,4-phenylene oxide	167	
Dimethylsiloxane	-127	-40
2,4-Dimethylstyrene	112	
2,5-Dimethylstyrene	143	
3,5-Dimethylstyrene	104	
Dodecyl acrylate	-3	
Dodecyl methacrylate	-65	
Dodecyl vinyl ether	-62	
Epibromohydrin	-14	
Epichlorohydrin	-22	
1,2-Epoxybutane	-70	
1,2-Epoxydecane	-70	
1,2-Epoxyoctane	-67	
2-Ethoxyethyl acrylate	-50	
4-Ethoxystyrene	86	
Ethyl acrylate	-24	
Ethyl cellulose	43	
Ethylene, HDPE	-125	130
Ethylene adipate	-46	54
Ethylene-*trans*-1,4-cyclohexyldicarboxylate	18	–
Ethylene isophthatate	51	
Ethylene malonate	-29	
Ethylene 2,6-napthalenedicarboxylate	113	
Ethylene oxide	-66	66
Ethylene terephthalate	72	265
2-Ethylhexyl acrylate	-50	
2-Ethylhexyl methacrylate	-10	
2-Ethylhexyl vinyl ether	-66	
Ethyl methacrylate	65	
Ethyl vinyl ether	-43	86
4-Fluorostyrene	95	
Formaldehyde	-82	181
Hexadecyl acrylate	35	
Hexadecyl methacrylate	15	
Hexyl acrylate	57	
Hexyl methacrylate	-5	
2-Hydropropyl methacrylate	76	
Hydroquinone-*alt*-epichlorohydrin	60	
2-Hydroxyethyl methacrylate	57	
Indene	85	
Isobornyl acrylate	94	
Isobornyl methacrylate	110	

[1]See catalog numbers Z41,247-3, Z41,255-4, Z22,171-6, Z40,603-1 and Z22,195-3 in the *Book section*.

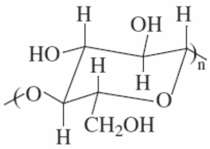
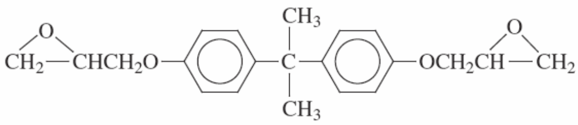
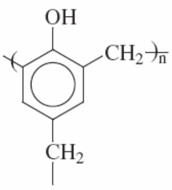
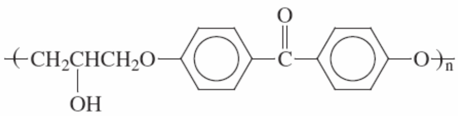
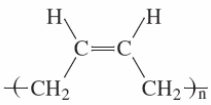
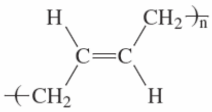
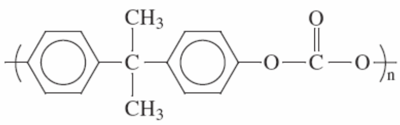
Thermal Transitions of Homopolymers: Glass Transition & Melting Point (continued)

Table I: Thermal Transitions of Homopolymers: Glass Transition (T_g) & Melting Point (T_m) Temperatures (continued)

Repeating Unit	T_g (°C)	T_m (°C)
Isobutyl acrylate	-24	
Isobutylene	-73	
Isobutyl methacrylate	53	
Isobutyl vinyl ether	-19	165
cis-Isoprene	-63	28
trans-Isoprene	-66	65
N-Isopropylacrylamide	85-130	
Isopropyl acrylate, isotactic	-11	162
Isopropyl methacrylate	81	
Methacrylic acid	228	
Methacrylic anhydride	159	
Methacrylonitrile	120	
2-Methoxyethyl acrylate	-50	
4-Methoxystyrene	113	
Methyl acrylate	10	
Methyl cellulose		
Methyl glycidyl ether	-62	
Methyl methacrylate, atactic	105,120	
Methyl methacrylate, syndiotactic	115	200
4-Methylpentene	29	250
Methylphenylsiloxane	-86	
Methylstyrene	20	
3-Methylstyrene	97	
4-Methylstyrene	97	
Methyl vinyl ether	-31	144
Nylon 4,6 (tetramethylene adipamide)	43	
Nylon 6 (-caprolactam)	52	225
Nylon 6,6 (hexamethylene adipamide)	50	265
Nylon 6,9 (hexamethylene azelamide)	58	
Nylon 6,10 (hexamethylene sebacamide)	50	227
Nylon 6,12 (hexamethylene dodecane-diamide)	46	
Nylon 11 (ω–undecanamide)	42	189
Nylon 12 (ω-dodecanamide)	41	179
1-Octadecene	55	
Octadecyl methacrylate	-100	
1-Octene	-63	
Octyl methacrylate	-20	
Oxy-4,4'-biphenyleneoxy-1,4-phenylenesulfonyl-1,4-phenylene	230	290
Oxy-1,4-phenylenesulfonyl-1,4-phenyleneoxy-1,4-phenyleneisopropylidene-1,4-phenylene	165	190
Oxy-1,4-phenylenesulfonyl-1,4-phenylene ether	214	230
p-Phenylene isophthalamide	225	380
p-Phenylene terephthalamide	345	
Phenylene vinylene	80	380
Phenyl methacrylate	110	
Phenyl vinyl ketone	74	
Potassium acrylate	194	
Propylene, atactic	-13	
Propylene, isotactic	-8	176
Propylene, syndiotactic	-8	
Propylene oxide	-75	66
Propyl vinyl ether	-49	76
Sodium acrylate	230	
Sodium methacrylate	310	
Styrene, atactic	100	
Styrene, isotactic	100	240
Tetrabromobisphenol A carbonate	157	
Tetrafluoroethylene	117	327
Tetrahydrofuran	-84	
Tetramethylene adipate	-118	
Tetramethylene terephthalate	17	232
Thio-1,4-phenylene	97	285
2,2,2-Trifluoroethyl acrylate	-10	
Trimethylene oxide	-78	
Trimethylsilyl methacrylate	68	
2,4,6-Trimethylstyrene	162	
Vinyl acetal	355	82
Vinyl acetate	30	
Vinyl alcohol	85	220
Vinyl benzoate	71	
Vinyl 4-*tert*-butylbenzoate	101	–
Vinyl butyral	322	49
Vinyl carbazole	227	320
Vinyl chloride	81	227
Vinyl cyclohexanoate	76	
Vinylferrocene	189	
Vinyl fluoride	41	200
Vinyl formal	105	
Vinylidene chloride	-18	200
Vinylidene fluoride	-40	171
2-Vinyl naphthalene	151	
Vinyl pivalate	86	
Vinyl propionate	10	
2-Vinylpyridine	104	
4-Vinylpyridine	142	
1-Vinyl-2-pyrrolidone	54	
Vinyl trifluoroacetate	46	

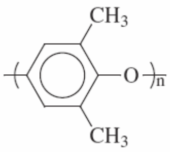
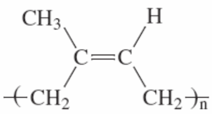
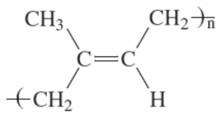
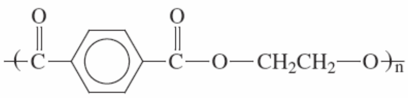
http://www.sigmaaldrich.com/img/assets/3900/Thermal_Transitions_of_Homopolymers.pdf

TABLE I Structures and Selected Thermal Data for Polymers

Polymer	Chain unit	T_m (°C)[a]	T_g (°C)[b]
Cellulose			
Epoxy resin (diglycidyl ether of bisphenol A)		43	
Ionomer resin	$-(CH_2CH_2)_n \cdots (CH-C(CH_3)(CO_2Na))_m-$		
Nylon 6	$-(CH_2)_5CONH-_n$		75 (dry)
Nylon 66	$-NH(CH_2)_6NHCO(CH_2)_4CO-_n$	265	49
Nylon 11	$-(CH_2)_{10}CONH-_n$		46
Nylon 12	$-(CH_2)_{11}CONH-_n$		37
Phenol-formaldehyde			
Phenoxy resin			
Polyacrylonitrile	$-(CH_2CH(C\equiv N))-_n$		~105 (two transitions)
Polybutene-1, isotactic	$-(CH(CH_2CH_3)-CH_2)-_n$	142	−20 (several crystalline forms)
Polybutadiene	$-(CH(CH=CH_2)-CH_2)-_n$		−4
1,2-isotactic		125	
1,2-syndiotactic		154	
Cis-1,4		6	−108
Trans-1,4		148	−18
Polycarbonate		267	149
Polychloroprene	$-(CH_2C(Cl)=CHCH_2)-_n$		−48

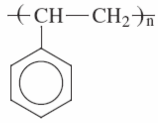
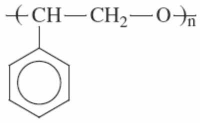
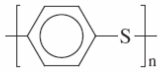
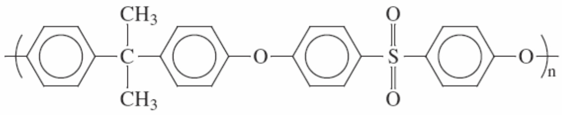
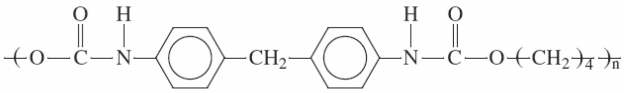
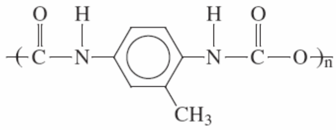
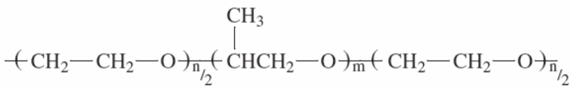
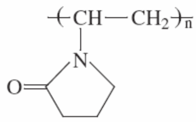
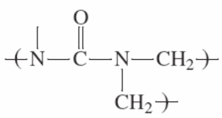
continues

TABLE I (*Continued*)

Polymer	Chain unit	T_m (°C)[a]	T_g (°C)[b]
Polychlorotrifluoroethylene	$-[CF_2CF(Cl)]_n-$	218	45
Poly(2,6-dimethylphenylene oxide)			
Poly(dimethylsiloxane)	$-[Si(CH_3)_2-O]_n-$		−123
Polyisobutene	$-[C(CH_3)_2CH_2]_n-$		−73
Polyisoprene			
Cis-1,4			−73 (natural rubber)
Trans-1,4			−58 (gutta percha)
Poly(ethyl acrylate)	$-[CH_2CH(CO_2CH_2CH_3)]_n-$		−24
Polyethylene			
High pressure, branched		~115	
Linear	$-[CH_2CH_2]_n-$	135	−125 (?)
Linear, low density (ethyl branches)			
Poly(ethylene oxide)	$-[CH_2CH_2O]_n-$	66	−67
Poly(ethylene terephthalate)		265	69
Poly(methyl acrylate)	$-[CH(CO_2CH_3)CH_2]_n-$		6
Poly(methyl methacrylate)	$-[C(CH_3)(CO_2CH_3)-CH_2]_n-$		
Isotactic		160	~45
Syndiotactic		200	115
Atactic			105
Poly(oxymethylene)	$-[OCH_2]_n-$	195	−85
Polypropylene	$-[CH(CH_3)-CH_2]_n-$		
Isotactic		165	−10
Atactic			−20
Poly(propylene oxide)	$-[CH(CH_3)-CH_2-O]_n-$	75	−75

continues

TABLE I (*Continued*)

Polymer	Chain unit	T_m (°C)[a]	T_g (°C)[b]
Polystyrene			
Atactic			100
Isotactic		240	100
Poly(styrene oxide)		149	37
Polyphenylene sulfide			
Polysulfone			219
Poly(tetrafluoroethylene)	$-(CF_2CF_2)_n-$	327	
Polyurethane 4,4′-diphenylmethane Diisocyanate (MDI) Hard segment chain— extended with butanediol			
Toluene diisocyanate Hard segment			
Polyol soft segment			
Poly(vinyl acetate)	$-(CH(OCOCH_3)-CH_2)_n-$		28
Poly(vinyl alcohol)	$-(CH(OH)-CH_2)_n-$	258	85
Poly(vinyl chloride)	$-(CH(Cl)-CH_2)_n-$		81
Poly(vinylidene chloride)	$-(CCl_2CH_2)_n-$	190	
Poly(vinyl fluoride)	$-(CH(F)-CH_2)_n-$	200	−20(?)
Poly(vinylidene fluoride)	$-(CF_2CH_2)_n-$	171	−45
Poly(vinylpyrrolidone)			
Urea-formaldehyde			

[a] Melting temperature.
[b] Glass transition.

10.1. Thermoplastics

Abbre-viation	Name		Density kg/dm^3	Price-class*
LDPE	Low density polyethene		0.92	1
HDPE	Highdensity polyethylene		0.95	1
PP	Polypropylene		0.90	1
PVC	Polyvinylchloride		1.38	1
PS	Polystyrene		1.05	1
TPS	High impact polystyrene		1.05	1
SAN	Styrene-acrylonitril copolymer		1.08	2
ABS	Acrylonitrile-butadiene-styrene copolymer		1.05	2
ASA	Acrylonitrile-styrene-acrylate copolymer		1.07	3
PMMA	Polymethylmethacrylate		1.18	2
PA 6	Polyamide-6	(nylon-6)	1.13	4
PA 6.6	Polyamide-6.6	(nylon-6.6)	1.13	4
PA 11	Polyamide-11	(nylon-11)	1.04	4
PA 12	Polyamide-12	(nylon-12)	1.02	4
POM	Polyoxymethylene		1.42	3
PC	Polycarbonate		1.22	4
PETP	Polyethylene terephtalate		1.37	1
PBTP	Polybutylene terephtalate		1.29	3
PPE/PS	Polyphenyleneether + polystyrene		1.06	3
PSU	Polysulfone		1.24	5
PPS	Polyphenylenesulfide		1.34	4
PI	Polyimide		1.43	6
PTFE	Polytetrafluorethylene		2.17	6
FEP	Hexafluorpropylene-tetrafluorethylene copolymer		2.15	7
PVDF	Polyvinylidenefluoride		1.78	6
ETFE	Tetrafluorethylene-ethylene copolymer		1.70	7
CA	Celluloseacetate		1.30	3
CAB	Celluloseacetate-butyrate		1.20	3
PB	Polybutylene		0.92	2
PMP	Polymethylpentene		0.83	4
PEEK	Polyether-ether-ketone		1.30	7
PES	Polyethersulphone		1.37	7
PK	Polyketone		1.24	3

*

price class	1	2	3	4	5	6	7
€/kg	0.5–1	1–3	3–5	5–8	8–14	14–25	25–55

Abbr.	T_g	T_m	Vicat B	ISO/A	λ	α	c
	°C	°C	°C	°C	W/m·K	10^{-5} /K	kJ/kg·K
LDPE	–120	110	55	35	0.35	23	2.4
HDPE	–120	130	70	45	0.45	13	2.1
PP	–15	170	90	60	0.24	18	1.7
PVC	87	–	85	70	0.16	8	0.9
PS	95	–	90	85	0.15	7	1.3
TPS	90	–	85	80	0.17	8	1.3
SAN	105	–	100	85	0.18	7	1.2
ABS	105	–	100	95	0.17	9	1.4
ASA	100	–	85	85	0.18	9	
PMMA	110	–	100	95	0.19	7	1.45
PA 6	50	223	210	85	0.21	10	1.9
PA 6.6	50	260	230	90	0.20	8.5	1.7
PA 11	45	175	170	70	0.27	12	1.4
PA 12		175	170	70	0.23	9	1.2
POM	–50	175	165	115	0.29	12	1.5
PC	150	–	145	135	0.21	6.5	1.3
PETP	75	260	170	80	0.24	7	1.0
PBTP	70	210	180	60	0.21	7	1.3
PPO/PS	140	–	130	125	0.23	6.5	1.25
PSU	190	–	185	175	0.22	5.5	1.0
PPS	85	290		135	0.29	5.5	
PI	> 400	–		> 250	0.52	5.5	1.15
PTFE	126	327	110	55	0.25	12	1.0
FEP		290			0.23	9	1.15
PVDF	–40	170	130	92	0.12	8.5	1.4
ETFE		270		75	0.24	7.5	1.95
CA	70	210	70	60	0.20	10	1.5
CAB	55		65	60	0.20	12	1.5
PB	–25	130	85	60	0.23	12	1.8
PMP	130	240	165		0.17	12	2.2
PEEK	143	334		160	0.25	4.7	
PES	230		226	210			
PK	15	220	205	100	0.27	11	1.8

T_g = glass-rubber transition temperature
T_m = meting point
Vicat B = softening T at bij 10 N
ISO/A = heat deflection T at 1.85 MPa
λ = heat transmission coefficient
α = linear expansion coefficient
c = specific heat

Abbreviation	E-modulus (short-term)	Tensile strength (short-term)	Strain at fracture	Notched impact strength
	MPa	MPa	%	kJ/m^2
LDPE	150–250	20	300–1000	> 40
HDPE	600–1400	30	100–1000	5–20
PP	1100–1600	30–70	150–700	3–15
PVC	2900–3400	50–80	20–40	2–5
PS	3000–3600	45–60	3–4	2
TPS	1600–2500	20–50	20–50	5–10
SAN	3600	70–80	5	3
ABS	1600–3000	20–50	15–30	8–30
ASA	2300–2600	45–60	15–20	7–14
PMMA	3300	50–80	3–7	2–3
PA 6	1000–2000	35–50	150–250	> 20
PA 6.6	1700–2000	55–60	100–200	15–20
PA 11	1100–1200	40–45	200–250	30–40
PA 12	1200–1350	40–45	100–350	15–30
POM	3000–6000	65–70	15–60	5–8
PC	2000–2200	60–65	80–150	20–35
PETP	2800–3100	55–75	50–150	3–6
PBTP	2600–2800	50–55	100–200	3–6
PPE/PS	2200–2500	50–65	60	> 15
PSU	2450	75–90	50–100	3–10
PPS	3400	75	3	
PI	3200	75–90	4–8	4–8
PTFE	450–750	20–40	250–500	14–16
FEP	360	18–22	250–330	> 20
PVDF	800–1800	40–50	50–200	> 20
ETFE	850–1400	30–55	200–400	> 20
CA	1500–3000	50–60	30–40	5–30
CAB	500–2000	35–50	20–70	5–30
PB	450–600	22–25	200–350	> 40
PMP	1500	25–30	15	3–10
PEEK	3700	90	50	55
PES	2440	84	40–80	
PK	1500	55	350	20

10.2. Thermosets

	d kg/dm³	*E* GPa	tensile strength MPa	notched impact strength kJ/m²	ISO/A °C
PF phenolformaldehyde					
+ anorg. filler	1.8–2.1	6–15	15–25	2–10	120–170
+ org. filler	1.4–1.5	4–8	25–30	2–10	120–150
UF ureumformaldehyde					
+ org. filler	1.5	6–10	30	6–8	110–140
MF melamineformaldehyde					
+ anorg. filler	1.8–2	8–13	25	2	150–200
+ org. filler	1.5	6–10	30	2	140–180
UP polyester (normal)	1.2	3.5	30		70
id (high T)	1.2	3.5	55		120
+ short glass fibres	2.0	12–15	30–50	10–20	100–200
EP epoxy (solid)	1.2	4	60	2	90
+ filler	1.8	12	40	2–15	100–200
+ short glass fibres	1.9	15	30–60	10–20	150–220
(fluid resin)	1.2	4	55	2	110–160
+ filler	1.8	12	45	2–10	130–200
(cold-curing)	1.2	4	50	2	40–60
+ filler	1.6	12	35	2	45–90

10.3. Elastomers

Abbr.	Name	density kg/dm³	price class see p. 185	min. temp. °C	max. temp. °C	tensile strength unfilled MPa	tensile strength filled MPa
NR	natural rubber	0.92	2	–50	80	18–30	25–35
SBR	styrene-butadiene rubber	0.91	2	–45	100	1–2	18–25
BR	butadiene rubber	0.91	2	–70	100	8	17
IR	isoprene rubber	0.91	2	–50	80	27	29
IIR	butyl rubber	0.92	3	–45	150	18–21	18–21
CR	chloroprene rubber	1.23	3	–40	115	21–29	21–29
NBR	nitrile rubber	1.00	3	–40	130	4–7	21–32
EPR	ethylene-propylene rubber	0.86	3	–50	120	2	14–23
SI	silicone rubber	1.10	6	–75	270	2	10–14
SBS	thermoplastic rubber	0.95	3	–70	60	20–25	20–25
PUR	polyurethane rubber	1.07	4	–20	110	20–40	
Fl.R.	fluor rubbers	1.85	7	–30	280	15–25	15–25

http://www.cottoninc.com/product/NonWovens/Nonwoven-Technical-Guide/Cotton-Morphology-And-Chemistry/

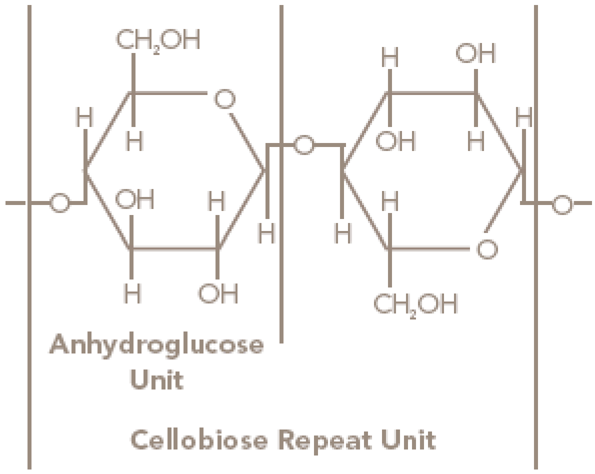
Cotton Morphology and Chemistry

Cellulose Chemistry

After scouring and bleaching, cotton is 99% cellulose. Cellulose is a macromolecule — a polymer made up of a long chain of glucose molecules linked by C-1 to C-4 oxygen bridges with elimination of water (glycoside bonds). The anhydroglucose units are linked together as beta-cellobiose; therefore, anhydro-beta-cellobiose is the repeating unit of the polymer chain (see Figure 5). The number of repeat units linked together to form the cellulose polymer is referred to as the "degree of polymerization."

Wood pulp, rayon and cellophane (all three derived from wood cellulose) are also constructed of cellulose polymers. Cotton cellulose differs from wood cellulose primarily by having a higher degree of polymerization and crystallinity. Crystallinity indicates that the fiber molecules are closely packed and parallel to one another (as illustrated in Figure 6). Table 5 (see page 24) shows the average degree of polymerization and the average crystallinity of the cellulose fibers cotton, viscose rayon and wood pulp. Higher degree of polymerization and crystallinity are associated with higher fiber strengths.

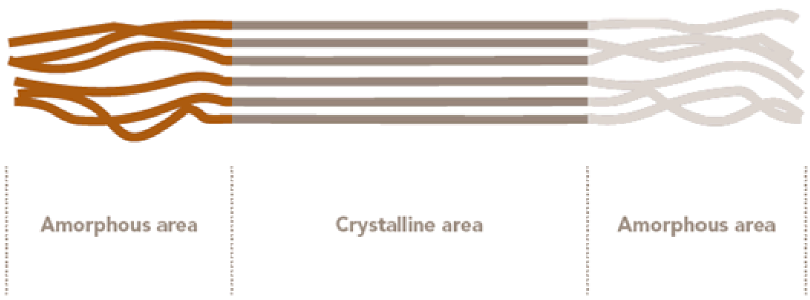
Figure 6 Chemical Structure of Cellulose



The cellulose chains within cotton fibers tend to be held in place by hydrogen bonding. These hydrogen bonds occur between the hydroxyl groups of adjacent molecules and are most prevalent between the parallel, closely packed molecules in the crystalline areas of the fiber.

The three hydroxyl groups, one primary and two secondary, in each repeating cellobiose unit of cellulose are chemically reactive. These groups can undergo substitution reactions in procedures designed to modify the cellulose fibers or in the application of dyes and finishes for crosslinking. The hydroxyl groups also serve as principal sorption sites for water molecules. Directly sorbed water is firmly chemisorbed on the cellulosic hydroxyl groups by hydrogen bonding.

Figure 7 Amorphous and crystalline Areas of Polymers



Of particular interest in the case of cellulose fibers is the response of their strength to variations in moisture content. In the case of regenerated and derivative cellulose fibers, strength generally decreases with increasing moisture content. In contrast, the strength of cotton generally increases with increased moisture. This difference among fibers in their response to moisture is explained in terms of intermolecular hydrogen bonding between cellulose chains and their degree of crystallinity (see Tables 5 and 6).

Table 5 Degree of polymerization and crystallinity of cellulose fibers

Fiber	Average Degree of Polymerization*	Average Crystallinity (%)**
Cotton	9,000–15,000	73
Viscose rayon Regular	250–450	60
High tenacity	500–650	
High wet modulus	400–550	
Wood pulp	600–1,500	35

* Joseph, M., Introduction to Textile Science, 5th Edition, 1986.
** Shirley Institute; measured by X-ray diffraction.

Thermoplastic fibers melt at elevated temperatures and have a glass transition temperature at some point below the polymer’s melting point. At the glass transition temperature, a thermoplastic fiber becomes brittle and loses its elasticity. Cotton is not a thermoplastic fiber; therefore, it has no glass transition temperature and remains flexible even at very low temperatures. At elevated temperatures, cotton decomposes instead of melting. Long exposure to dry heat above 300°F (149°C) causes cotton fibers to decompose gradually, and temperatures above 475°F (246°C) cause rapid deterioration.

Table 6 Dry and wet strengths of fibers (g/tex)

Fiber	Dry	Wet
Cotton	27–45	30–54
Rayon (regular)	22–27	10–14
Wood pulp	27–54	27–54

Cotton's Unique Fiber Morphology

A mature cotton fiber has the following six parts.

The “cuticle” is the outer waxy layer, which contains pectins and proteinaceous materials. It serves as a smooth, water-resistant coating, which protects the fiber. This layer is removed from the fiber by scouring.

The “primary wall” is the original thin cell wall. Mainly cellulose, it is made up of a network of fine fibrils (small strands of cellulose). This makes for a well-organized system of continuous, very fine capillaries. It is well known that fine capillaries rob liquids from coarse capillaries. The fine surface capillaries of each cotton fiber contribute greatly to cotton’s wipe-dry performance.

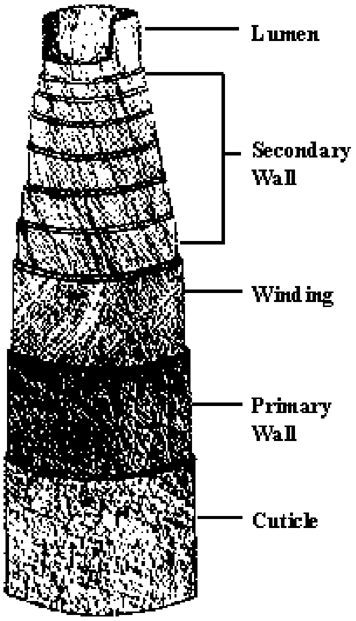


***Figure 8* Structure of a cotton fiber**

The “winding layer” (also called the S1 layer) is the first layer of secondary thickening. It differs in structure from both the primary wall and the remainder of the secondary wall. It consists of fibrils aligned at 40 to 70-degree angles to the fiber axis in an open netting type of pattern.

The “secondary wall” (also called the S2 layer) consists of concentric layers of cellulose, which constitute the main portion of the cotton fiber. After the fiber has attained its maximum diameter, new layers of cellulose are added to form the secondary wall. The fibrils are deposited at 70 to 80-degree angles to the fiber axis, reversing angle at points along the length of the fiber. The fibrils are packed close together, again, forming small capillaries.

The “lumen wall” (also called the S3 layer) separates the secondary wall from the lumen and appears to be more resistant to certain reagents than the secondary wall layers.

The “lumen” is the hollow canal that runs the length of the fiber. It is filled with living protoplast during the growth period. After the fiber matures and the boll opens, the protoplast dries up, and the lumen naturally collapses, leaving a central void, or pore space, in each fiber.

Figure 8 shows a schematic structure of a mature cotton fiber, identifying its six parts.

Throughout the fiber structure, there are variously sized pores or capillary spaces between the variously sized fibrils in each of the six fiber parts. Thus, the cotton fiber can be viewed as a microscopic physical sponge with a complex porous structure. This internal structure makes cotton fibers accessible to liquids and vapors. The capillary action of the fibrils pulls liquid in, where it is held in pores between the fibrils. This structure accounts for cotton’s wickability and unique absorbing capacity.

The cotton fiber, when observed in its entirety, is a flat, twisted ribbon, with 50 to 100 convolutions per inch. The fiber is tapered on one end and fibrillated on the other, where it was joined to the cottonseed. This provides the fiber with a soft touch or feel, because it has no sharply cut ends, as do synthetic staple fibers.