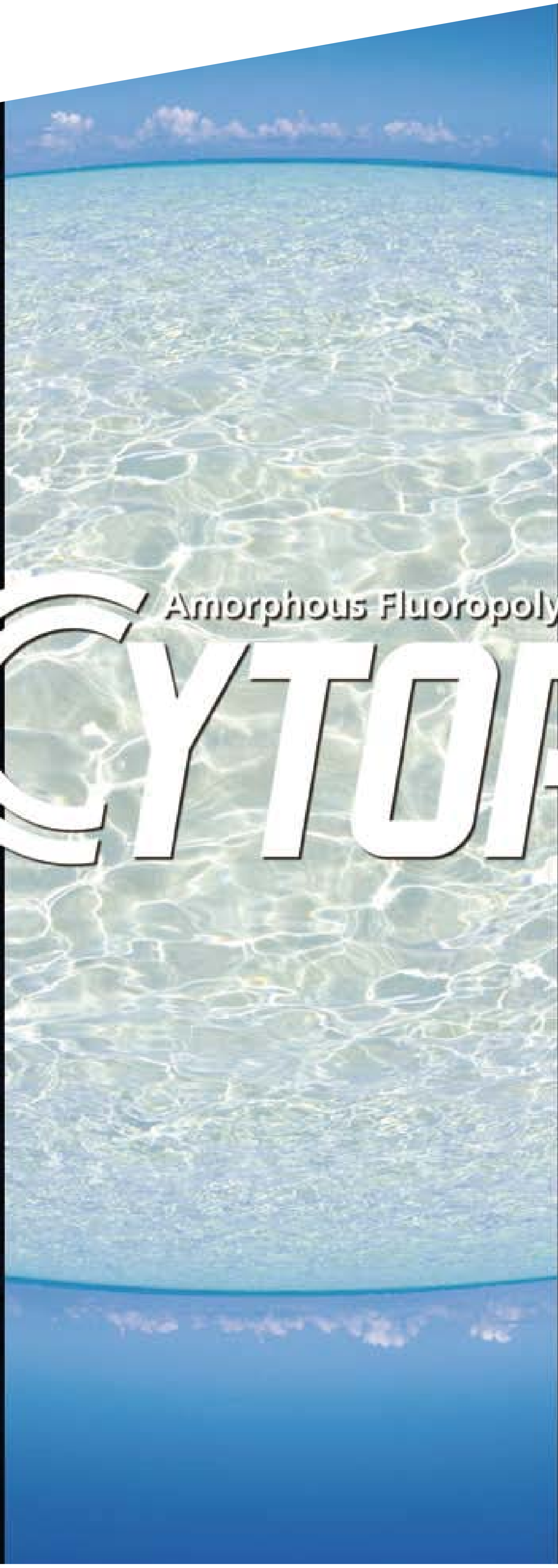
AGC

Your Dreams, Our Challenge



Amorphous Fluoropolymer

CYTOP

AGC Chemicals

CYTOP

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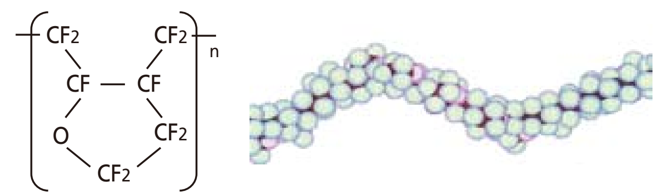
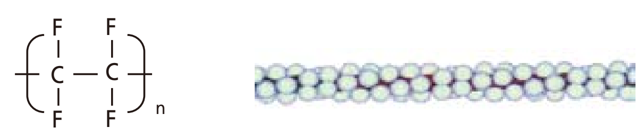
Expanding to unlimited zone. Six excellent characteristics are highly acclaimed.

AGC's CYTOP has achieved extremely high transparency, of which the visible light transmission ratio is more than 95% or more, with an amorphous structure completely different from existing fluoropolymers. Since CYTOP can be dissolved with a special fluorinated solvent, it can be used in thin film coatings to a thickness of a few sub-microns. Furthermore, as it has the characteristics of fluoropolymers, CYTOP is attracting attention as an innovative material. From the Cytop polymer, three types of products are made — type A, type M and type S —according to the application. It is used in various fields by taking advantage of its six characteristics (transparency, electric insulation, water and oil repellency, mold release, chemical resistance, and moisture-proof property).

Amorphous Fluoropolymer CYTOP	**Example of common fluoropolymer PTFE**
	
Amorphous (non-crystalline) ▼ Transparency and solubility 	Crystalline ▼ Opacity and insolubility 

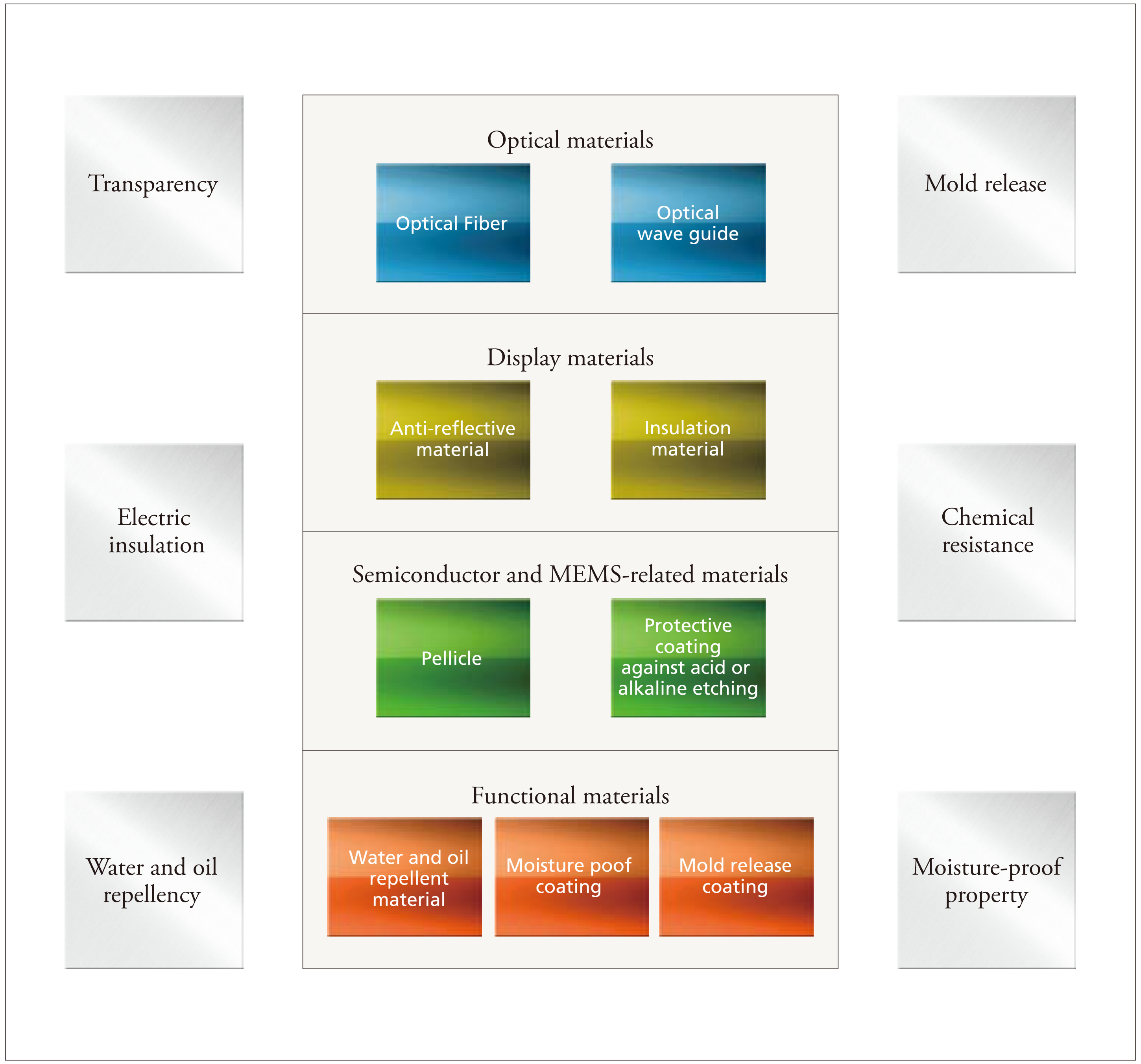
Type A | Type M | Type S

Transparency	Electric insulation	Water and oil repellency	Mold release	Chemical resistance	Moisture-proof property

Advanced Technology

New material in places where advanced technology is used. CYTOP is used in various fields.

CYTOP has many excellent characteristics. Each characteristic has achieved the top performance among organic materials. CYTOP has been attracting a lot of attention in the field of advanced technologies. It has already solved many technological issues, and it also meets various requirements in a wide range of industries and is highly acclaimed.



Amorphous Structure

CYTOP provides transparency and desired coating. Three types are available for applications.

Since most fluoropolymers are insoluble, they need to undergo a baking process to fix them onto the substrate. CYTOP can eliminate this process. Since it can be dissolved in a special fluorocarbon solvent, it is easy to coat it onto a substrate. CYTOP takes advantage of maintaining its high transparency. CYTOP has three types each with a different functional group at both ends of the polymer.

Type	End functional group	Characteristics	Example of application
Type A	— COOH	• Metal and glass can be coated by using a silane coupling agent together with this type of CYTOP • Plastic can be coated by using a special primer together with this type of CYTOP • Transparent to visible light	Anti-reflection film Optical membrane Protective layer Water and oil repellent Electric insulator
Type M	— CONH ~ S i(OR)n	• One-step coating of metals and glass can be done.	Protective layer Water and oil repellent Electric insulator
Type S	— CF_3	• High transparency for wide range of light from visible light to UV • Tough UV resistance • Non-adhesion	Pellicle Optical materials Mold release material

Name of Cytop solution type

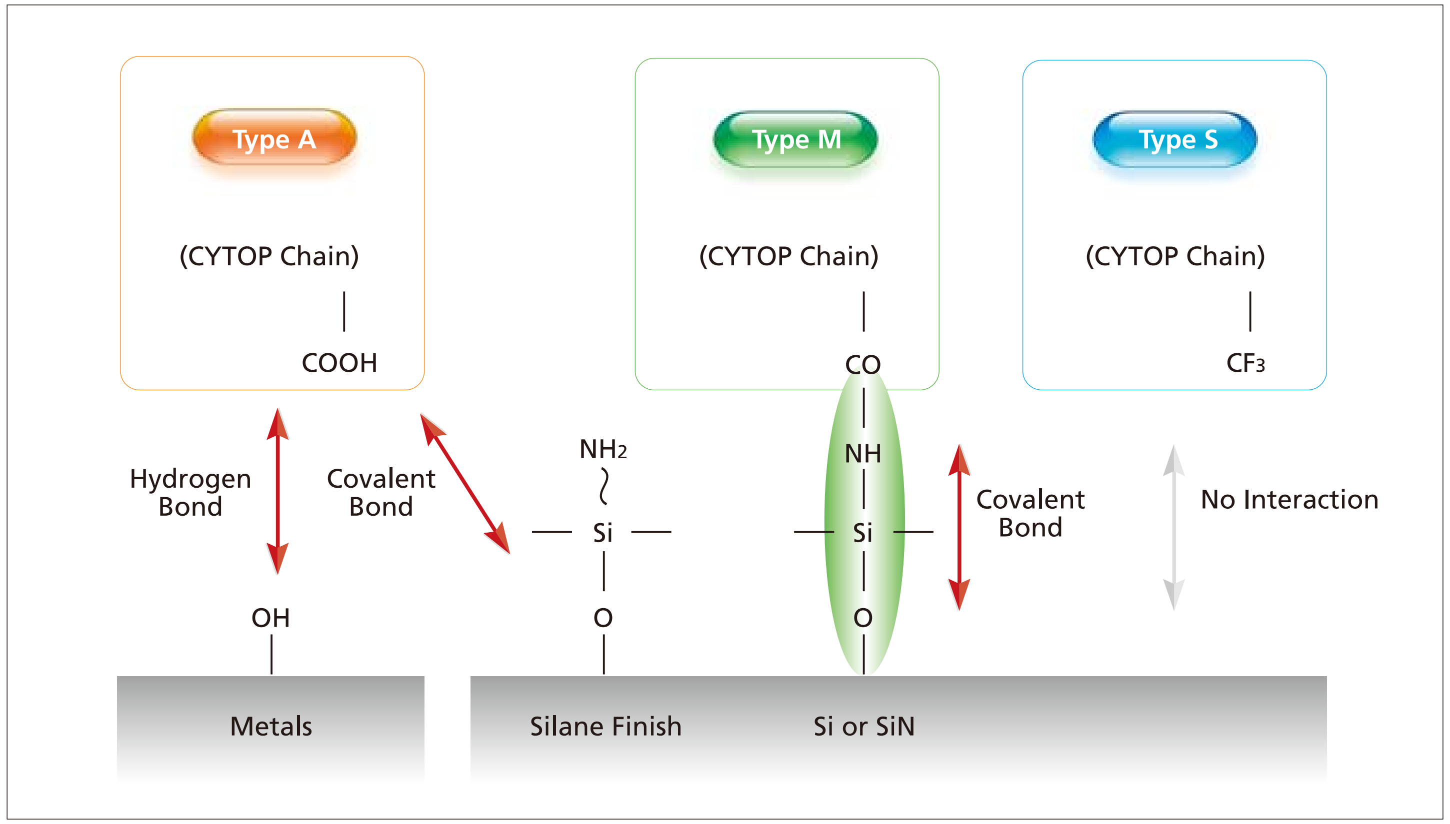
CTX-807AP
- Grade of microfilter
- Type
- Polymer Concentration (7%)
- Solvent type (boiling point of 180°C)
- Classification by molecular weight (standard molecular weight)

(1) Type: Three Types (A, M and S)
(For evaluation, refer to "Characteristics for each Type.")
(2) Classification by molecular weight: X:Standard
L: Low molecular weight
(3) Solvent type: Solvent 100 series:Boiling point of 100°C (for dip coating)
Solvent 800 series:Boiling point of 180°C (for spin coating)
(4) Concentration: Standard sample: 9%
(5) Solution filtration: without P: 5 µm (Standard), P: 1 µm , P2: 0.2 µm

Interaction of Molecules

CYTOP's adhesion mechanism for three types is introduced in detail.

For example, the functional groups of type A and type M form chemical bonds with molecules on surface of substrate after heat treatment, resulting in firm adhesion of CYTOP to the substrate. In contrast, since the functional group of type S is not joined to the substrate, it can be independently used. If the Type S is applied to the substrate, it can be used together with other types of CYTOP. By appropriately combining the three different types of CYTOP, you can achieve the optimum coating on various substrates under different conditions.



Comparison of adhesion

CYTOP	Pretreatment	Result of chessboad Peeling Test
Type A	Silane*	0 (No change)
Type M	No	1 (Peel 5% or less)
Type S	No	5 (Complete peel)

*Silane Treatment
Apply CYTOP after spin coating with a 0.05% water/ethanol solution of $H_2NC_3H_6Si(OC_2H_5)_3$.

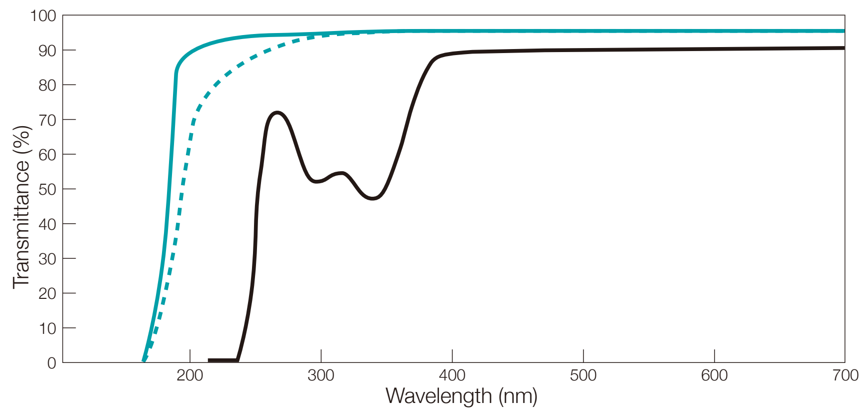
[Evaluation conditions]
Substrate: Glass top surface
CYTOP: CTL-800 series
Spin coating: Membrane thickness:approx. 1μm
Cure: 180°C, 1 hour
[Evaluation method]
Chessboad Peeling Test (according to JIS K5600)

Peeling rank
0: No change
1: Corner peel 5% or less
2: Linear peel 15% or less
3: Peel 35% or less
4: Peel 35% or more
5: 100% peel

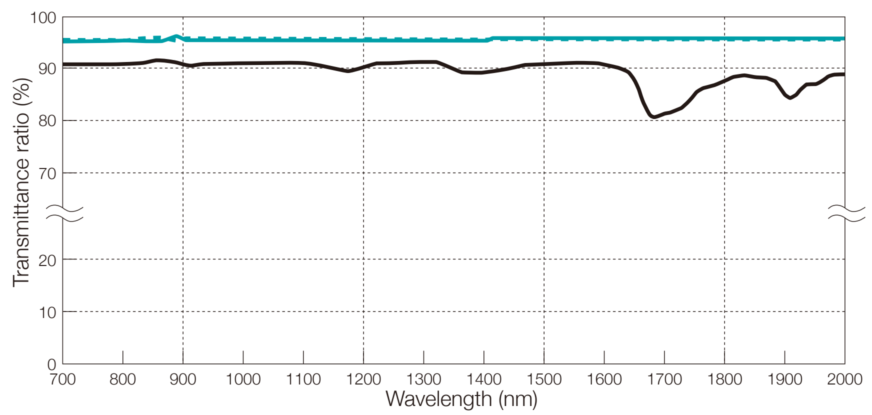
Optical Characteristics

	CYTOP	PTFE	PFA	PMMA	Remarks
Refraction index	1.34	1.35	1.35	1.49	Abbe's refractometer
Light transmission ratio (%)	95	Translucent	Translucent	93	Visible light range, 200 µm
Abbe's number	90	–	–	55	Abbe's number

CYTOP Transmittance in the Visible and UV Region



CYTOP Transmittance in the Near IR Region



CYTOP 200 µm
High ultraviolet light transmission ratio Type S

CYTOP 200 µm
Standard Type A

PMMA 200 µm

Internal transmittance (for 5 mm thickness)

Wavelength (nm)	250	400	550	850	1300	1550	1600	1700	1800	1900	2000
Internal transmittance (%)	100	100	100	100	100	100	100	99.9	99.85	99.75	99.15

Photo-elastic characteristics

Sample	CYTOP	PC	PSt	PMMA	CR-39	Optical glass
Photo-elastic constant $\times 10^{-12} Pa^{-1}$	6.5	76	8.5 ～10.3	−2.8～−3.9	41	0.5～2.9
Photo-elastic sensitivity $\times 10^{-6} m/N$	0.108	1.02	0.16	0.05	0.68	—

* Photo-elastic sensitivity α : Number of interference fringes appeared when unit simple stress (or main stress difference) is applied to the unit thickness plate.

Refractive Indices in the Near IR

	CYTOP	PMMA	Remarks
Refractive index	1.34	1.48	Abbe's refractometer (λ= 589 nm)
	1.3395	1.4878	Prism coupler (λ= 633 nm)
	1.3348	1.4792	Prism coupler (λ= 1,300 nm)
	1.3335	1.4778	Prism coupler (λ= 1,550 nm)

Refractive Indices in the short wavelength Region

Wavelength (nm)	Refractive index	Standard deviation
238	1.35764	1.3×10^{-5}
245	1.35637	1.2×10^{-5}
275	1.35393	1.5×10^{-5}
313	1.35132	1.7×10^{-5}
365	1.34840	2.1×10^{-5}
407	1.34566	2.0×10^{-5}
436	1.34404	2.0×10^{-5}
546	1.3402	3.3×10^{-5}

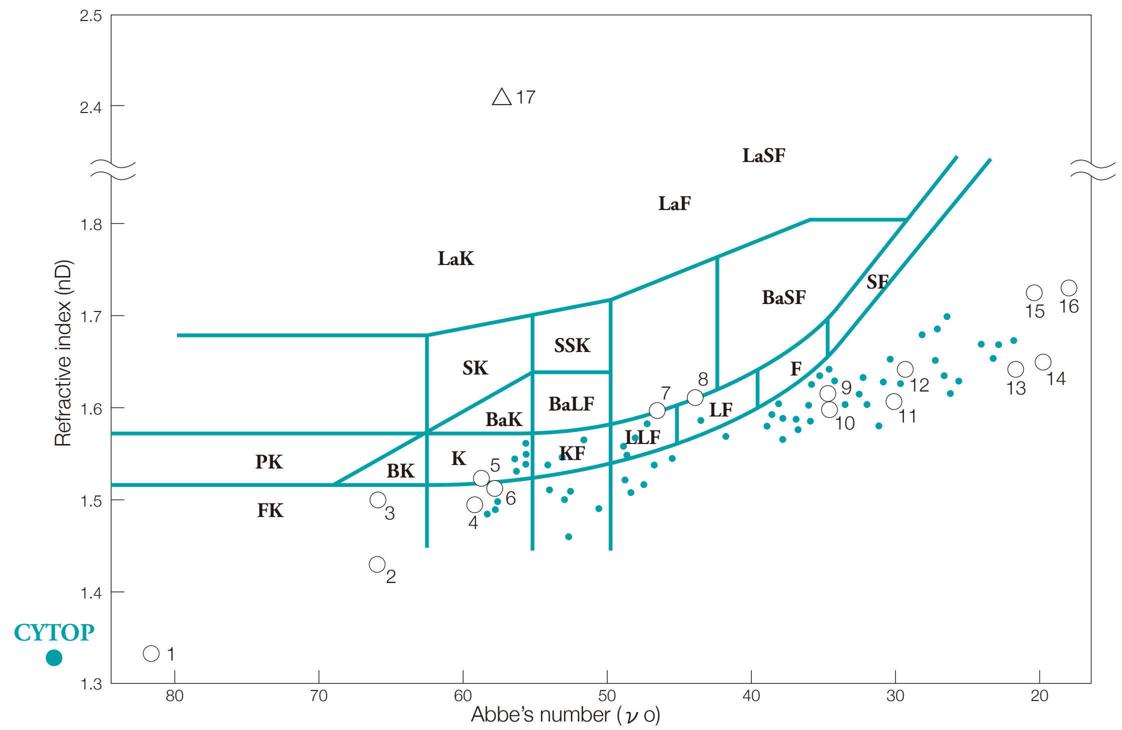
Measurement of refractive index
*Experimental method:

A 60° prism with a mercury lamp as the source of white light was used to illuminate the sample at the minimum angle which refraction occurs. From this angle, the refractive index is calculated as follows;

$n(\lambda)=\sin((\theta m+\alpha)/2)/\sin(\alpha/2)$
α is the vertical angle of the prism and
θm is the angle of minimum deviation.

The results are showed in the table. The polymer wes CTL.

Refractive index and Abbe's number



1 FEP
2 Polymethacrylic acid trifluoroethyl
3 Polymethacrylic acid isobutyl
4 Polyacrylic acid methyl
5 Diethylene glycol bisallyl Carbonate (CR-39) polymer
6 Polymethacrylic acid methyl
7 Poly α-bromoacrylic acid methyl
8 Polymethacrylic acid 2,3-dibromopropyl
9 Phthalic acid diallyl polymer
10 Polymethacrylic acid phenyl
11 Polybenzoic acid vinyl
12 Polystyrene
13 Polymethacrylic acid pentachlorophenyl
14 Poly o-chlorostyrene
15 Polyvinyl naphthalene
16 Polyvinyl carbazole
17 Diamond
· Other polymers including FK and PK Optical glass

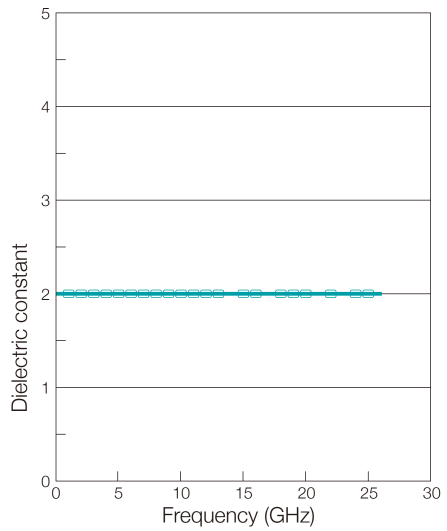
* Refractive index and Abbe's number of a typical organic polymer

E Electrical Characteristics

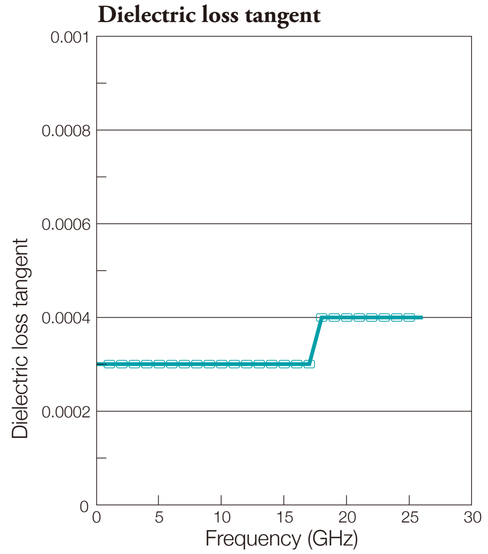
	CYTOP	PTFE	PFA	PMMA	REMARKS
Dielectric constant	2.0～2.1	>2.1	2.1	4	Room temperature 100 Hz to 1 MHz
Dielectric loss tangent	0.0008>	>0.0007	0.0002	0.04	Room temperature 100 Hz to 1 MHz
Volume resistivity (/cm)	$>10^{17}$	$>10^{18}$	$>10^{18}$	$>10^{18}$	Room temperature, in Air
Breakdown voltage (kV/0.1 mm)	9	13	12	2	Room temperature, in Air
Arc resistance (s)	>200	>280	>180	No track	

Microwave dielectric characteristics of CYTOP

Dielectric constant

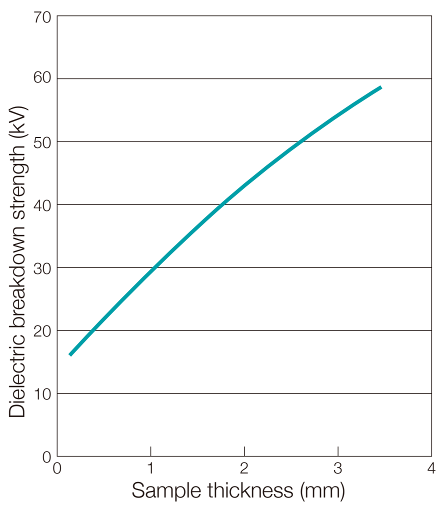


Dielectric loss tangent



Measurement method: Triplate rail resonance method

Dielectric breakdown strength



Measurement method: JIS C2110

P Physical Characteristics

	CYTOP	PTFE	PFA	PMMA	Remark
Glass transition temperature (°C)	108	(130)	(75)	105～120	DSC
Melting point (°C)	not observed	327	310	iso 160 sys 200	DSC
Specific gravity	2.03	2.14～2.20	2.12～2.17	1.09～1.20	
Water contact angle (°)	110	114	115	80	25°C
Critical surface tension γc (mN/m)	19	18	18	39	25°C
Water absorptivity (%)	<0.01	<0.01	<0.01	0.3	60°C in water
Durometer hardness	HDD81	HDD55	HDD58～60	HDD92	ASTM D2240
Linear expansion coefficient (K^{-1})	$1.15～1.20 \times 10^{-4}$	1.0×10^{-4}	1.3×10^{-4}	8.0×10^{-5}	TMA(40～100°C)

Gas permeability coefficient

Gas	Permeability coefficient ($cm^3 \cdot cm/cm^2 \cdot S \cdot cmHg$)
Helium	1.58×10^{-8}
Oxygen	8.34×10^{-10}
Nitrogen	1.94×10^{-10}

Comparison of oxygen permeability

	Permeability coefficient ($cm^3 \cdot cm/cm^2 \cdot S \cdot cmHg$)
CYTOP	8.34×10^{-10}
PTFE	4.3×10^{-10}
PE	2.9×10^{-10}
Polyvinylidene chloride	5.3×10^{-13}

Comparison of steam permeability

	Permeability coefficient (g/m^2 24hr)
CYTOP	0.2 (Sample thickness 100μm)
Polyimide	84 (Sample thickness 25μm)
Silicon rubber	840 (Sample thickness 25μm)
High-density polyethylene	0.5 (Sample thickness 25μm)
Polyvinylidene chloride	0.5 (Sample thickness 25μm)

Water absorption of CYTOP

	CYTOP	High-density polyethylene	Polyimide
Water absorption ratio (%)	< 0.01	< 0.01	0.5

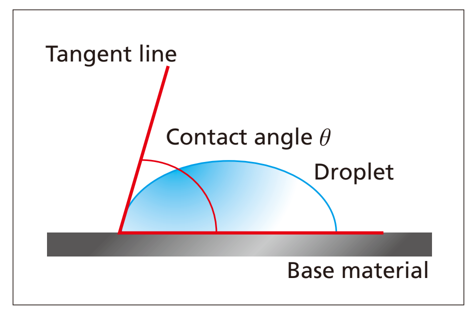
S Surface Characteristics

Surface contact angle of glass surface coated with Type CTL-A

Surface energy: 19 mN/m (PMMA 41 mN/m)

Medium / Coat	Water	Normal hexadecane
No	44°	21°
CYTOP Type A	112°	53°

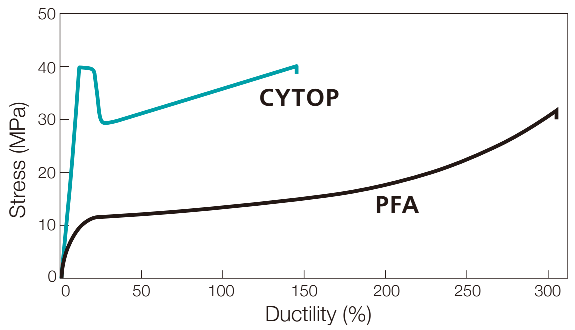
Repellent surface characteristics → Water and oil repellent membrane



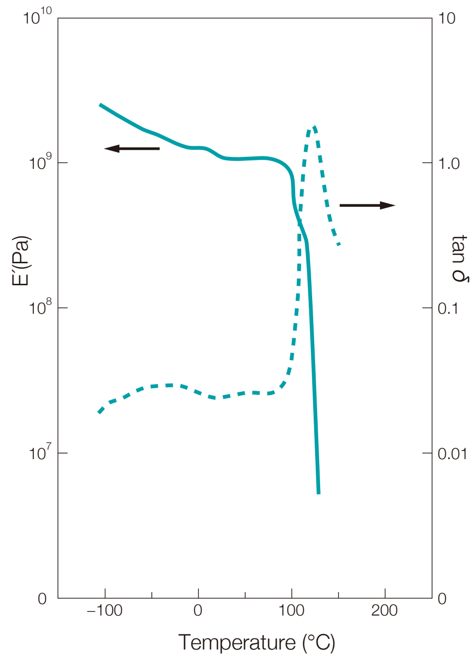
M Mechanical Characteristics

	CYTOP	PTFE	PFA	PMMA
Tensile strength (MPa)	41～49	14～32	28～32	65～73
Tensile extension ratio (%)	162～192	200～400	280～300	3～5
Yield strength (MPa)	40	11～16	10～15	(65)
Tensile modulus (MPa)	1400～1600	400	580	3000

Stress-strain curve of CYTOP (25°C)



Dynamic visco-elasticity of CYTOP



Measurement conditions: 35Hz, Temperature increase at 3°C/min

C Chemical Resistance

Reagent		Change of weight (%)	Change of appearance	Remark
Acid	35% HCl	0.0	No change	60°C × 1 week
	96% H_2SO_4	0.0	No change	60°C × 1 week
	50% HF	0.0	No change	60°C × 1 week
Alkaline	10% NaOH	0.0	No change	60°C × 1 week
	44% NaOH	0.0	No change	60°C × 1 week
	48% KOH	0.0	No change	60°C × 1 week
	2.38% TMAH	0.0	No change	60°C × 1 week
Organic solvent	Hexane	0.0	No change	Room temperature × 1 week
	IPA	0.0	No change	Room temperature × 1 week
	Acetone	0.0	No change	Room temperature × 1 week
	Methyl ethylene	0.0	No change	Room temperature × 1 week

Test piece: 20 × 30 × 0.2 mm

List of Data

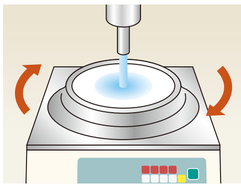
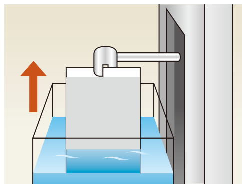
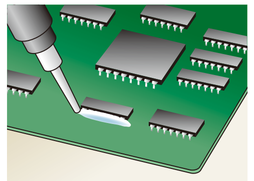
	Unit	Characteristic value	Remarks
Specific gravity		2.03	ASTM D792
Glass-transition temperature	°C	108	DSC
Melting point	°C	not observed	
Contact angle (water)	degree	112	Contact angle gauge
Contact angle (normal hexadecane)	degree	53	Contact angle gauge
Critical surface tension γc	mN/m	19	
Water absorptivity	%	>0.01	
Yield strength	MPa	40	Tensiron
Yield strain	%	5.0	Tensiron
Tensile strength	MPa	41～49	Tensiron
Tensile elongation	%	162～192	Tensiron
Tensile modulus	MPa	1400～1600	Tensiron
Bending strength	MPa	70	ASTM D790
Bending modulus	MPa	2000	ASTM D790
Compression strength	MPa	30	ASTM D695
Compression modulus	MPa	2900	ASTM D695
Poisson's ratio		0.42	
Durometer hardness		HDD81	JIS K7215
Izod impact strength	kPa·m	40	JIS K7110
Thermal deformation temperature	°C	90	1.82MPa Deflection temperature under load
		100	0.45MPa Deflection temperature under load
Specific heat	kJ/(kg·K)	0.861	JIS K7123
Thermal conductivity	W/(m·K)	0.12	Laser flash method
Linear expansion coefficient	ppm/°C	74	TMA(0～80°C)
Volume resistivity	Ω·cm	$>10^{17}$	JIS K6911
Dielectric constant		2.0～2.1	100 Hz to 1 MHz, Room temperature, JEC-6150
		2.04～2.05	1 GHz to 25 GHz, Room temperature
Dielectric loss tangent		$1\sim 8\times10^{-4}$	100 Hz to 1 MHz, Room temperature, JEC-6150
		$3\sim 4\times10^{-4}$	1 GHz to 25 GHz, Room temperature, Triplate rail resonance method
Dielectric strength	kV/mm	20	2.3 mm in thickness, JIS C2110
	kV/0.1mm	10	0.14 mm, JIS C2110, Triplate rail resonance method
Arc resistance	Sec	200<	JIS K6911
Refractive index		1.34	Abbe's refractometer, JIS K7142, 25°C or higher
Photoelastic coefficient	$\times10^{-12}Pa^{-1}$	6.5	
Photo-elastic sensitivity	$\times10^{-6}m/N$	0.108	

Coating method of CYTOP

Various methods to coat the CYTOP solution are available depending on the base material, shape and target film thickness.
To maintain the characteristics of the coating film and to have it adhere to the base material,
pretreatment suitable for each base material is required.

Features of various coating methods of CYTOP

Feature

Coating method	Spin-Coating 	Dip-Coating 	Potting 
Membrane thickness of CYTOP	10 µm or less	1 µm or less	1 to 20 µm
Shape of substrate	Flat board (or sheet), Circular board	Any type of board may be used.	Any type of board may be used.
Control factors of membrane thickness	Solution concentration, Solution viscosity, spining speed	Solution concentration, Solution viscosity, Pull-up speed	Solution concentration, Nozzle shape
Thickness controllability	Highly accurate	Highly accurate if dip coater is used	Variable
Suitable CYTOP series	CTX-800 series CTL-800 series Solvent: CT-solv180	CTX-100E series CTL-100E series Solvent: CT-solv100E	CTX-100E series CTX-800 series

Notes: Whichever coating method is used, it can be repeated several times to give the thickness. In such case, after applying the first coat, let it dry uncompletely before applying another coat (1~10 minutes at 70~120°C). Any bubbles in the CYTOP liquid must be removed before drying.

Pretreatment method of base material

Type of base material	Pretreatment method (for use with Standard grade A)	Applications
Glass	Treatment with silane coupling agent ($H_2NC_3H_6Si(OC_2H_5)_3$, etc.) Dilution solvent: ethanol, water, etc. Concentration: 0.001 to 0.05% Solvent drying (spin drying, etc.)	Glass, Quartz, Silicon wafer
Metal	No special pretreatment is required. (Silane coupling pretreatment similar to that for glass is also effective.)	Iron, SUS, Aluminum, Silver, etc.
Plastic	Treatment with primer (CT- P10: Containing 15% of active constituent) Dilution solvent: Isopropyl alcohol acetic acid isobutyl in a ratio of 9:5, etc. Concentration: 0.1 to 1% Solvent drying (nitrogen blow, etc.)	PMMA, PC, PS, PSF, etc.

Example of CYTOP curing conditions

* This is only an example for reference. Please examine and determine the optimum conditions.
80°C × 60 min. (oven) + 200°C × 60 min. (oven)

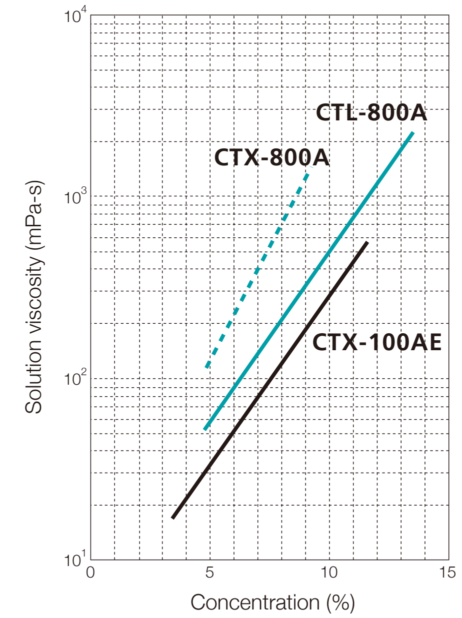
Solution

Boiling point

Two types of CYTOP solution are available to meet the different coating methods of customers.

· 180°C: For spin coating
· 100°C: For dip coating

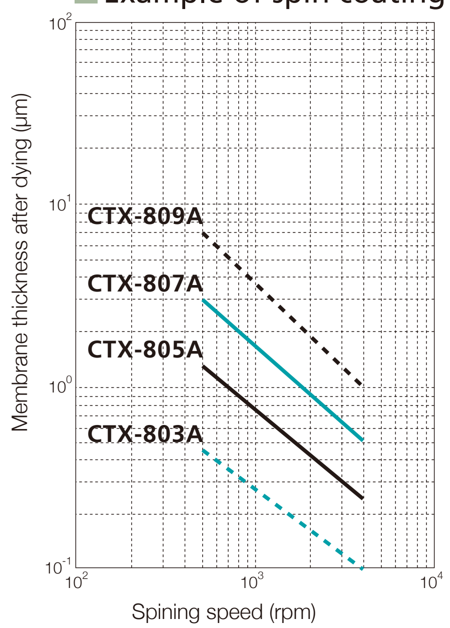
Viscosity of CYTOP



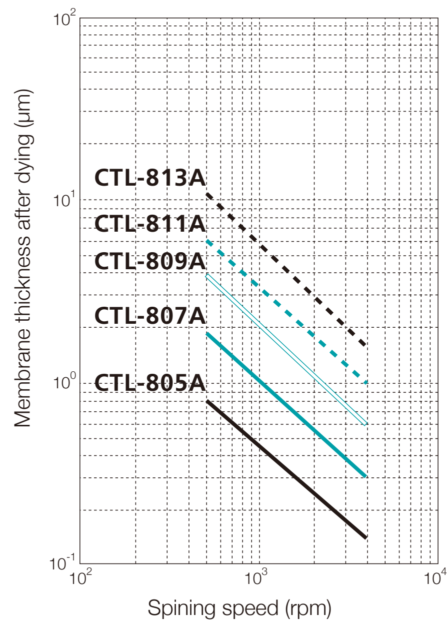
25°C, E-type viscometer
CTX-100E: Solution CT-Solv100E (Boiling Point 100°C)
CTX, L-800: Solution CT-Solv180 (Boiling Point 180°C)

Coating characteristics

Example of spin coating

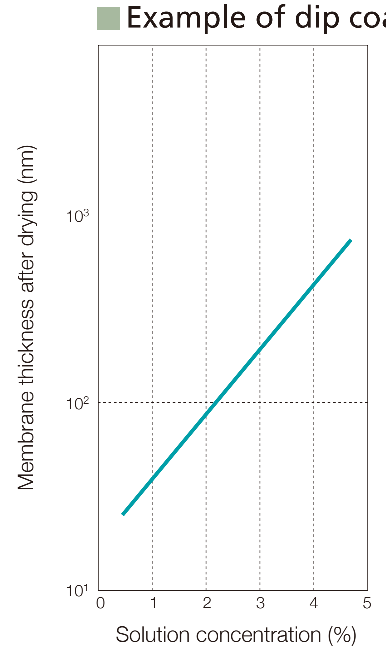


Standard type (CTX- 800A)



Low-molecular weight type (CTL-800A)
Coating conditions: 500 rpm × 10 sec + specified number of revolutions × 20 sec

Example of dip coating



CYTOP CTX-100E series
Example is pull-up speed at 6 cm/min.

Analysis Results of Heavy Metal and Bromine: Reference example

Item / Sample name	Cd Lower limit of detection: 5ppm	Cr Lower limit of detection: 2ppm	Pb Lower limit of detection: 5ppm	Hg Lower limit of detection: 5ppm	Br Lower limit of detection: 20ppm
CTL-109AE	Not detectable	Not detectable	Not detectable	Not detectable	Not detectable
CTX-809A	Not detectable	Not detectable	Not detectable	Not detectable	Not detectable
CT-SOLV100E	Not detectable	Not detectable	Not detectable	Not detectable	Not detectable
CT-SOLV180	Not detectable	Not detectable	Not detectable	Not detectable	Not detectable

Precautions for Handling CYTOP

When using CYTOP, please comply with MSDS.

◆ **Precautions for thermal decomposition**

Thermal decomposition at high temperature (starts at 400°C) and a fire may generate hazardous substance like hydrofluoric acid. Therefore, do not use the product under conditions in which it will thermally decompose and ensure good ventilation for use at high temperature such as forming by melting.
(Use the product at normal air pressure and a temperature of 350°C or less.)

What to do in emergencies	• Inhalation	· If someone has become sick by inhaling vapor, gas, or similar substances, rest them in a place with clean air and consult a doctor. · If their breathing is weak or has stopped, perform artificial respiration. Consult a doctor immediately.
	• If CYTOP comes into contact with your skin	· Wipe deposit immediately with a cloth. · If the affected area's appearance has changed or if the area concerned hurts, consult a doctor. · Rinse with a lot of water and soap or a detergent for skin. Do not use a solvent or thinner.
	• If CYTOP gets into your eye	· Consult a doctor as soon as possible. · Wash the eyes with a lot of clean water immediately for 15 minutes or more. Wash it off completely at the back of the eyelids.
	• If you have swallowed CYTOP	· If it is swallowed by mistake, rest and consult a doctor immediately. · Do not let a person throw up unless otherwise instructed so by a medical expert.
In the event of a fire	• Fire extinguisher	· Use a non-flammable fire extinguisher suitable for an ambient fire.
	• Specific hazard of fire	· If it is burning, a poisonous gas may be emitted.
	• Specified extinguishing method	· Remove movable containers from the area of the fire as long as it is safe to do so.
	• Protecting persons who are engaged in fire extinguishing	· If it is burning, a poisonous gas (hydrogen fluoride, halocarbonil, carbon monoxide and very toxic perfluoro-isobutylene) may be emitted. Persons who are engaged in fire extinguishing should wear self-contained breathing apparatuses.
In the event of a leakage	• Precautions for health and safety	· For indoor work, ventilate the area well until the work is completed. · When working, wear appropriate protective equipment (such as gloves, protective masks, aprons and goggles). · Wear some breathing apparatus in places with insufficient ventilation.
	• Precautions for the environment	· Dispose of deposit or waste according to the relevant laws.
	• Method of removal	· If there is a lot of waste, cover the drain and build up a bank to prevent it from entering the sewer. · Absorb waste in inert material such as dry sand and collect it in containers for disposal. · Ventilate the peripheral area. · Dispose of collected substances as soon as possible.
	• Preventing secondary accidents	· Collect any leaks in a sealable container and move it to a safe place.
Precautions for handling and storage	*Handling*	
	• Technical measures	· Use is limited for industrial purpose or experts. · Seal the container each time. · Move sources of fire away during handling and while vapor still remains after handling. · Install a local exhaust system if the fluid is handled at temperatures above its boiling point. A performance of 25 cm/sec or more must be maintained. If the fluid is at a temperature above its boiling point in a place without an exhaust system, put on a respirator, stop the heat source and evacuate the place.
	• Precautions	· Handle the fluid in a well-ventilated place. · Install a local exhaust system if the fluid is handled at a temperature above its boiling point. A performance of 25 cm/sec or more must be maintained.
	• Precautions for safe handling	· Do not eat, drink or smoke when using the product. Use soap and water to wash any areas that come into contact with this product.
	Storage	
	• Appropriate storage conditions	· Store the product in a well-ventilated, cool, dark place. · Do not store it near a source of fire. · Store it away from a strong base.
	• Safe container and packaging materials	
Exposure prevention and protection measures	• Measures for facilities	· Install a local exhaust system in a handling area. · Install a shower, hand washing basin and eye wash system near the working area. · If decomposed material may be generated because of heat, use an appropriate local exhaust system to keep the concentration of the decomposed material at below the allowable limit.
	• Protective equipment	· Protective equipment for breathing: Wear a gas mask for organic gas. · Protective equipment for hands: Wear gloves which are resistant to organic solvents or chemicals. · Protective equipment for eyes: Wear protective goggles. · Protective equipment for skin and body: Wear them as required.

Precautions for Relevant Regulations

(1) Many types of CYTOP apply to Clause 5 in Table 1 of the Export and Trade Control Law in Japan. To export or take out CYTOP from Japan, you will need permission from the minister of Economy, Trade and Industry. The product must not be given to a third party.
(2) CYTOP applies to Export Administration Regulations (EAR) in the United States. Exporting or taking the product out of the US is controlled under the regulations.
(3) CYTOP must be used for industrial application. It has not been developed and manufactured for medical or food-related applications.

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