Plastics

Besides glass, plastics play a very important role in laboratories. In general, plastics can be divided into the three groups:

■ Elastomers

Polymers with loosely cross-linked molecules, exhibiting rubber-like elasticity at room temperature. Heating causes irreversible curing (vulcanization). The most popular Elastomers are natural rubber and silicone rubber.

■ Thermosets

Polymers with tightly cross-linked molecules are very hard and brittle at room temperature; heating causes irreversible curing. These plastics are rarely used for plastic labware. The best known thermosets are the melamine resins. Melamine resin is produced by polycondensation of melamine with formaldehyde.

■ Thermoplastics

Polymers with a linear molecular structure with or without side branches are transformed into objects during molding operations without changing their thermoplastic properties. Thermoplastics are the materials commonly used in plastic labware production. Hence we provide here a brief description of some individual plastics explaining their structural, mechanical, chemical and physical properties. The most popular thermoplastics are polyolefins like polyethylene and polypropylene.

PS **Polystyrene**

Polystyrene is glass-clear, hard, brittle, and dimensionally stable due to its amorphous structure. PS has good chemical resistance to aqueous solutions but limited resistance to solvents. Disadvantages include low thermal stability and its tendency to suffer from stress-cracks.

SAN **Styrene-acrylonitrile copolymer**

This is a glass-clear material with good resistance to stress-cracking. It has slightly better chemical resistance than PS.

PMMA **Polymethyl methacrylate**

Rigid, glass-clear ("organic glass"). Resistant to atmospheric agents. Replaces glass in many applications where temperatures are below 90 °C and low chemical resistance is required. PMMA has excellent UV radiation stability.

PC **Polycarbonate**

These are thermoplastic linear carboxylic acid polyesters combining many of the properties of metals, glass and plastics. The materials are transparent and have good thermal properties between -130 to +130 °C. Note: PC may be weakened by autoclaving or exposure to alkaline detergents.

PA **Polyamide**

Polyamides are linear polymers with repeating amide chain linkages. With their favorable strength characteristics and high durability, polyamides can often be used as structural materials and for surface coating metals. They have good chemical resistance against organic solvents, but are easily attacked by acids and oxidizing agents.

PVC Vinyl chloride polymers

The vinyl chloride polymers are mainly amorphous thermoplastics with very good chemical resistance.
Their combination with plasticizers opens up many useful applications, ranging from artificial leather to injection molding components. PVC has good chemical resistance, especially with oils.

POM Polyoxymethylene

POM has superior properties with regard to hardness, rigidity, strength, durability, chemical resistance and favorable slip and abrasion characteristics. It can replace metals in many applications. POM can withstand temperatures up to 130 °C.

PE-LD Low Density Polyethylene

The polymerization of ethylene under high-pressure results in a certain number of branches in the chain. PE-HD exhibits a less compact molecular structure than PE-HD, with very good flexibility and good chemical resistance, but less chemical resistance to organic solvents than PE-HD. Use is limited to temperatures below 80 °C.

PE-HD High Density Polyethylene

If the polymerization of ethylene is controlled by a catalytic process, a very small number of branches in the chain are obtained. The result is a more rigid and compact structure with enhanced chemical resistance and usability up to 105 °C.

PP Polypropylene

PP has a similar structure to Polyethylene, but with methyl groups at every second carbon atom of the chain. The major advantage, compared with PE, is its higher temperature resistance. It can be repeatedly autoclaved at 121 °C. Like the above mentioned polyolefins, PP has good mechanical properties and good chemical resistance but is sligthly more susceptible to be attacked by strong oxidizing agents than PE-HD.

PMP Polymethylpentene

PMP is similar to PP but has isobutyl groups instead of the methyl groups. Chemical resistance is comparable to PP but tends to suffer from tension cracks when exposed to ketones or chlorinated solvents. The most important qualities of PMP are its excellent transparency and good mechanical properties at temperatures up to 150 °C.

ECTFE
Ethylene-Chlorotrifluoroethylene copolymer

ETFE
Ethylene-Tetrafluoroethylene copolymer

These are ethylene copolymers of chlortrifluoroethylene and tetrafluoroethylene respectively. Both are plastics of high chemical inertness, but lower temperature resistance than PTFE.

PTFE Polytetrafluoroethylene

PTFE is a fluorinated carbon with a high-molecular, partly crystalline structure. PTFE is resistant to virtually all chemicals. It offers the widest working temperature range, from -200 to +300 °C. Its surface is adhesion resistant. The slip properties and electrical insulation capacity of the material are better than those of FEP and PFA. The only disadvantage is that it can only be molded by sintering processes. PTFE is opaque. It is suitable for use in microwave ovens.

FEP Perfluoroethylene-propylene copolymer

PFA Perfluoroalkoxy copolymer

These are fluorinated carbons with a high-molecular, partly crystalline structure. Their surface is adhesion-resistant. Mechanical properties and chemical inertness are comparable with those of PTFE. Temperature use is restricted to range -100 to +200 °C. The water absorption of FEP is extremely low. FEP and PFA are translucent.
PFA is manufactured without the addition of catalysts or plasticizers, and can be molded to produce an extremely smooth, readily cleanable surface, and is therefore particularly well suited for trace analysis.

General Properties

Resistance to breakage and low weight are important advantages of plastics. The application determines which plastic to select.

Many factors have to be taken into consideration: exposure time and concentration of chemicals, thermal stress (e.g., autoclaving), exertion of force, exposure to UV radiation, and aging, which may be caused by the action of detergents, or other environmental factors.

A careful evaluation of the necessary properties by the user is of prime importance. The recommendations listed here are based on technical literature and information provided by the manufacturers of raw materials. They were prepared carefully and are intended as general guidance. However, they cannot replace suitability testing perfomed by the user under actual working conditions.

Physical Properties

	Max. operating temperature (°C)	Brittle temperature (°C)	Micro wave suitability*	Density (g/cm³)	Flexibility	Transparency
PS	70	-20	no	1.05	rigid	transparent
SAN	70	-40	no	1.03	rigid	transparent
PMMA	65 to 95	-50	no	1.18	rigid	transparent
PC	125	-130	yes	1.20	rigid	transparent
PVC	80	-20	no	1.35	rigid	transparent
POM	130	-40	no	1.42	good	opaque
PE-LD	80 to 90	-50	yes	0.92	very good	translucent
PE-HD	105	-50	yes	0.95	good	translucent
PP	125	0	yes	0.90	moderate	translucent
PMP	150	0	yes	0.83	moderate	transparent
ECTFE/ETFE	150	-100	yes	1.70	moderate	translucent
PTFE	300	-200	yes	2.17	very good	opaque
FEP/PFA	205/250	-270	yes	2.15	moderate	translucent
FKM	220	-30	–	–	very good	–
EPDM	130	-40	–	–	very good	–
NR	80	-40	no	1.20	very good	opaque
SI	180	-60	no	1.10	very good	translucent

* Observe chemical and temperature resistance

Sterilization

	Autoclaving* at 121 °C, t_e 20 min to DIN	β/γ-radiation 25 kGy	Gas (ethylene oxide)	Chemical (formalin, ethanol)
PS	no	yes	no	yes
SAN	no	no	yes	yes
PMMA	no	yes	no	yes
PC	yes[1)]	yes	yes	yes
PVC	no[2)]	no	yes	yes
POM	yes[1)]	yes (restricted)	yes	yes
PE-LD	no	yes	yes	yes
PE-HD	no	yes	yes	yes
PP	yes	yes (restricted)	yes	yes
PMP	yes	yes	yes	yes
ECTFE/ETFE	yes	no	yes	yes
PTFE	yes	no	yes	yes
FEP/PFA	yes	no	yes	yes
FKM	yes	–	yes	yes
EPDM	yes	–	yes	yes
NR	no	no	yes	yes
SI	yes	no	yes	yes

* Before autoclaving, labware must be carefully cleaned and rinsed with distilled water. Always remove covers from containers!

[1)] Frequent autoclaving may reduce mechanical stability. PC centrifuge tubes may become unusable.

[2)] With the exception of PVC tubing, which is autoclavable up to 121 °C.

Biological Properties

The following plastics are generally non-toxic to cell cultures:

PS, PC, PE-LD, PE-HD, PP, PMP, ECTFE, PTFE, FEP, PFA.

Chemical Properties

With regard to chemical resistance, plastics are classified as follows:

+ = Excellent chemical resistance

Continuous exposure to the substance does not cause damage within 30 days. The plastic may remain resistant for years.

o = Good to limited chemical resistance

Continuous exposure to the substance causes minor damages, some of which is reversible, within 7-30 days (e.g., swelling, softening, decrease of mechanical strength, discoloration).

– = Poor chemical resistance

Not suitable for continuous exposure to the substance. Immediate(!) damage may occur (loss of mechanical strength, deformation, discoloration, cracking, dissolution).

Chemical resistance of plastics to categories of substances

Classes of substances at 20 °C	PS	SAN	PMMA	PC	PVC	POM	PE-LD	PE-HD	PP	PMP	ECTFE ETFE	PTFE FEP PFA	FKM	EPDM	NR	SI
Acids, weak or diluted	o	o	–	o	+	–	+	+	+	+	+	+	+	+	o	o
Acids, strong or concentrated	o	–	–	–	+	–	+	+	+	+	+	+	o	+	–	–
Oxidizing acids, oxidizing agents	–	–	–	–	–	–	–	–	–	–	+	+	o	o	–	–
Alkalis	+	+	+	–	+	+	+	+	+	+	+	+	o	+	+	o
Alcohols, aliphatic	+	+	–	+	+	+	+	+	+	+	+	+	–	+	+	+
Ketones	–	–	–	–	–	+	o	o	o	o	o	+	–	o	–	–
Aldehydes	–	–	o	o	–	o	–	+	+	o	+	+	+	+	o	o
Esters	–	–	o	–	–	–	+	o	o	o	+	+	–	o	o	o
Hydrocarbons, aliphatic	–	–	+	o	+	+	+	+	+	o	+	+	o	–	–	–
Hydrocarbons, aromatic	–	–	–	–	–	+	+	+	o	–	+	+	o	–	–	–
Hydrocarbons, halogenated	–	–	–	–	–	+	+	o	o	–	+	+	o	–	–	–
Ether	–	–	–	–	–	+	+	o	o	–	+	+	–	–	–	–

Abbreviations of the described plastics (to DIN 7728)

PS Polystyrene
SAN Styrene-acrylonitrile copolymer
PMMA Polymethyl methacrylate
PC Polycarbonate
PVC Polyvinyl chloride
POM Polyoxymethylene
PE-LD Low-density polyethylene
PE-HD High-density polyethylene
PP Polypropylene
PMP Polymethylpentene
ECTFE Ethylene-chlorotrifluoroethylene copolymer
ETFE Ethylene-tetrafluoroethylene copolymer
PTFE Polytetrafluoroethylene
FEP Perfluoroethylene-propylene copolymer
PFA Perfluoroalkoxy copolymer
FKM Fluoro elastomer
EPDM Ethylene-propylene-diene-rubber
NR Natural rubber
SI Silicone rubber