

Processing of PBS

PBS grades adapted to various processes are available on the market, with viscosities (and subsequent Melt Flow Index) adapted to standard plastic processing methods. **They are well adapted for all processes** (extrusion of foil, thermoforming and injection moulding) **but not for extrusion blowing and film production.**

PBS grades are suitable as pure materials, without equipment modifications. However some improvements may be needed depending upon processes and targeted application:

- for injection moulding : a quicker crystallization kinetics may be needed to decrease cooling time
- for thermoforming : a higher modulus at solid state and a better cohesion in the process condition may be needed
- for film blowing : bubble stability during film blowing operations has to be improved

To improve PBS processability, the following options should be advised:

| Increasing crystallization rate (injection moulding) | Increasing modulus at solid state and cohesion at molten state (foil extrusion - thermoforming) | Improving bubble stability (extrusion blowing) |
|---|--|--|
| <ul style="list-style-type: none"> - blending with PLA - blending with talcum powder - blending with TPS | <ul style="list-style-type: none"> - blending with PLA - blending with talcum powder | <ul style="list-style-type: none"> - blending with PBSA - blending with PBAT |

The formulation work has taken into account the need to find compromise between improving processability (increase crystallinity, ease film blowing ability, etc.) and maintaining good level of properties (brittleness vs softness). The main recommendations for PBS formulations are summarized below:

| Blending PBS with | Maximum content advised | Targeted process |
|-------------------|-------------------------|-------------------------------------|
| PLA | 15 wt% | Injection moulding Thermoforming |
| TPS | 15 wt% | Injection moulding |
| PBSA | 25 wt% | Extrusion blowing |
| PBAT | 15 wt% | Extrusion blowing |
| Talcum powder | 20 wt% | Injection moulding Thermoforming |

Processing guidelines have also been built depending on the nature of the polymer or compound and the process considered.

Prior to any processing, PBS and PBS-based compounds pellets should be dried 4 hours at 80°C in an oven or a desiccator except for blends with PBSA and PLA where temperature should be lowered (around 60°C).

Depending on processes, the following temperature ranges should be advised for selected PBS grades and PBS-based compounds:

| Processing method | Extrusion | Foil extrusion | Thermo forming | Injection moulding | Extrusion blowing |
|--------------------|--|-------------------|--------------------------------|------------------------------|-----------------------------|
| Material or blends | All except with PLA | PBS PBS-talcum | PBS PBS-talcum | PBS PBS-talcum PBS-TPS | PBS PBS-PBSA PBS-PBAT |
| Temperature range | 110-130°C | 110-130°C | 105-115°C | 130-150°C | Not suitable |
| Comments | Cooling in water Standard pelletizing | | Foil thickness >300 µm for PBS | Mould at ambient temperature | |

Higher temperatures may be used, up to ~200°C, however degradation and chain scissions may occur if residence time at those temperatures is not kept low (increase in fluidity and loss in properties are observed).

For blends with PLA, due to the higher melting temperature of PLA, processing temperatures have to be increased. The following ranges should be advised, in case PLA amount remains lower than 15 wt%:

| Processing method | Extrusion | Foil extrusion | Thermo forming | Injection moulding | Extrusion blowing |
|-------------------|--|----------------|----------------|------------------------------|-------------------|
| Type of blends | PBS-PLA | PBS-PLA | PBS-PLA | PBS-PLA | PBS-PLA |
| Temperature range | 160-170°C | 160-170°C | 110-120°C | 160-170°C | Not suitable |
| Comments | Cooling in water Standard pelletizing | | | Mould at ambient temperature | |

PBS is not compatible with a wide variety of polymers. An extended purge of the system might be considered.

In a nutshell, except the need of special grades for extrusion film blowing, the improvement of the material properties can be obtained through available commercial grades associated to different compounding strategies, by blending PBS and its copolymers with other aliphatic polyesters or with mineral fillers.

Guidelines for smart processing are proposed in Deliverable D.2.7.