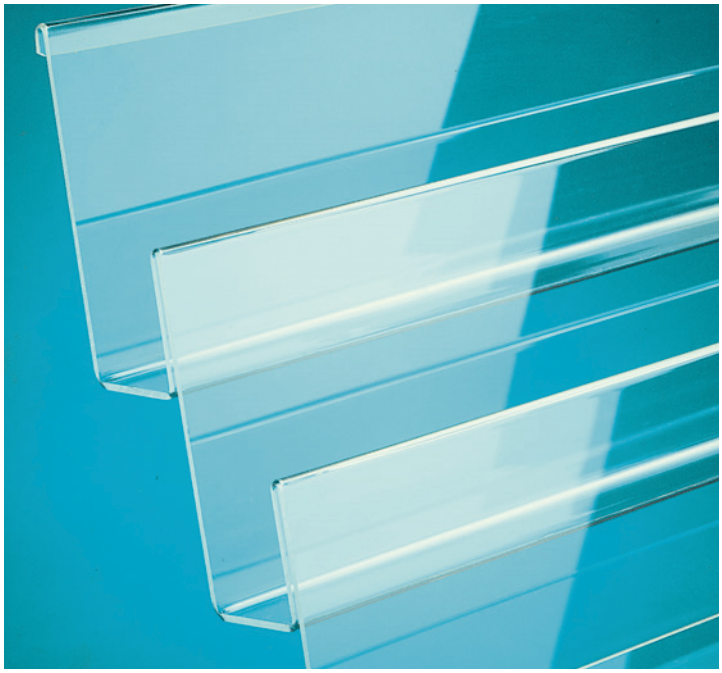
Vivak® plastics sheets offer superior thermoforming properties.



BAYER vivak®

Vivak® unites design and function in complex transparent shapes.

Our solid sheet products: Vivak®

	Vivak®	Vivak® UV
Logo		
The added extra:	• simple and cost-effective processing • good optical properties • good chemical resistance • good mechanical properties • food compatible	• simple and cost-effective processing • good weathering resistance
Colors	clear bronze fluo orange, red and green black	clear white translucent

The trademarks Vivak® and Vivak® UV stand for thermoplastic copolyester sheets with superior thermoforming behaviour and very good mechanical properties. These benefits offer designers virtually unlimited scope for realising complex transparent shapes.

The range of applications for this universal material go from industry to visual communications – displays, vending machines, shopfitting – right up to medicine. The constant high quality of these products is based on the use of carefully selected raw materials, comprehensive quality management and production processes certified to ISO 9002.

Contents

1. Fabricating

Fig. 1: Ribbon saw

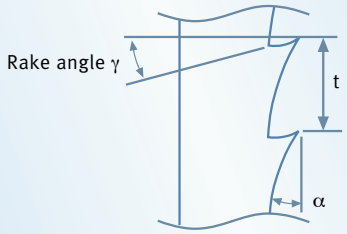
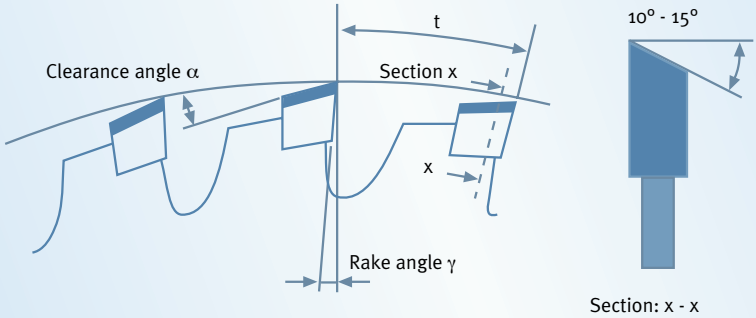


Fig. 2: Circular sawblade



1.1 General

Tools
Vivak® sheets can be machined using the standard tools commonly used for metal and woodworking. We recommend carbide-tipped tools. Above all, it is important to use sharp cutting tools with the right geometry.

Cooling
No cooling is required during the normal machining of Vivak® sheets. In the event of local overheating during machining, we recommend cooling with water or oil-free compressed air.

Oil emulsions and cutting oils should not be used when machining Vivak® as these may contain additives to which Vivak® is not resistant, resulting in stress crack formation.

Dimensional accuracy
The coefficient of linear expansion of Vivak®, being 0.050 mm/mK, is significantly higher than for metal or glass. For this reason, dimensions should always be checked at room temperature. Remember that shrinkage of approx. 3 to 6 % depending on thickness occurs when the material is heated above the glass transition temperature (approx. 81 °C) for the first time.

Masking
Vivak® sheets have a solvent-free PE masking film on both sides to ensure that the smooth surfaces are not damaged during transport and machining. This masking should be left in place during machining. Sunlight and weathering can affect the properties of the film with the result that it may under some circumstances be very difficult to remove any remaining masking.

Marking
Marking out drill holes, cut edges etc. should be done on the masking. If marking is required, use a soft pencil or felt-tip pen. Marking tools should not be used as the tracing mark has a notching effect, and a higher load at this point may cause the sheet to break.

1.2 Sawing

Hand saws
Standard hand saws may be used to separate Vivak® sheets. A saw with fine spacing between the teeth should be used.

Circular saws
Using a circular saw is the easiest way to cut Vivak® sheets. Experience has shown that carbide-tipped circular saw blades produce the cleanest cuts. The pitch varies from fine for thin sheets to coarse for thicker materials. Ensure that no shavings are left on the cutting surface as these could damage the masking and scratch the Vivak® sheets.

When handling sheets thinner than 2 mm use a thick underlay board or a pair of shears instead of a circular saw.

Band saws
Band saws are ideal for curved cutting of formed parts or irregular shapes. To achieve a clean cut edge it is important to work on a solid cutting surface. A wide pitch is required when working with thick materials. For higher quality cut edges, circular saws or routers achieve a better result than band saws.

	Band saw	Circular saw
Clearance angle α	20 -40°	10 -30°
Rake angle γ	0 -5°	5 -15°
Cutting speed v (m/min)	600 -1000	1000 -3000
Tooth pitch t (mm)	1,5 -3,5	2 -10

(see Figures 1 and 2)

Fig. 3: Clean cut edges

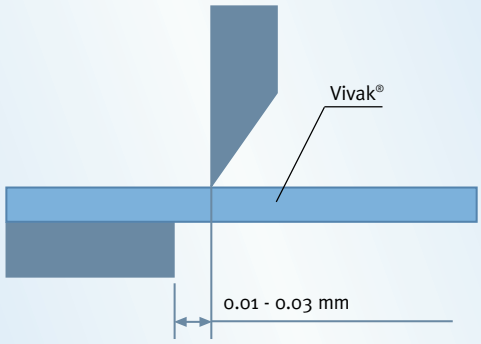
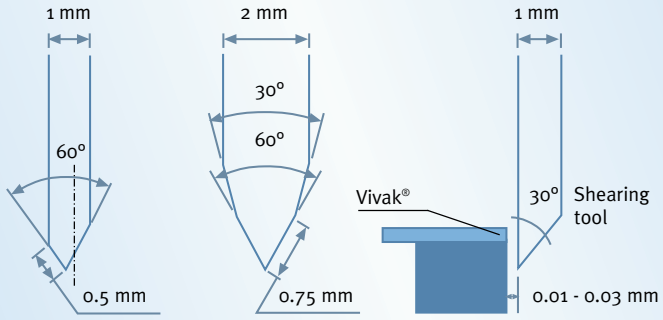


Fig. 4: Depending on sheet thickness, various differtent types of cutters are recommended for punching.



Trouble-shooting
Fused cut edge:
- Check tool sharpness
- Check cutting speed and reduce if necessary
- Check feed rate and reduce or increase as necessary
- Cool if necessary

Notched cut edge:
- Check tool sharpness
- Check tool geometry
- Check cutting speed and increase if necessary
- Improve cutting surface (use an underlay if necessary)

1.3 Cutting and punching

Vivak® sheets up to 3 mm thick are easy to cut and punch, producing a good result. The thicker the sheet, the poorer the quality of the cut and the greater the risk of cracking. Good results can be obtained using a sharp shearing tool with a wedge angle of max. 30°, with clearance between the tool and the cutting surface of 0.01 to 0.03 mm (see Fig. 3).

If you require smooth cut edges it is better to saw or mill Vivak® sheets with a thickness of 1.5 mm and upwards. When punching close-tolerance holes, allowance must be made for shrinkage if machining is to be followed by heat treatment of over 80 °C. This means that the hole should be measured approx. 5 % larger than actually required. The bigger the hole and the thicker the sheet, the lower the tendency for the sheet to shrink. Good results are obtained using symmetrically bevelled shearing tools.

For punching/shearing Vivak® sheets that are more than 1.5 mm thick, we recommend asymmetrically bevelled blades. To achieve right angles, blades on one side bevelled with a wedge angle of 30° should be used. Make sure that the back-up pad (polyamide or high density polyethylene) remains in place and is properly centered with the punching tool to ensure clean cut edges.

1.4 Drilling

Standard drills used for metalworking are perfectly suitable for machining Vivak®.

Make sure that the cutters on the drill are sharp. Cooling during drilling is generally not necessary. When working with relatively large drilling depths we recommend using water or compressed air and/or regularly with- drawing the drill from the hole to reduce heat and remove shavings.

Oil/water emulsions or cutting oils should not be used when drilling through Vivak® sheets. Standard circle-cutting equipment (e.g. circle cutters or compass saws) is suitable for large-scale drilling.

The drill holes should be smooth and as free as possible of notches or rough areas to ensure secure fastening.

Recommended angles for drilling:

Point angle φ.	110° - 130°
Helix angle β,	19° - 40°
Cutting speed	30 -60 m/min.
Feed	0,1 -0,3 mm/Rev.

(see Fig.5)

The distance between the drill hole and the edge of the sheet should be at least 1.5 times the diameter of the hole.

2.Forming

Fig. 5: Drills for Vivak® sheets.

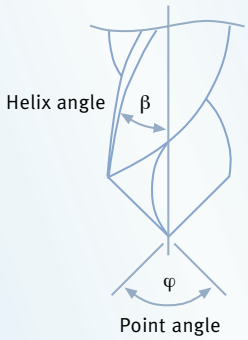
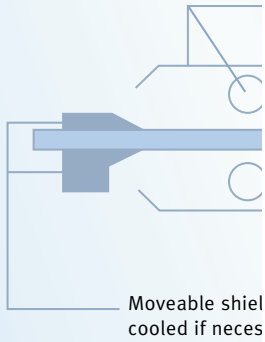


Fig. 6: Hot line blending



1.5 Milling

Vivak® sheets are easy to process using milling machines. The choice of milling machine depends on the type of machining required.

Ensure that your tool has good chip clearance and sharp cutters.

1.6 Laser cutting

Various designs of laser can be used for the thermal separation of Vivak® sheets – with or without masking. Lasers are particularly suitable for cutting complex contours. It is recommended that the sheets be annealed after the cutting process.

2.1 Cold forming

Cold bending
All Vivak® sheets can be subjected to cold bending with a minimum radius of 150 times sheet thickness.

Minimum radius = 150 x sheet thickness

Thermoforming is recommended for smaller radii.

Cold brake
Vivak® sheets can be cold formed. The best results are achieved with a rotating bending machine. Cavity folding is possible up to a thickness of 2 mm.

The relaxation immediately following the cold folding process means that the sheet has to be overstretched by approximately 25°. The internal and external stress levels take a few days to become balanced with the parts only then taking on their final shape.

The sheet should be folded parallel to the extrusion direction marked on the masking.

Bear in mind that cold brake forming places high stresses on the edge areas of the material. Avoid the use of

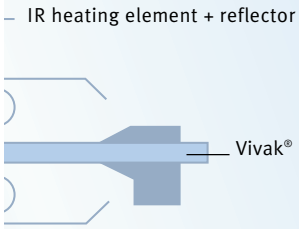


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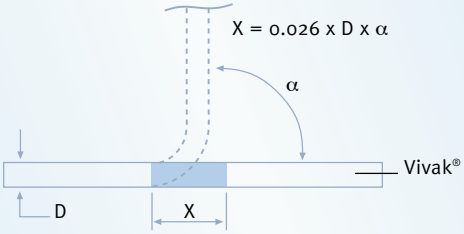
Fig. 7: Adjustment of heating zone



Heating zone X (mm)

aggressive chemicals, particularly with cold brake formed and cold bent parts.

The use of cold folding should be restricted to thin Vivak sheets.

2.2 Thermoforming

Vivak® sheets can be thermoformed even at low temperatures (100 to 160 °C).

Pre-drying
Vivak sheets do not need to be predried.

Hot line bending
Hot folding is a relatively easy forming process for the production of uniaxially formed parts. The Vivak® sheet simply requires local heating to approx. 100 °C. The masking does not need to be removed.

The Vivak® sheet is heated using IR heaters or heating elements in a linear manner (see Fig. 6). As soon as the ideal temperature is reached, the sheet is removed from the heating element, folded, placed in the mold and clamped into position. The desired shape should be fixed until the material rigidifies.

If using one-sided heating, the Vivak® sheet must be turned over several times to guarantee even heating on both sides. With sheet thicknesses of 2 mm or more and when producing large numbers of units, we recommend simultaneous heating of both sides using a sandwich heating appliance. By adjusting the heating width using the shields (see Fig. 7), various different bending radii can be achieved, although a minimum bending radius of 3 times the sheet thickness should not be undershot.

Local heating creates stresses in the finished part. Care should be taken when using chemicals with bent formed parts.

Heating during thermoforming
To achieve compliant formed parts, the Vivak® sheets should be heated evenly as part of a controlled process to a temperature of 100 to 160 °C. The best forming precision of the parts is achieved at the upper end of the forming temperature range.

Vivak® sheets cool quickly, so that we recommend that the sheets be heated directly on the forming machine and not – as is frequently done with other thermoplastics – in separate air circulating ovens.

For heating the Vivak® sheets we recommend IR heating systems, if possible two-sided, which can be heated up relatively quickly. The advantage of two-sided heating lies in the more even and quicker heating of the material. This enables shorter cycle times and is more economical.

Cooling the finished part
It is very important that Vivak® material is cooled quickly. It should be cooled using compressed air or – where possible – water fog mist until the parts are completely cooled.

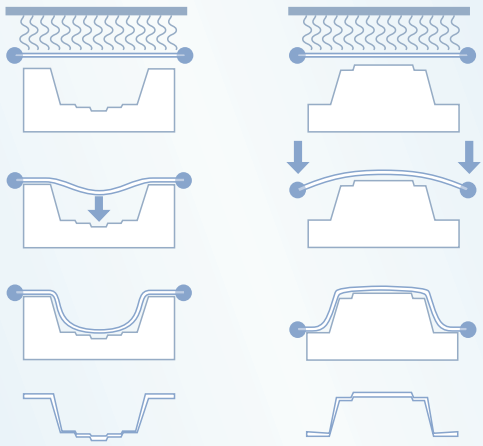
Vivak® shrinks by 0.4 % upon cooling.

Male forming
You can stretch simple, uniaxially curved mouldings with large bending radii. The Vivak® sheets are heated to the correct temperature in an air-circulation oven and rapidly conveyed to a mould heated to approx. 55 °C.

The inherent weight of the sheet or the exertion of slight pressure using gloves or fabric is sufficient to shape the sheet over the male mould.

Afterwards, the sheets must be subjected to air cooling. Caution: draughts may cause warping and internal stress.

Fig.: 8:



Female tool:
Details on the outer surface

Male tool:
Details on the inner surface

We advise you to remove the masking film before heating the sheet in an oven.

Thermoforming
Depending on the size of the production series and desired surface quality, tools made from different materials can be used.

Please note that the material selected will influence cooling time and surface properties. The mold should be sufficiently rounded.

Vivak® sheets effectively reproduce detail.

We recommend not polishing the surface of the mold but slightly matting it to avoid impressions on the formed part. When constructing forming molds, allowance should be made for shrinkage of 0.4 %. Special materials are available for producing porous forming tools without vents.

Male and female tools
The decision on whether to use a male or female tool depends on the application. To achieve a better surface quality on the outer side of the finished part, use of a female tool is recommended to attain greater detail.

Free blowing or free drawing
This technique is used to form domes. Blowing without a countermold involves working with air pressure, whilst the thermoforming process without a countermold is carried out in a vacuum.

To produce perfect moldings, the sheets should be evenly heated. At a sheet temperature of approx. 80 °C, the part retains its desired shape and can be removed.

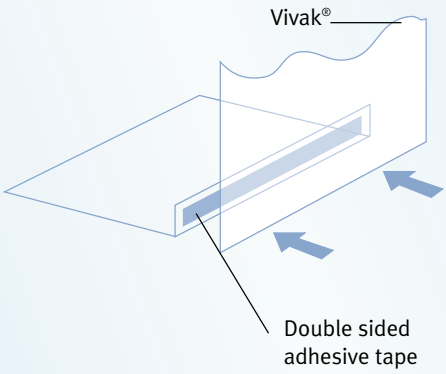
Thermoforming Tips

Problems	Possible causes	Solution	Hot bending	Thermo-forming	Free blowing/ free drawing
Badly formed parts					
	Sheets too hot	Reduce heating	•	•	•
	Production cycle too long	Shorten cooling period		•	•
	Vacuum speed too fast	Limit vacuum		•	
	Sharp edges	Round off edges		•	
Thin edges	Sheets too small	Use larger sheets		•	
Wave formation	Uneven heating	Check heating surface		•	•
	Too small a distance between molds	Increase min. distance between parts		•	•
	Vacuum too fast	Limit vacuum		•	•
	Sheet surface too large	Distance between clamp and tool < 50 mm		•	
Reduced details	Insufficient vacuum or compressed air	Increase vacuum or compressed air or check for lack of tightness		•	•
	Sheet temperature too low	Increase heating		•	
Molding sticks to mold					
	Mold too hot	Reduce mold temperature		•	
	Release angle too small	Release angle > 4°		•	
Impressions					
	Mold surface too smooth	Slightly matt tool		•	
	Sheet temperature too high	Reduce heating/heating time		•	
Surface defects	Dust on sheet or mold	Clean with ionized compressed air		•	•
Uneven finished parts					
	Heating/cooling	Check for draughts; check heating		•	•
	Release too fast	Sufficient cooling of part		•	
Tears or cracks	Excessive stress	Slow heating, heat large surface area	•	•	•

3. Bonding & Fastening

Be careful when working with solvents, since they may be toxic or contain carcinogenic substances. Good ventilation is essential. Please observe the indications in the safety data sheets of the respective solvent manufacturer.

Abb. 9: Bonding using adhesive tape.



When bonding Vivak® sheets, make sure to distribute the load evenly over the entire adhesive layer. Please ensure that the bond is not exposed to peeling stress, but only to shear or tensile stress (see figure: Recommended bonds).

Solvent-type adhesives are the simplest and most economical means of bonding parts made of Vivak®.

The addition of 8 % Vivak® chips provides a solution adhesive with reduced evaporation speed and increased viscosity, which makes it much easier for you to apply and handle. A further advantage of this solution adhesive is that it is gap-filling, meaning that the surfaces to be bonded do not need to be so flush as when using a pure solvent-type adhesive.

Please bear in mind the following during bonding:

- Thoroughly clean the surfaces of grease, dirt and other impurities using a soft cloth soaked in isopropyl alcohol;
- Apply the solvent-type adhesive in a thin layer to only one adherend surface (excess adhesive produces weak bonds);
- Place the surfaces on top of each other immediately and press them together briefly to ensure close contact over the entire surface;
- The bonded parts can be moved after only a few minutes, although the bond only reaches maximum strength after a few days, at normal room temperature (as the solvent gradually escapes from the bonded part.

Vivak® can also be bonded with other thermoplastics whose surface can be partially dissolved, using solvent-type adhesives. These bonds are generally rather weak, depending on the combined materials. In this case, preference should be given to adhesive bonding.

3.1 Bonding with adhesives

Please observe the general protective measures recommended by the respective adhesives manufacturer. Vivak® parts can be bonded with each other or with other materials using commercially available adhesives suitable for polyester.

When selecting the adhesive for a particular application, please bear in mind the following parameters: heat resistance, elasticity, appearance of the adhesive layer, ease of processing, etc.

Please remember during bonding:

- the adherend surfaces must be roughened and thoroughly cleaned to improve adhesion
- the instructions for use stated by the adhesives manufacturer must be observed.

3.2 Bonding with adhesive tape

Transparent, double-sided adhesive tape (acrylic based) may be used for rapid bonding. These tapes are elastic and adhere well to Vivak. They are particularly suitable for bonding thin Vivak sheets to other plastics, glass or metal.

Tips for good bonding:

- Fold the sheet so that it is slightly wider than the adhesive tape.
- Clean this area with isopropyl alcohol.
- Carefully apply the adhesive tape.
- Use a roller to apply even pressure to remove any air bubbles and improve adhesion.

Fig. 10: Avoid screws with beveled heads.

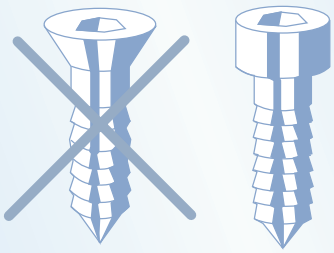
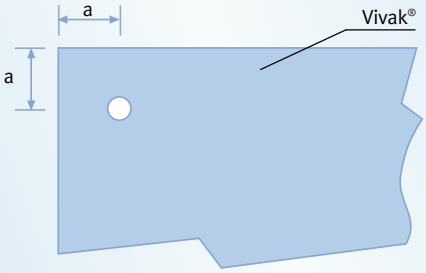


Fig. 11: Mechanical fastening

Distance a:
2 x ø hole, but at least 10 mm



3.3 Welding

Welding is mainly performed on opaque sheets. It does not produce optimum optical quality, and should therefore be carefully considered.

Should you nevertheless decide to weld the material, please bear in mind the following points:

- The Vivak® workpieces and welding rod, if required, must be cleaned before welding is performed to prevent dirt becoming trapped in the weld;
- To release the internal stress that occurs during welding due to local thermal expansion, the workpiece should be annealed after welding.

Hot-gas welding
We recommend an air volume of 50 – 100 l/min and an air temperature of 250 – 300 °C, measured 5 mm in front of the nozzle. Round or profiled extruded rods, or even narrow strips cut from a Vivak® sheet, can be employed as welding rods.

Ultrasonic welding
Vivak® sheets can be joined by means of ultrasonic welding. Please contact the relevant manufacturers for detailed information on ultrasonic welding devices and welding conditions.

3.4 Mechanical fastening

Due to its good impact resistance, Vivak® can be fastened mechanically using any method.

When using screws, opt for screws with a cylindrical head to bond various parts further and avoid any with beveled heads, as these can cause cracking (see Fig. 10). Drill holes should be measured to allow for expansion and shrinkage.

All plastic screws are suitable. When using metal screws a suitable plastic underlay is required. Avoid over-tightening screws. Use a through bolt rather than cutting a thread in the sheet.

The table below shows the expansion of a sheet measuring 1 m in length under a temperature increase of 20 °C.

	Linear thermal expansion coefficient (mm/mK)	Expansion at Δ 20 °C (mm)
Vivak®	0.050	1.00
Aluminium	0.024	0.48
Steel	0.012	0.24
Glass	0.008	0.16

4. Finishing

4.1 Polishing

Flame Polishing
Propane, butane or other types of gas burner may be used for flame polishing.This technique can produce excellent results but requires experience and ongoing practice. Cracks may appear in the polished area in the long term.

Buffing
Medium-density reiter polishing wheels with a peripheral velocity of 20 to 30 m/s can be used to polish Vivak® sheets with alkali-free polishing pastes. A clean polishing wheel without polishing paste is then used to complete the polishing process.

Large-surface polishing should be avoided.

4.2 Decorating

Before treating Vivak® sheets – e.g. by coating, screen printing or thermoforming – we recommend removing any loose particles of dirt or dust adhering to the surface using ionized air (see Section 5 on Cleaning).

Transfer printing
Vivak® sheets and finished parts can be printed using transfer printing.

Screen printing
Vivak® may be printed with standard screen printing equipment and inks suitable for thermoplastic polyesters (PETG). The ink manufacturer 's recommendations should be followed.

Vivak® sheets can be printed with UV-cured inks. The short-term UV radiation has no impact on the physical properties.
The maximum application temperature of 65 °C should not be exceeded during the drying process.

Coating
After prior cleaning, Vivak® may be coated without being pre-treated. The coatings must be suitable for use with Vivak®.

5. Cleaning

Vivak® has a pore-free surface to which it is difficult for dirt to adhere. Dusty parts can be cleaned with water,
a soft cloth or a sponge but **should never be rubbed when dry!**

For thorough cleaning, we recommend a non-abrasive detergent. Razor blades or other sharp tools, abrasive or strongly alkaline detergents, solvents, leaded benzine and carbon tetrachloride should not be used.

The only way to achieve effective cleaning without streaks is to use a microfiber cloth that is simply dampened with water. In the case of a greater build-up of dirt or greasy stains in particular, benzene-free pure petroleum spirit (cleaner 's naphtha or light gasoline)may be applied.

Splashes of dye, grease etc. may be removed using a soft cloth soaked in ethyl alcohol, isopropyl alcohol or petroleum ether (boiling point 65 °C) and gentle rubbing prior to curing.

Vivak® has good electrical insulation properties resulting in electrostatic charging and the attraction of dust particles.

Before treating Vivak® sheets we recommend removing any loose particles of dirt or dust on the surface by blowing with ionized air. The particles cannot be removed using a normal compressed air gun or a cloth but will generally just be moved around.

6. Material properties

Properties	Values	Unit	Test method
Physical			
Density	1.27	g/cm³	DIN 53479
Moisture absorption: 23 °C, 24 h immersion (3 mm)	0.2	%	
Refractive index at 20 °C	1.57	%	DIN 53491
Mechanical			
Tensile stress at yield	50	N/mm²	DIN 53455 (1)
Elongation at yield	5	%	DIN 53455 (1)
Tensile strength	26	N/mm²	DIN 53455 (1)
Elongation at break	›100	%	DIN 53455 (1)
Tensile modules of elasticity	2050	N/mm²	DIN 53457 (2)
Limiting flexural stress	77 - 83	N/mm²	DIN 53452
Impact strength: - Charpy unnotched	no break	kJ/m²	DIN 53453
- Charpy notched	16	kJ/m²	DIN 53452
- Izod notched (4 mm)	90	J/m	ASTM D256
- Instrumented impact (4 mm) at Fmax	28	J	ASTM D3763
Rockwell hardness	R104-R117	class	ASTM D785
Thermal			
Glass transition temperature	81	°C	
Thermal conductivity	0.32	W/m °C	DIN 52612
Coeff. of linear thermal expansion	0.050	mm/m °C	
Heat deflection temperature under load acc. to ISO/R75			DIN 53461
- Method A: 1.81 N/mm²	63	°C	
- Method B: 0.45 N/mm²	70	°C	
Max. service temperature in air (3)	65	°C	
Min. service temperature	-40	°C	
Electrial			
Dielectric strength (4)	20	kV/mm	ASTM D149
Volume resistivity	10^{15}	Ohm·cm	DIN 53482
Surface resistivity	10^{16}	Ohm	DIN 53482
Dielectric constant bei 10^3 HZ	2.6	-	DIN 53483
bei 10^6 HZ	2.4	-	DIN 53483
Dielectric factor bei 10^3 HZ	0.005	-	DIN 53483
bei 10^6 HZ	0.020	-	DIN 53483

The above -mentioned values are typical values at 23 °C, unless otherwise stated. They are intended as a guideline for material determination. They cannot be used for drawing up material specifications. They do not discharge the user of effecting his own tests in order to determine whether a material is suitable for the application.

(1) Test speed: 50 mm/min.

(2) Test speed: 5 mm/min.

(3) Temperature resistance over a period of several month to several years. The given temperature limits are determined by the thermal-oxidative degradation which takes place and causes a fall-off in properties (embrittlement). Besides, as for all thermoplastics, the maximum service temperature depends essentially on the duration and the magnitude of the mechanical stress to which the material is subjected.

(4) Measured on a 2 mm thick test specimen. As with other materials, the dielectric strength dimishes with increasing sheet thickness, e.g. for 3 mm sheet the dielectric strength is 16 kV/mm, for 6 mm sheet 11 kV/mm.

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