TECHNICAL PAPER

DEVELOPMENTAL BIAXIALLY-ORIENTED PEEK FILM FOR FLEXBILE ELECTRONICS

HIGH TEMPERATURE CAPABILITY, FLEXIBILITY AND STRENGTH

Victrex plc
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SHAPING FUTURE PERFORMANCE

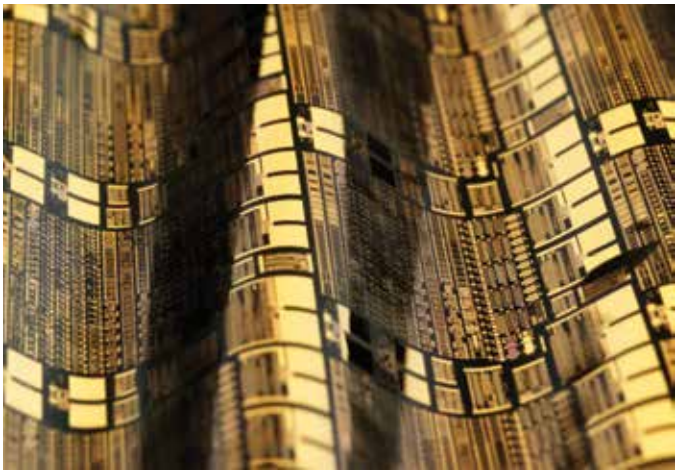
Flexible electronics in light of Internet of Things have been pushing the performance envelope for thin film substrate in emerging applications and processing technologies to shape future performance, such as wearables and hybrid systems, encompassing silicon, lithographic and printed electronics. Applications in aerospace, automotive, medical and power electronics can demand more from the substrate than traditional film substrate materials can deliver.

From its beginnings as the first company to commercialise PEEK over 35 years ago, innovation has been at the core of Victrex values. As a result, Victrex is a world leader in specialised development of high performance, PAEK-based solutions and applications for extreme environments. Following success of APTIV™ film, Victrex is now working with third parties to develop new technology to make biaxially oriented polyetheretherketone (BOPEEK) film with potential for use as a substrate in flexible electronics applications.

This paper presents potential benefits of BOPEEK film based on preliminary data generated from tests* at Victrex. Evaluation samples of the films may be available in limited quantities and configurations subject to change. With a temperature capability above 250°C, BOPEEK film made with VICTREX™ PEEK has the potential to provide a bridge between organic and high temperature inorganic oxide technologies, allowing both classes of materials to be processed on the same substrate, with consequent performance advantages and design freedom.

BIAXIALLY-ORIENTED PEEK FILM

BOPEEK film has the potential to be used in the flexible electronics applications due to its excellent high temperature performance with good clarity, low shrinkage, excellent chemical resistance and its suitability for foil-on-carrier or roll-to-roll processing. The advantages of BOPEEK film over other commonly used films for flexible electronics such as polyethylene naphthalate (PEN) and polyethylene terephthalate (PET) are expected to be its high temperature stability and, when compared with polyimide (PI), its moisture and chemical resistance. With a melting point of 343°C, BOPEEK film is able to extend the processing window for flexible electronics up to 250°C for film-on-carrier processing.



Transistors on thin BOPEEK film de-bonded from carrier

BOPEEK FILM POTENTIAL BENEFITS

- Allows high temperature sintering up to 250°C
- Enables thinner devices to be made with increased flexibility
- Suited to transistor processing for high electron mobility (oxide transistors)
- Versatile thermoplastic material that can be welded/bonded/thermoformed

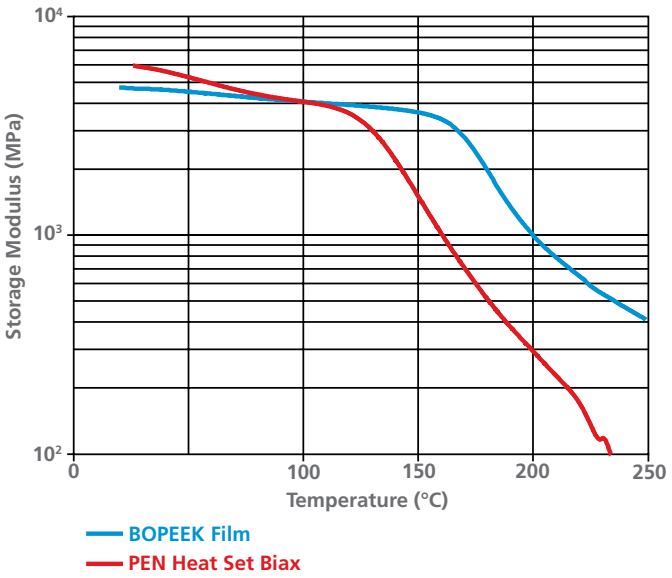
BOPEEK FILM FEATURES

- High temperature capability
- Suited to bond/de-bond process
- Strong yet flexible
- Thin film format
- Clear and colourless
- Low shrinkage
- Excellent chemical resistance
- Excellent hydrolysis resistance
- Low moisture uptake

THERMAL PROPERTIES

BOPEEK film can be produced as a clear, colourless substrate with excellent stability at temperatures in excess of 250°C. Figure 1 illustrates the thermo-mechanical properties of BOPEEK film in comparison with PEN film, as measured using DMA.

Figure 1[1]: Dynamic Mechanical Analysis (DMA)



The modulus of BOPEEK film is comparable to PEN at room temperature, so has similar flexibility at an equivalent thickness. However, BOPEEK film has a higher stiffness throughout its working range of temperatures above the T_g of PEN and is therefore easier to handle on a high temperature roll-to-roll process such as may be applied to oxide transistor processing.

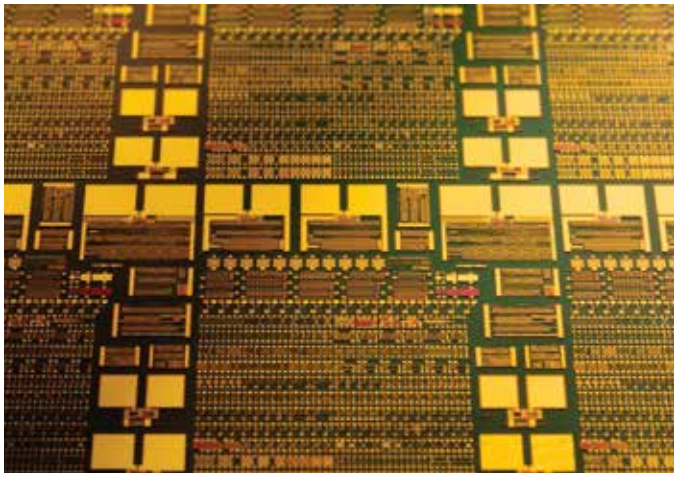
BOPEEK film displays ultra low levels of shrinkage, even at 250°C. The coefficient of thermal expansion (CTE) is comparable with PEN up to T_g.

SURFACE SMOOTHNESS

BOPEEK film is readily 'planarized' to provide an ideally smooth surface finish, as necessary for fine detailed and thin electronic structures. BOPEEK film with surface Ra values of <5nm (as measured using AFM) have been produced by roll-to-roll and spin coating.

FLEXIBILITY AND STRENGTH

BOPEEK film is highly flexible and strong, and would enable the production of displays that can be folded or rolled for next generation devices.



Thin film transistors with high overlay accuracy on top of BOPEEK film

MOISTURE UPTAKE

BOPEEK film shows low moisture absorption and, as a consequence, stable properties under general atmospheric conditions of 50% RH, ISO 62:2008(E). Equilibrium moisture content is low at only 0.5% by weight compared with 4% for polyimide film.

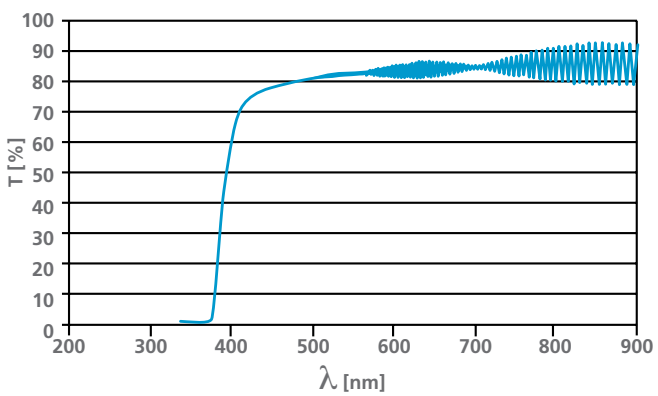
CHEMICAL RESISTANCE

BOPEEK film has excellent resistance to a wide range of chemical environments including common solvents, strippers and reagents used in the processing of electronic devices. Tests have shown no yellowing, cracking or changes in light transmission after exposure to common chemicals in this industry. BOPEEK film is indium tin oxide (ITO) process compatible. Compared with polyimide film, BOPEEK film is significantly more resistant to hydrolysis.

OPTICAL TRANSPARENCY

Polymer processing creates a clear nearly 'water white' film with a good level of light transparency over the visible range of wavelengths, as illustrated in Figure 2.

Figure 2[1]: Transmission as a Function of Wavelength



LAMINATION

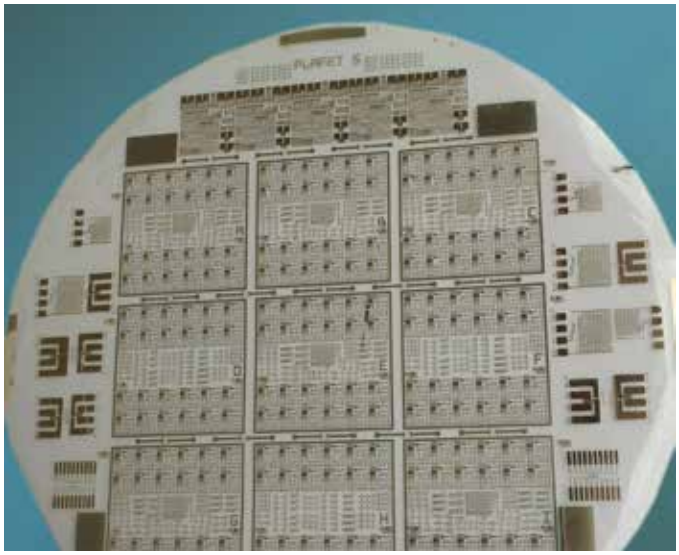
BOPEEK film could be laminated onto a variety of substrates including glass and silicon (Si) wafers using permanent or temporary adhesives for so called 'bond/de-bond' processing, developed for display backplanes, as illustrated in Figure 3. Such laminates have successfully been exposed to 250°C in air and 300°C in inert environments with no delamination or blistering.

Figure 3[1]: BOPEEK film laminated on a silicon carrier

MIM STACKS

The backplane for a display, containing the thin film transistors (TFT), is the most critical part of the flexible display; the processing of which requires high alignment accuracy. Metal-insulator-metal (MIM) stack demonstrators, in the form of organic light-emitting diode (OLED) backplane displays, have been produced using a BOPEEK film substrate of 25µm thickness on a silicon carrier. This process involved a number of lithography steps, including exposure to heat, etchants and strippers.

The properties of the resulting transistors have been measured together with overlay accuracy of gate, source and drain.



MIM Stack on BOPEEK Film[1]

OVERLAY ACCURACY

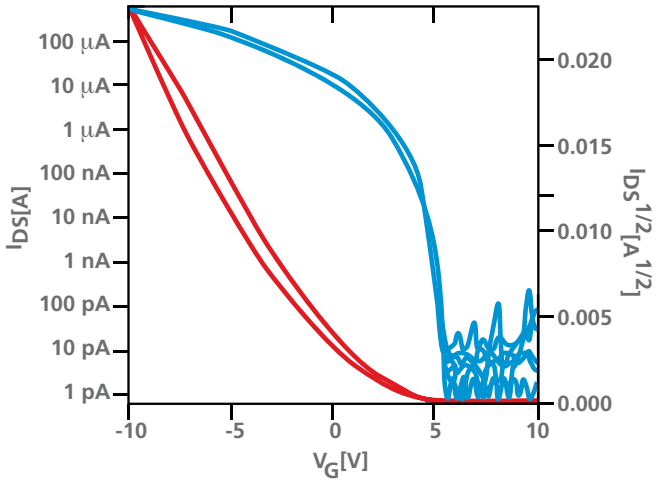
The overlay high accuracy of gate, source and drain layers has been achieved and the results for BOPEEK film are comparable with best-in-class flexible substrates.

TRANSISTOR PERFORMANCE

The current-voltage (I-V) performance of organic thin film transistors (OTFTs) on BOPEEK film is shown in Figure 4. Electron mobilities are comparable with OTFTS on PEN film.

Oxide transistor can be also manufactured on BOPEEK film at high annealing temperatures to maximise their performance.

Figure 4[1]: Organic Transistor Performance of BOPEEK Film



Mobility: 0.66 cm²/(V.s)

CONCLUSION

Versatile high performance BOPEEK film has the potential to provide the right balance of high temperature capability, flexiblity and strength to successfully design displays for next generation flexible electronics. The use of these thin, lightweight films in applications such as displays, sensors and RFID tags could help to lower cost, improve performance and reliability, it can also provide optical transparency required for certain electronic applications.

* data on file at Victrex, available on request

[1] As part of development work at the Holst Centre in Eindhoven, Netherlands.

APPENDIX 1

BOPEEK Film Typical Properties*

*data based on test with reference to BOPEEK film made with VICTREX™ PEEK

Property	Test Method	Units	(MD)	(TD)
Tensile Modulus	ISO 527-3 (50mm/min)	GPa	3.7	4.1
Tensile Strength (at break)	ISO 527-3 (50mm/min)	MPa	215	321
Tensile Elongation (at break)	ISO 527-3 (50mm/min)	%	150	124
Puncture Strength	Def Stan 81-75	kJ/m²	9.1	
Tear Strength	ISO 6383-1	N/mm	1.8	1.5
Shrinkage: 200°C 250°C	Victrex Internal Test Method	%	 ≤1 ≤2	 ≤1 ≤2
Water Absorption (50% RH)	ISO 62:2008(E)	%	0.5%	
Pencil Hardness	ISO 15184		4H	
Gloss Units: 20° 60°	Victrex Internal Test Method	Gloss Units (GU)	 72 184	 77 182
Flammability	UL94	nil	VTM-0	VTM-0

APPENDIX 2

BOPEEK Compared With Other Substrates For Use In Flexible Electronics*

*data (excluding BOPEEK) was originated in a paper by Choi et.al. (2008). Victrex has added BOPEEK for the purposes of comparison.
Choi, et.al. (2008) Polymers for flexible displays: From material selection to device applications, Progress in Polymer Science. Vol 33 (2008) 581–630.

Polymer Substrates	Amorphous				Semi-crystalline		
	PC	PAR	PES	PI	BOPET	BOPEN	BOPEEK
Optical clarity	++	+	+	−−	+	+	+
Process temperature	−	++	+	++	−	+	++
Dimensional stability	−	−	−	+	+	+	+
Surface roughness	+	+	+	+	−−	−−	−−
Solvent resistance	−−	−−	−−	+	+	+	++
Water uptake	−	−	−−	−−	+	+	+
Young's Modulus	−	−	−	−	+	+	+

ABOUT VICTREX

Based in the UK, Victrex is an innovative, leading global provider of high-performance polymer solutions for the aerospace, automotive, electronics, energy and medical industries. Every day, millions of people use products and applications containing our polymers – from smart phones, aircraft and cars all the way to medical devices via oil and gas installations. With over 35 years' experience, we provide cutting-edge technological solutions that shape future performance for our customers and markets, and drive value for our shareholders. Further information is available online at www.victrex.com

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