Plastic Displays – Latest Developments In Polyester Film For Plastic Electronics

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Abstract

DuPont Teijin Films (DTF) have developed a family of films engineered specifically for the flexible electronics market. Teonex®Q65A is a biaxially oriented crystalline polyester with an engineered surface and it is emerging as a competitive material for the base substrate in OLED displays and active matrix backplanes. This contribution will describe the properties of this film, its uniquely different property set compared to amorphous high performance films and discuss examples of the film in use in flexible electronic applications.

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1. Introduction

There is currently considerable interest in flexible displays and many electronic based companies are actively researching flexible displays based on liquid crystal displays (LCD), organic light emitting diodes (OLEDs) and electrophoretic displays. To replace glass however, a plastic substrate needs to be able to offer the properties of glass i.e. clarity, dimensional stability, thermal stability, barrier, solvent resistance, low coefficient of thermal expansion coupled with a smooth surface. No plastic film offers all these properties so any plastic based substrate will almost certainly be a multilayer composite structure [1-5]. In addition to choosing the right materials for the different layers, one now has a new set of issues associated with the properties of multilayer structures. These issues include the adhesion between the different layers, the effect of thermal and environmental cycling and the effect of flexing the structure on not only specific properties such as barrier and conductivity, but also the robustness of the total structure. Understanding the impact of these effects and optimising both the product structure and the processing steps involved in device manufacture will be critical to achieving the demanding property requirements being asked of substrates in flexible electronic based applications. The properties of Teonex® Q65A have been discussed in detail elsewhere[1-5] and the key propeties relevant to display manufacture are summarised in Figure 1. This figure shows that has an excellent balance of the key properties required for flexible electronics and it is this property set that is leading to Teonex® Q65A emerging as a competitive material for the base substrate of OLED displays and active matrix backplanes.

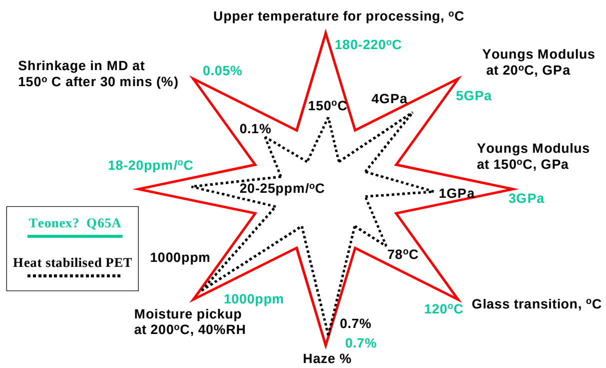

Fig 1 Key properties of Teonex® Q65A compared with heat stabilised PET film

2 Optical Properties

All the films considered have good optical properties except polyimides which tend to be yellow. The base films are likely to have additional coatings which act as planarisers or hardcoats –it is essential that these coatings do not affect the optical properties.

2.1 Rigidity

Production of glass based displays currently involves moving batches of glass between the different processing stages. The mechanical difference, in particular stiffness between rigid glass and flexible substrates will likely require very different methods of processing. Polyethylene terephthalate (PET) and PEN films are inherently stiffer than amorphous films with their Youngs Modulus being typically three times higher-an artefact of being semi-crystalline and biaxially oriented

2.2 Dimensional Stability

Dimensional and thermal stability is critical in order to withstand the high temperatures of deposition of the barrier and ITO coatings, to ensure the registration of the different layers in the final device and for the multilayer device to be able to withstand thermal cycling. The dimensional stability in terms of the shrinkage and the coefficient of linear thermal expansion (CLTE) of Teonex® Q65A has been discussed in detail in previous papers [2,3,4] Teonex® Q65A is dimensionally stable up to the temperature at which it has been stabilised and typical laboratory measured shrinkages are of the order of 300ppm after 30 minutes at 150^{o}C. Dimensional reproducibility down to 25ppm is being requested for the more demanding applications such as inorganic AM backplanes on flexible substrates and it has been shown that it is possible to achieve this level of shrinkage [6]. In addition to this residual shrinkage, the processing environment, in effect the prevailing humidity, must be taken into account. With a knowledge of the solubility level of moisture in PEN film and its rate of diffusion as a function of temperature, it is possible to model the impact of such environmental conditions on volumetric changes in the film.

2.3 Maximum Operating Temperature

The upper operating temperature of the potential substrates for flexible electronics can be summarised as:-

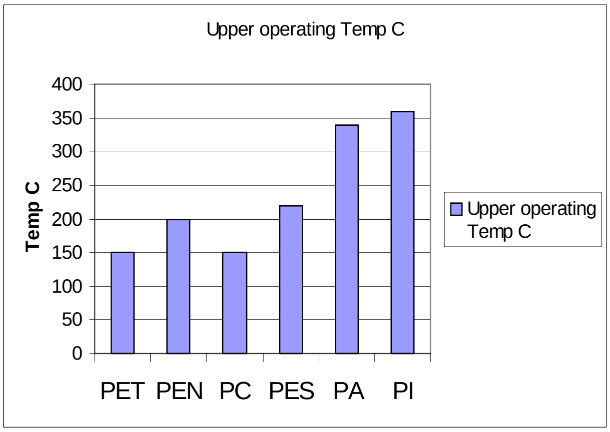

Figure 2. Upper Operating Temperatures of Flexible Substrates

3. Surface Quality

Teonex® Q65A has a proprietary surface coating which imparts excellent surface smoothness and hardness-this has been discussed in previous papers [2,3,4,5]. The surfaces have been characterised by white light interferometry (WYKO). Average roughness is given by the Ra and Rq representing the majority of the surface area in the table below (Table 1).

Table 1. WYKO Analysis of uncoated and coated PEN

	Uncoated PEN film	Coated PEN film
Average Roughness (Ra)	0.64	0.58
Root Mean Square Roughness (Rq)	0.9	0.74

Surface smoothness and cleanliness of the Teonex ®Q65A films are both essential to prevent pinholes in subsequent barrier coatings and to ensure the integrity of the ITO conductive coating.

4. Properties of Multilayer Structures

The final engineered substrate for OLED displays will be a multilayer structure. Issues such as adhesion at the interface between the different layers under thermal cycling and environmental testing, curl, the wetting characteristics, ability to withstand flex testing etc will be critical to determining their robustness in use. The planarising coating under development within DuPont Teijin Films is optimised to survive a boil test in water. The choice of pretreat on the Teonex® Q65A before application of the planarising coating is critical. The planarised substrate passes a tape adhesion test after 2 minutes in boiling water.

The proprietary planarising coating does not show significant thermal degradation as measured by weight loss until over 300°C. The coating is more thermally stable than acrylic based coatings which start to show significant thermal degradation above 250°C.

5. Roll to Roll Processing

One of the main drivers in moving to plastic substrates is that it opens up the possibility of roll to roll processing (R2R) and the process and economic advantages that this brings. Under these conditions a winding tension will clearly be present and polymer film substrates with low moduli will be susceptible to internal deformation, particularly at elevated process temperatures. Figure 3 shows a comparison between PET and PEN films. The storage modulus, E' is recorded using DMTA and as the temperature is increased, the stiffness of both materials is seen to fall. However in the region 120 – 160°C PEN is significantly stiffer and stronger, with a modulus almost twice that of PET.

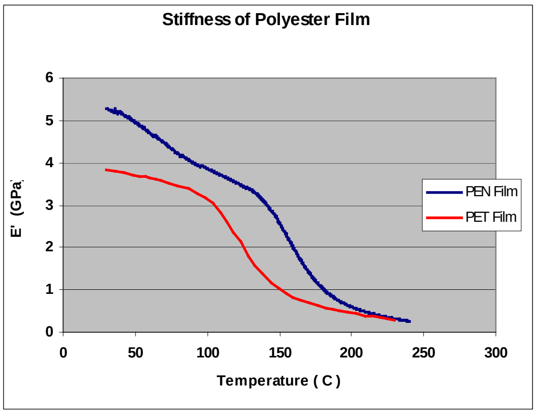

Figure 3. Stiffness of Polyester film with temperature

6. Summary

As discussed above plastic based substrates for flexible electronic are likely to be multilayer structures. To date the main focus has been on achieving a particular property in a particular layer e.g. barrier or conductivity. However as these structures become more complex it becomes increasingly important to consider the structure as a whole and to understand how the composite structure will behave both through device manufacture and also in use. For example through careful optimisation of the layer structure in display design it may be possible to minimise failure due to mechanical stresses. In addition an understanding of the impact of the environmental conditions during processing will be critical to minimising the effects of moisture on dimensional registration. Studies of this kind will be essential to achieving the demanding performance criteria required for substrates in flexible electronics applications.

7. References

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