Effect of anti-block particles on oxygen transmission rate of SiOx barrier coatings deposited by PECVD on PET films

Pierre Fayet, Bertrand Jaccoud, Richard Davis, Dagmar Klein

A collaboration between:

Tetra Pak protects what's good™

MITSUBISHI POLYESTER FILM

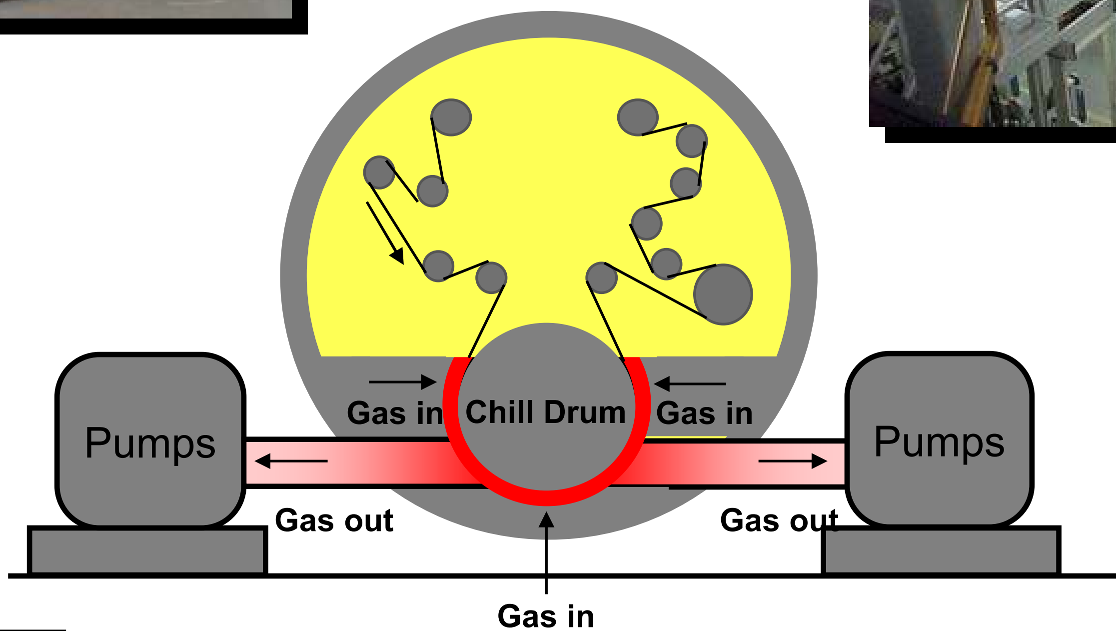
AIMCAL Fall Technical Conference and 18th International Conference on Vacuum Web Coating October 24 – 27, 2004, Francis Marion Hotel, Charleston, SC

Industrial PECVD Equipment at Tetra Pak

Typical OTR-Values:

Plain PET 12 µm
120 $cm^3/m^2/day/atm$

PET/SiOx (15 nm)
< 3 $cm^3/m^2/day/atm$



Plasma = Electrical Power + Gas mixture (Disiloxane, Oxygen)

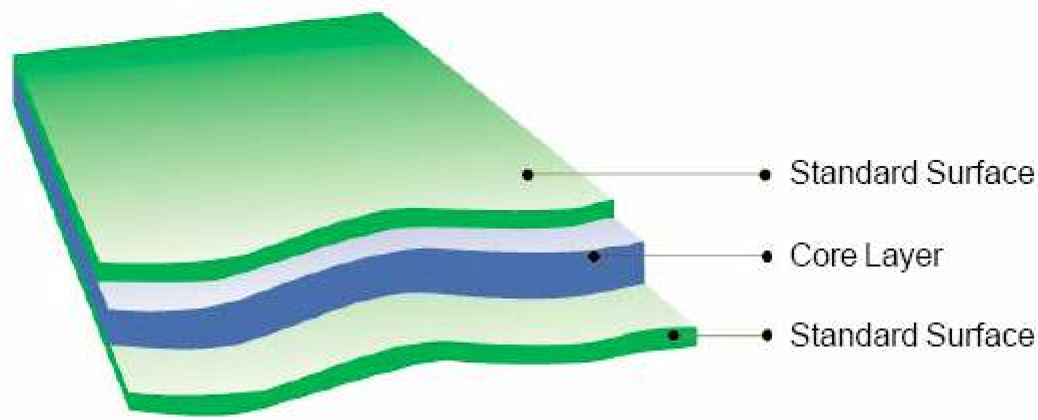
Tetra Pak
protects what's good

®Hostaphan RNK

Universal film with low haze

®Hostaphan RNK is a highly transparent, biaxially oriented, co-extruded film, made of Polyethylene Terephthalate (PET) and characterized by out-standing physical properties.

Layer structure ®Hostaphan RNK

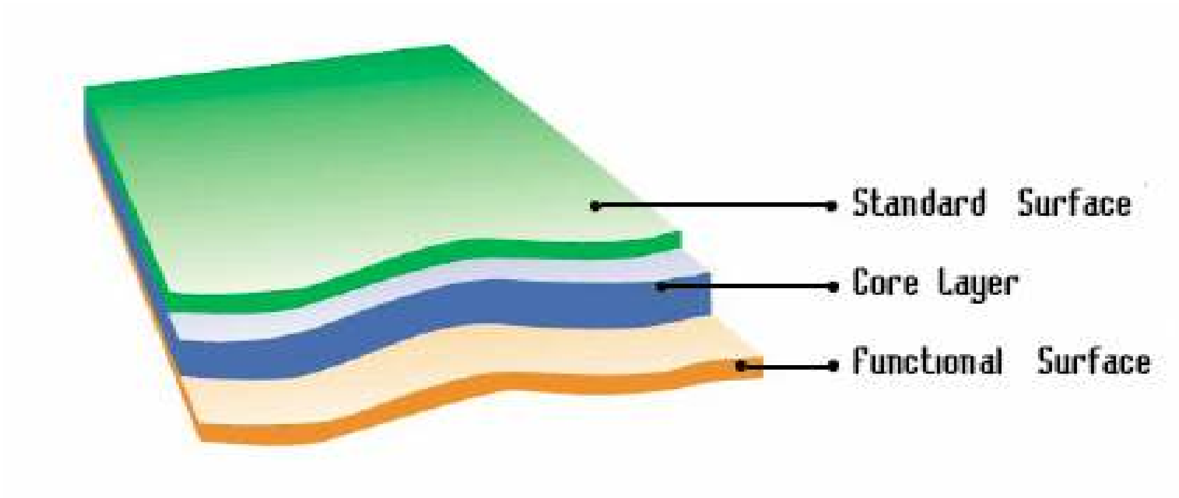


®Hostaphan RD

Film with one very smooth and glossy surface

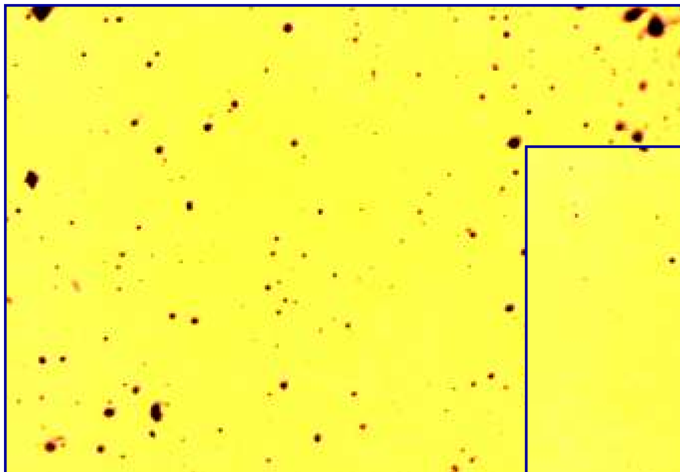
®Hostaphan RD is a highly transparent, biaxially oriented, co-extruded film, made of Polyethylene Terephthalate (PET) with different topography of the two surfaces. While the surface structure of one surface is the same as a standard PRT film, the functional surface side displays an extremely regular surface structure with very low roughness.

Layer structure ®Hostaphan RD

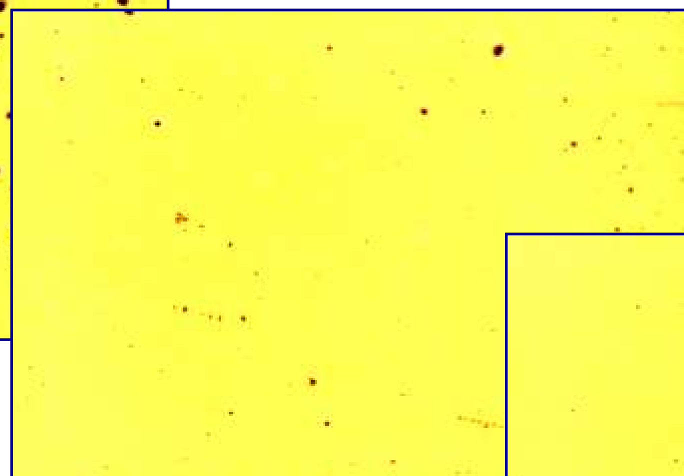


PET Film Characterisation

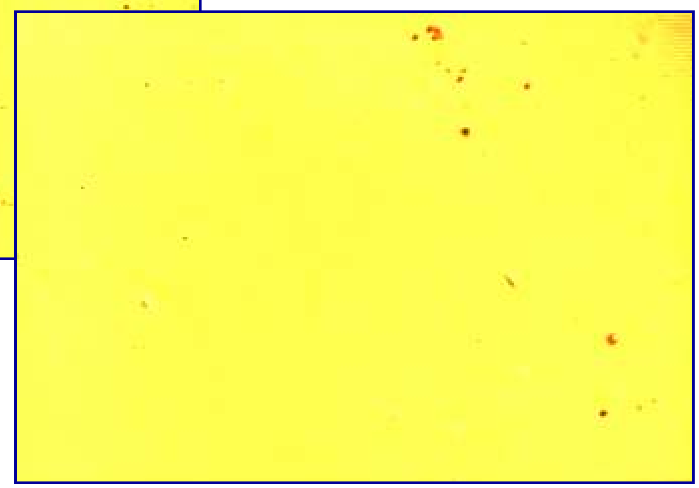
Reflexion Optical Microscopy (490x330 μm^2)



RNK12



RD12



RDO12

Defects on PET Films

Size dispersion of anti-blocking silica and dust particles

Defects of various sizes

0 15 μm

Silica Anti-blocking

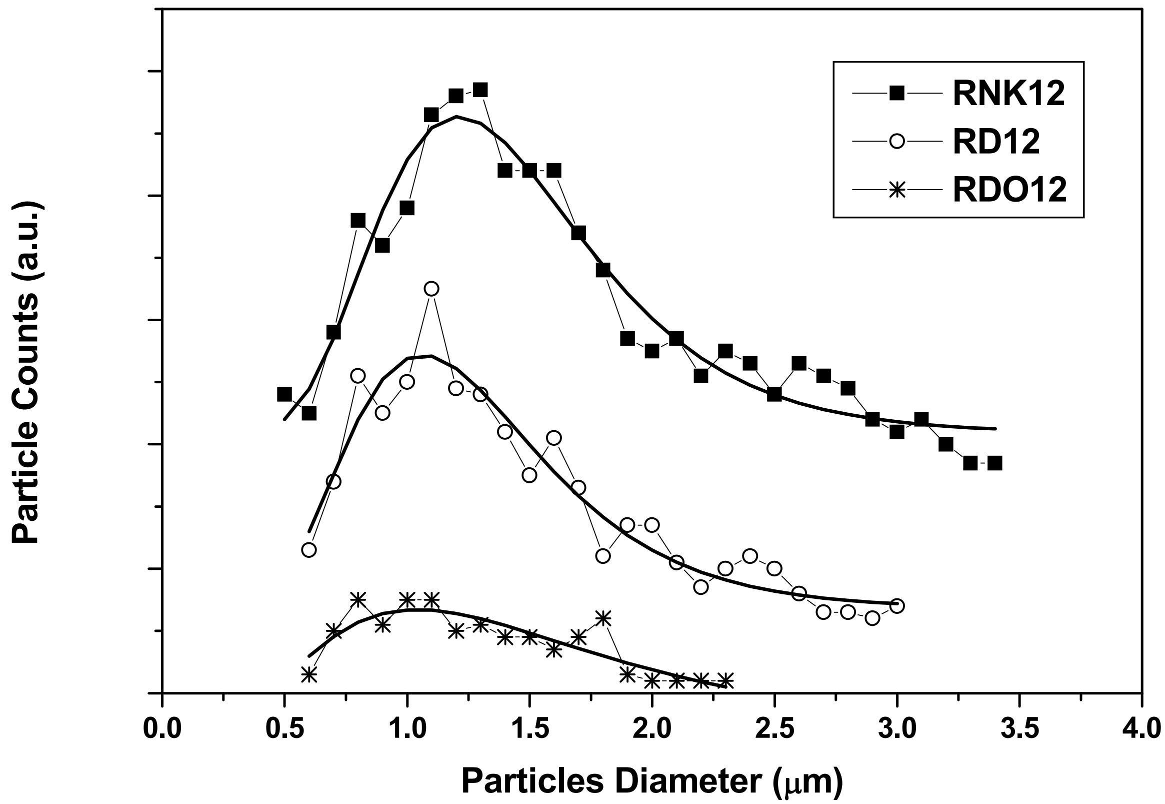
0 2 μm

Dust particles

0 3.2 μm

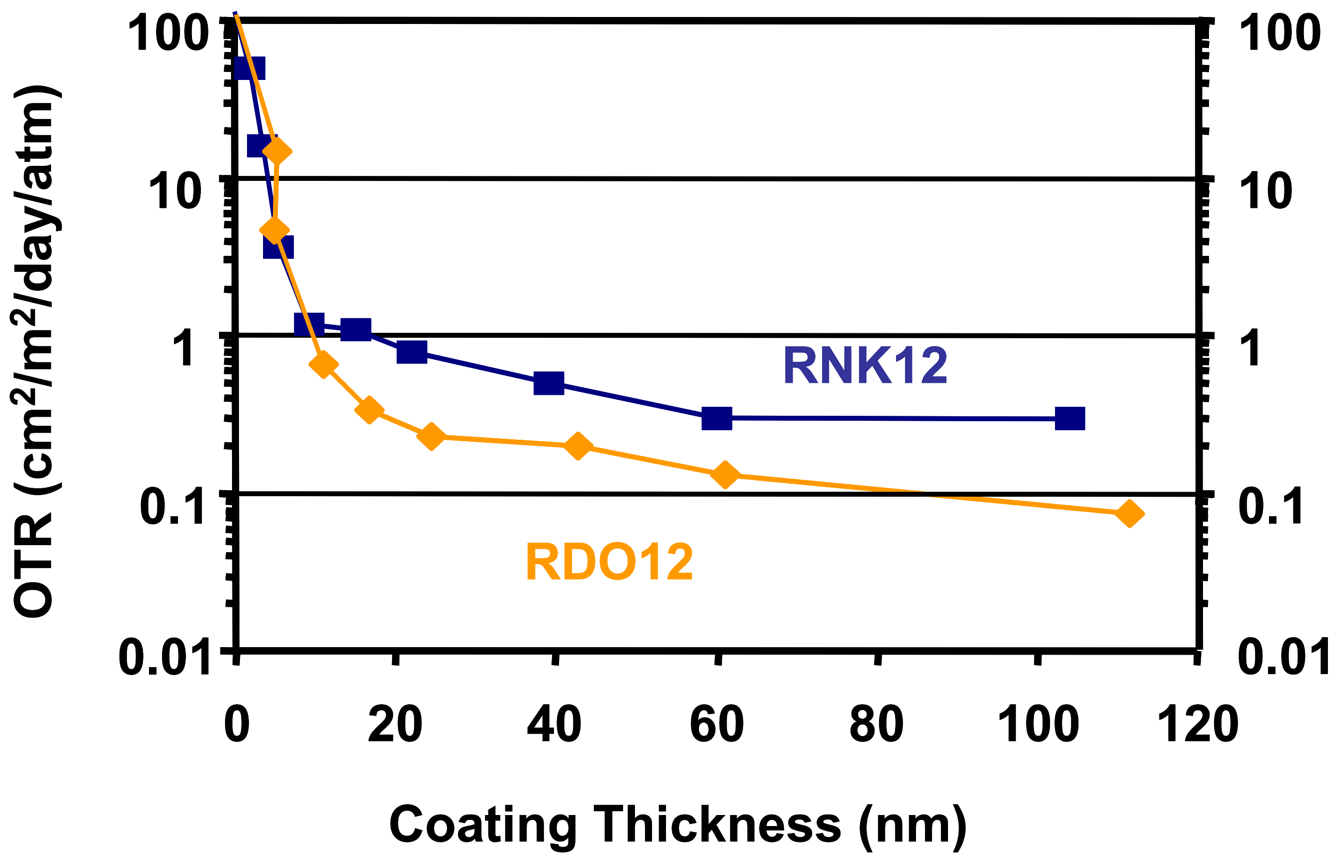
Data from tapping AFM: Amplitude

Size Distribution of Anti-blocking particles



Tetra Pak
protects what's good

OTR as a Function of Coating Thickness



Tetra Pak
protects what's good™

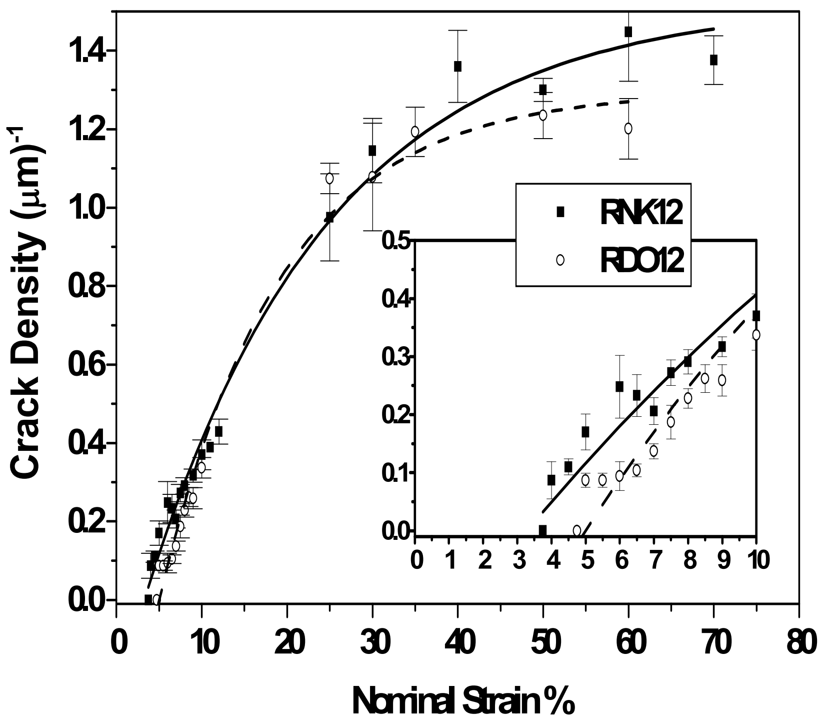
Effect of Anti-blocking Particles on Oxygen Transmission Rate (OTR) for 40-nm SiOx

Film	Particles per mm^{-2}	OTR* (cm^3/m^2/day/atm)
RNK12	1710	0.58 ± 0.1
RD12	860	0.39 ± 0.1
RDO12	290	0.21 ± 0.1

* 23 °C, 50% RH

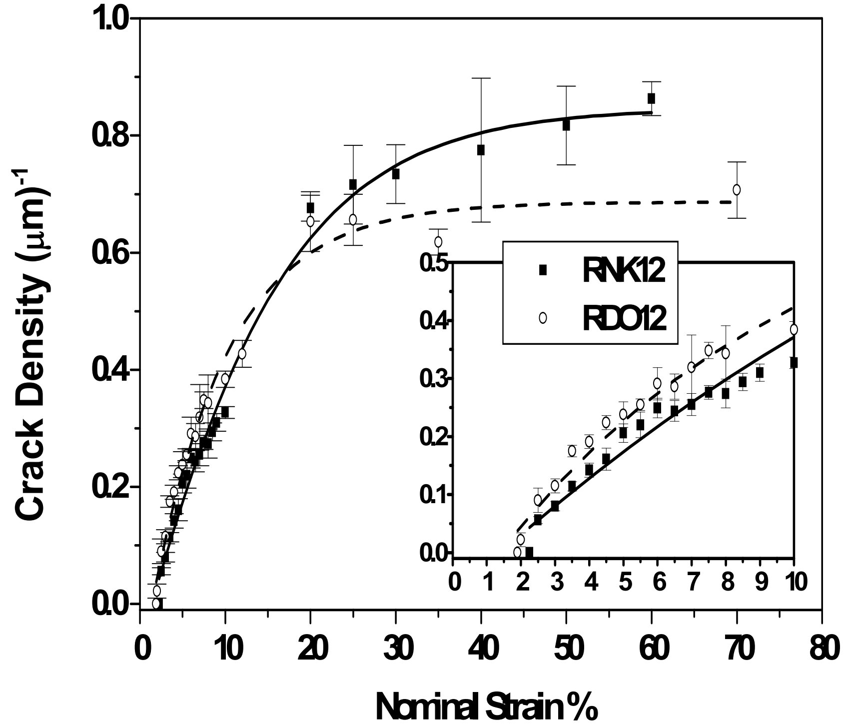
Fragmentation Tests for SiOx Coatings

9-nm Thick



COS: 3.8% RNK12
4.8% RDO12

40-nm Thick

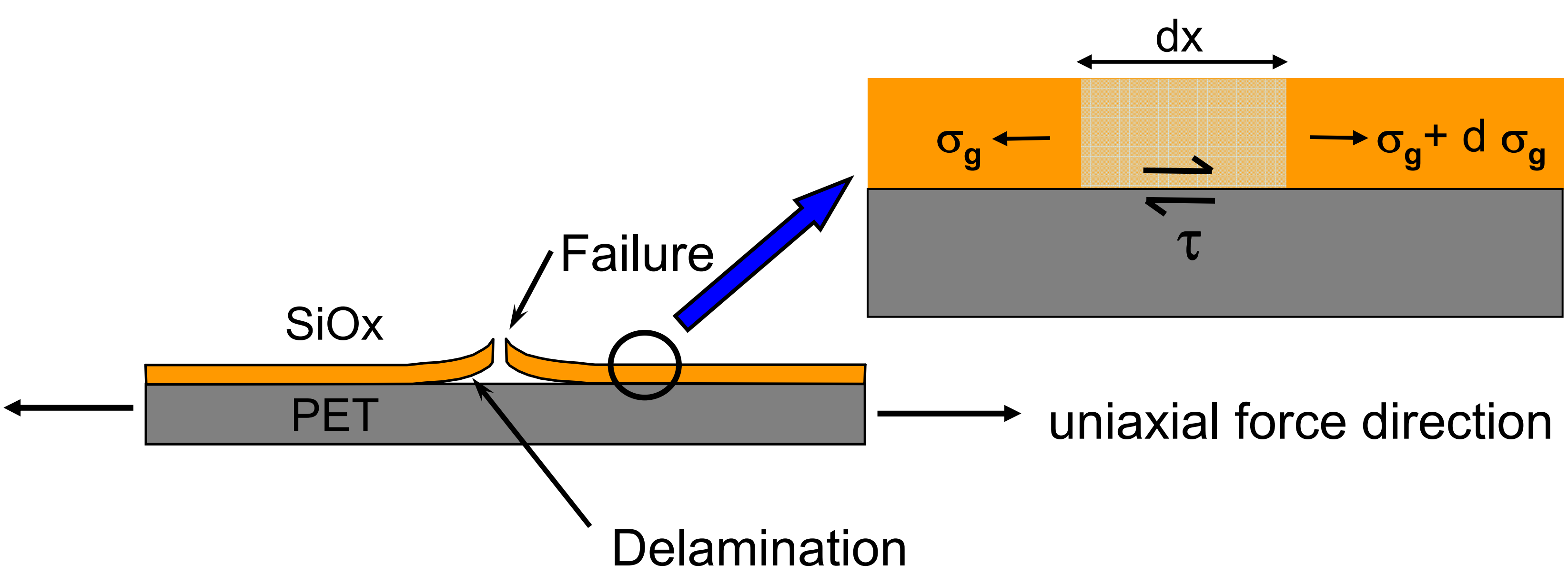


COS: 2.3% RNK12
1.9% RDO12

Durability of SiOx Coated PET Films

The durability of the coating relies on :

- **Failure controlled by the coating cohesion strength**
- **Delamination controlled by adhesion to substrate**
- **Stress transfer at the coating/substrate interface**



Interfacial Shear Strength (IFSS) or Adhesion Strength

The coating's fragmentation process provides the mean fragment length at saturation, l_s, and the coating tensile strength σ_{max} at critical length $l_c=(2/3)l_s$, from which is modeled the interfacial shear strength :

$$\tau = 1.337 \left(\frac{h}{l_s}\right) \sigma_{max}(l_c)$$

Cohesive Strength

The coating strength is modeled from a two parameters Weibull distribution :

$$\sigma_{\max}\left(l_c\right) = \beta\left(\frac{l_c h}{l_0 h_0}\right)^{-1/\alpha} \cdot \Gamma\left\{1 + 1/\alpha\right\}$$

The coating crack onset is derived from the theory of linear elastic fracture mechanics :

$$\varepsilon_f = \frac{C}{\sqrt{h_c\left(h_s + h_c\right)}}$$

Mechanical Properties

9-nm Thick SiOx

Film	COS (%)	σ_{max} (GPa)	τ (MPa)
RNK12	3.8 ± 0.05	9.5	137
RDO12	4.8 ± 0.05	7.4	128

40-nm Thick SiOx

Film	COS (%)	σ_{max} (GPa)	τ (MPa)
RNK12	2.3 ± 0.05	2.8	94
RDO12	1.9 ± 0.05	4.7	196

Conclusion

1. Oxygen transmission rate (OTR) and crack onset (COS) of PECVD SiOx depend on the density of anti-block particles at bi-oriented PET film surfaces.
2. OTR is proportional to the surface density of anti-blocking particles.
3. COS increased up by 20% for substrate with the lower anti-blocks density.
4. Micro-mechanical modeling of fragmentation process of SiOx coatings provided evaluation of their cohesive and adhesion strengths on PET.
5. Cohesion force of 9-nm thick SiOx is twice higher than 40-nm coatings.
6. Interfacial shear strength is as high as the bulk shear stress reflecting the presence of covalent bonds at the interface.

CLICK TO RETURN
TO LIST OF
PAPERS AND
PRESENTATIONS