Effect of polymer substrate surface on the water vapour permeation of coated gas-barrier films.

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Abstract

Polymer films coated in oxides (such as aluminium oxide or silicon oxide) are used for transparent high performance barrier materials in packaging. It has long been established that the rate of gas permeation, and hence performance of the gas barrier layer, depends upon the population of defects in the coating. The nature and population of the defects in the glassy oxide depend on deposition parameters and chemistry of the ceramic, but also depend heavily on the nature of the substrate, and any undercoating or overcoating polymer layers applied immediately adjacent to the glass.

Two techniques for characterizing these defects in barrier films will be explored. The first used conventional permeation measurements, taken at a range of temperatures. A plot of log(gas permeation rate) against $1/T$ has gradient proportional to the activation energy of gas permeation, and thus the nature of defects through which the gas permeates. We class the defects into two groups: those which give rise to an activation energy the same as the base polymer (macrodefects) as they are sufficiently large that the permeant can pass through without interaction with the coating material, and those that are small (nanodefects) such that there is significant interaction with the coating material and hence show a greater activation energy. From this, we can model the populations of each defect class for different barrier materials. In production of packaging films, the macrodefect density can be controlled by limiting substrate protrusions and scratches, as well as by careful material cleaning and handling, but the permeation due to nanodefects would need to be minimized by control of the nature of the substrate/coating interface, the chemistry of the coating, and the parameters of vapour deposition. Thus, it of significant value to be able to determine the contributions from each class.

A complimentary technique is a form of 'calcuim test' in which the Ca directly contacts the barrier, so that degradation of the Ca occurs locally in areas in which the permeant (in this case water vapour) passes through. By image analysis of the resulting micrographs we are able to quantify the relative contributions of the different defect types, and the spatial distribution of the defects observed, illustrating their origin.

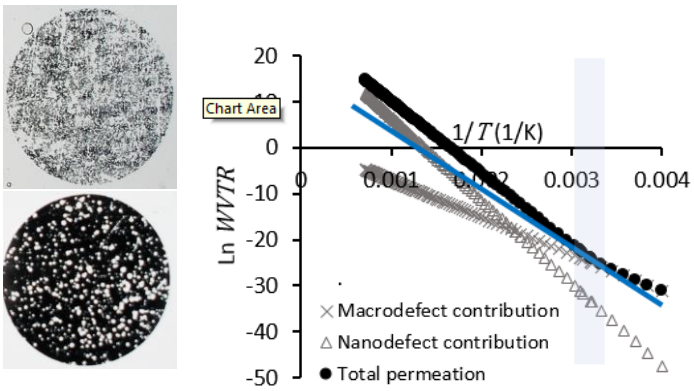


Figure 1 Ca test morphologies showing (upper) uniform permeation from a barrier on highly rough substrate and (lower) separate point-permeation from a barrier with a low density of defects. The graph illustrates how permeation measured as a function of temperature can be used to determine the contributions from different defect types.

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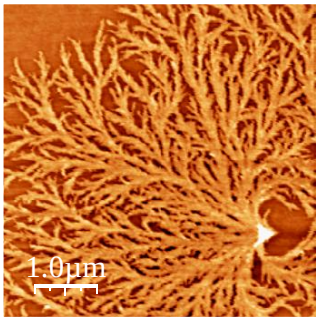
1. Howells DG, Henry BM, Madocks J, Assender HE (2008) High quality PECVD silicon oxide gas barrier coatings on polyester films. Thin Solid Films 516:3081-3088
2. Howells DG, Henry BM, Leterrier Y, Månson J-AE, Madocks J, Assender HE (2008) Mechanical Properties of SiOx Gas Barrier Coatings on Polyester Films. Surface Coatings and Technology 202:3529-3537
3. Moghal J, Suttle H, Cook AG, Grovenor CRM, Assender HE (2012) Investigation of the mechanical properties of aluminium oxide thin films on polymer substrates by a combination of fragmentation and scratch testing. Surface Coatings and Technology 206:3309-3315
4. Struller CF, Kelly PJ, Copland NJ, Tobin V, Assender HE, Holliday CW, Read SJ (2013) Aluminium oxide barrier films on polymeric web and their conversion for packaging applications. J. Thin Solid Films 553:153-156
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Biography

Prof Hazel Assender has led a research activity at the Department of Materials, University of Oxford, since 1996, with a focus in the area of thin films and coatings both of polymer materials or onto polymer substrates. She graduated from the University of Cambridge, following this with a PhD, and two years of postdoc in the Department of Materials Science & Metallurgy in Cambridge before moving to an academic post in Oxford. Her research spans fundamental studies of the thin film and near-surface properties of polymers, through to materials engineering of thin films and device structures in large area on polymer substrates. Particular areas of interest include roll-to-roll deposition, gas barriers, photovoltaics, and transistors/circuits. Her research has a technology-facing approach bringing underpinning scientific understanding to development of materials and technologies that integrates research relevant to industrial processing such as scale-up of manufacture with the development of new materials and structures.

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1.0μm