Institute of Physics

Printing, Papermaking and Packaging Prize 2003

The Printing, Papermaking and Packaging Group of the Institute of Physics presented their Annual Prize to Dr Justin Bradley on 28th October 2003 at 76 Portland Place. Dr Bradley is a Post Doctoral Research Assistant working with the Materials Science Group at The London College of Printing (London Institute).

The prize of three hundred pounds is awarded to the individual or organization that has contributed a significant theoretical or practical application of physics in the areas of interest of the Group.

Dr Bradley presented his findings at the AGM of the 3P's Group. The abstract of his paper is given below. Dr Bradley can be contacted at j.bradley@lcp.linst.ac.uk

Professor Bob Thompson, Group Chairman, presenting Dr Justin Bradley with his award.

The Surface Tension Components of Water-Based Inks and their Importance in Predicting Wetting Behaviour

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It has often been assumed that since the surface tension of water has a large polar component, the surface tension of water-based inks will also be highly polar in nature. This has led to attempts to increase the polarity of typical substrates in order to improve the print quality when using water-based inks. The results of these studies are not conclusive. In general, surface chemistry is regarded as of greater importance when printing on plastic films than when printing on paper where surface roughness and porosity is regarded as determining print quality. However, the wetting of a surface is not determined by the magnitude of its surface energy alone, rather by the free energy of adhesion between the solid and liquid and the surface tension of the liquid. For incomplete wetting the equilibrium at the triple point can be described by the Young- Dupré equation (1) in which the degree of wetting is characterized by a contact angle (θ) between solid and liquid.

$$(1+\cos\theta)\gamma_L = -\Delta G_{SL} \quad (1)$$

The prediction of wetting behaviour (θ) requires an expression for ΔG_{SL} in terms of the surface tension parameters of the solid and liquid. The Owens-Wendt(2) and Wu(3) theories of wetting express ΔG_{SL} in terms of the interaction of the dispersive and polar components of surface energies. The acid base theory(4) also takes account of the complimentary electron accepting/donating properties of the surfaces. The expressions for ΔG_{SL} in each case are:

$$(1+\cos\theta)\gamma_L = 2\{(\gamma_L^D\gamma_S^D)^{1/2}+(\gamma_L^P\gamma_S^P)^{1/2}\}(2)$$

$$(1+\cos\theta)\gamma_L = 4\gamma_L^D\gamma_S^D/(\gamma_L^D+\gamma_S^D) + 4\gamma_L^P\gamma_S^P/(\gamma_L^P+\gamma_S^P) \ (3)$$

$$(1+\cos\theta)\gamma_L = 2\{(\gamma_L^D\gamma_S^D)^{1/2}+(\gamma_L^+\gamma_S^-)^{1/2}+(\gamma_L^-\gamma_S^+)^{1/2}\}(4)$$

Therefore in order to understand the wetting of surfaces it is necessary to determine the components of the surface tension of the liquid in addition to the components of the surface energy of the solid.

In this paper we determine the components of the surface tension of a water based inks at a range of surfactant concentrations. For the formulation chosen it was found that the dispersive component of the surface tension was more than 50% of the total even with no surfactant present, increasing to approximately 75% of the total with a surfactant concentration of only 0.1% by mass. Further the polar contribution to the surface tension was found to be dominated by the basic component with the magnitude of γ_L^- up to 100 times that of γ_L^+.

In order to assess the importance of the form of the expression of ΔG_{SL} in predicting wetting behaviour, the contact angles between water based ink and an anilox roll were compared to those predicted by each of the three main theories of wetting. In each case the acid-base theory was found to give the most accurate prediction of the contact angle between solid and liquid, underlining the need to take into account the asymmetric nature of the polar contribution to surface tension when predicting wetting behaviour.

This has important implications for the wetting of typical printing substrates. The polar component of the commonly used substrates such as Polyethylene, BOPP or PVC are also dominated by the basic component, in some cases the acidic component is 0 resulting in $\gamma_S^P = 0$. From the form of equation 4 Therefore it is clear from the form of equation 4 that the wetting behaviour of the water based inks with plastic films will be dominated by the dispersive contribution to the free energy of adhesion rather than polar effects as previously believed.

Previous work on paper substrates has shown that oxygen plasma treatment markedly decreases the contact angle of water with paper but has little effect on the contact angle with flexo ink. Print trials also showed that plasma treatment had little effect on print quality. This was taken as evidence that surface chemistry had little effect on ink transfer when printing on paper. However the results of this study suggest that the free energy of adhesion between paper and ink would be dominated by the dispersive component which is not affected by oxygen plasma treatment (as evidenced by contact angle measurements with mineral oil), offering an alternative explanation for the failure of plasma treatment to influence print quality when using water based ink.