Using surface energy measurements to characterize printing applications

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It is well known in the printing industry that the relationship between the surface energy of a substrate and the surface tension of an ink is a critical element in the printing process. In practice, there are a number of factors that influence the printing process. Physical factors such as roughness, cleanliness, and homogeneity, and chemical factors such as surface energy, polarity matching, and dispersion are all known quantities in the printing industry. The need for greater sophistication in the area of surface and interface characterization methods has prompted more research and development in this area. In addition, changes in printing technology such as the gradual switch from solvent-based to water-based inks has stimulated the interests of the industry in recent years.

Historically, contact angle measurements have been widely used to help predict the printability of inks and other media onto paper, paperboard, and polymeric (film) surfaces. Simple, yet highly subjective optical test methods such as the dyne fluid or sessile drop technique are often done at the quality control level to determine gross pass/fail criteria. To perform these tests, a technician pipettes a known volume of a test liquid of known surface tension onto the surface of the substrate. Visually or with the aid of an optical goniometer, the spreading characteristics of the drop are cited to estimate the degree to which spreading has occurred. With the dyne fluid test, a series of test liquids of varying surface tension are tried until one is found to spread completely across the surface. The surface tension of this liquid is assigned as the approximate surface energy or critical surface tension of the solid.

As a quality control test procedure, the optical test procedures can be very useful as a measure of the gross wettability of a surface on a macro scale. In the R & D environment, however, there are many complications associated with the optical test methods that can and often do lead to an erroneous or misleading characterization of the surface. Alternatively, the wettability or contact angle between a liquid and solid can be measured to a much higher degree of precision with the dynamic Wilhelmy Balance Technique, a gravimetric (non-optical) technique that is less operator dependent and more suitable for research and development applications.

In "Practical Applications of Surface Energy Measurements in Flexography“ (Flexo, July 1990) , Bassemir and Krishnan summarize the important factors which are known to influence the flexographic printing process, and compare static (optical) contact angles with the dynamic (non-optical) technique incorporated in the Thermo Scientific CAHN DCA system. Qualitative features of the surface such as roughness and homogeneity are cited as critical elements that must be considered when evaluating the wettability (and printability) of a surface. Hysteresis effects, as measured by the DCA as the difference between advancing and receding contact angles, are shown in this paper to be a good way to distinguish between roughness and homogeneity effects that are impossible to separate with an optical test method. According to the authors, "Roughness tends to reduce the advancing contact angle, when less than 90 degrees, while surface non - uniformity tends to increase it.“

In practice, when printing on a film surface, an electronic corona discharge treatment is often applied to increase the energetics of the polymeric surface. During this treatment process, surface roughening which increases with prolonged exposure is known to occur, effectively altering the surface energy of the substrate. In addition to roughness and homogeneity, the polarity of both the substrate surface and the ink formulation is also demonstrated by Bassemir and Krisbnan to be a critical element that must be controlled and well characterized. Matching the polarity of an ink with the corresponding polarity of the substrate is required for optimum adhesion. This has become an especially important issue as ink formulations are changing from solvent-based to water-based systems. Corresponding changes in the substrate surface energy and polarity is thus required to match the new ink formulations.

To measure the surface polarity of a substrate with the DCA, a minimum of two liquids with known polarity and surface tension are required. Water and methylene iodide are commonly used as the two liquids of choice, and dynamic contact angles are calculated for each liquid independently. One of several equations can then be applied to calculate the polarity of the substrate. Conversely, the polarity of an unknown liquid (i.e. an ink formulation) can also be calculated from an experiment in which the dynamic contact angles between the ink and two standard non-polar solids (i.e. teflon and polyethylene) are measured. This ability to calculate the surface polarities of both solid substrates and ink formulations is a simple, yet powerful way to characterize the printability of a surface from a surface energy perspective.

As printing technology continues to advance, the need for more research and better development procedures will follow. Surface energy characterization methods must also improve to keep pace with this evolution in printing technology.
For a reprint of the Flexo article and information on the Thermo Scientific CAHN DCA systems, contact your local Thermo Fisher Scientific CAHN representative.

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C118_25.07.2007