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Application Note 1

The pendant drop method with the OCA of DataPhysics Instruments

Surface chemistry characterization of an important solvent for the paint and ink industry.

Problem

Many technical applications require a clear understanding of the networking properties of the liquids employed. These include the manufacture and processing of paints and inks, gluing, soldering and the development of special surfactants for the cosmetics industry. Also, when aiming to control the surface properties of silicon wafers and the chemical processes carried out during the production of microprocessors. It is therefore important that the networking properties of individual liquids can be quantitatively determined, in order to make predictions about the networking overall process. To do this, reliable calculation of the surface tension (and, additionally, its polar and dispersed components) is necessary.

Using DPM (dipropylen-glycol-monomethylether) is was demonstrated, how the video based contact angle measuring device, OCAxx, along with the supportive software for pendant drop measurements can be used to determine the total surface tension, together with the polar and dispersed components. DPM was chosen as an example liquid because its surface chemistry properties have not previously been reported, even though they are of significant interest for the paint industry. The pendant drop method is applicable to most low to medium viscosity liquids and as such applicable to many varied industries where an appreciation of the consequences of the aforementioned networking processes is crucial.

DPM is commonly found as a solvent in the paint and ink industry. Its universal solution properties allow its use in a variety of formulations classes. Most importantly is that DPM serves as a solution agent for water based systems and acrylic resins.

Once established, the quantification of the polar and dispersed components of the total determined surface tension will provide the formulators with the required tool to predict the degree of internal networking and the consequent fluid properties.

Method

A drop of the liquid to be analysed is formed on the open end of a needle, mounted within either an automated or manual dosing system. The surrounding medium can be either gaseous (most commonly 'air') or a second immiscible liquid. An image of the drop contour (Fig. 1.) is viewed and saved by the OCA device's camera component.

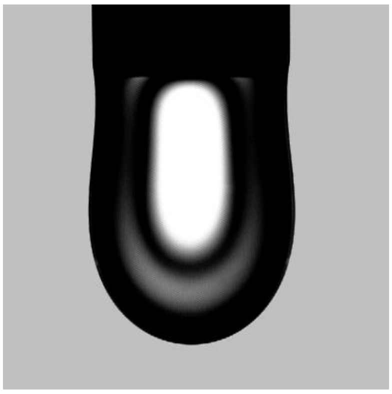

Figure 1: Pendant drop contour

Two distinct forces determine the outer shape of the drop: Firstly, the mass, which by virtue of gravity acts to lengthen the drop in a vertical direction. Secondly, the surface tension of the liquid, which would tend to require the liquid drop to maintain a spherical form, in order to minimize the surface area. So, the shape of the pendant drop contour illustrates the equilibrium between these two distinct forces.

The force equilibrium is described, mathematically, by the Young-Laplace equation. In theory; once the shape of the drop has been determined, the surface tension of the liquid can be reliably calculated. The dispersed (non-polar) components of the total surface tension are calculable when the surface tension of the test liquid is measured against a completely non-polar liquid.

According to Owens & Wendt surface tension $\sigma_{1/2}$ is calculated by equation (1):

$$\sigma_{1/2} = \sigma_1 + \sigma_2 - 2\left(\sqrt{\sigma_1^{\,d} \cdot \sigma_2^{\,d}} + \sqrt{\sigma_1^{\,p} \cdot \sigma_2^{\,p}}\right) \qquad (1)$$

(σ_1^d = dispersive components of the non-polar surrounding medium, σ_1^p = polar components of the non-polar surrounding medium; σ_2^d = dispersive components of the polar medium; σ_2^p = polar components of the polar medium).

In this case, the non-polar surrounding medium σ_1 is DPM and the polar medium σ_2.is perfluorhexane (C6F14).

According to equation 1, $\sigma_2^d = \sigma_2$ because $\sigma_2^p = 0$. The dispersed component result comes from changing equation (1):

$$\sigma_1^{\,d} = \frac{\left(\sigma_2 + \sigma_1 - \sigma_{1/2}\right)^2}{4\sigma_2} \qquad (2)$$

The polar component is calculated as:

$$\sigma_1^{\,p} = \sigma_1 - \sigma_1^{\,d} \qquad (3)$$

Using the SCA software module it is possible to analyze the pendant drop elaborately, by providing quantitative surface tension data based within the software database. They relate to the relevant properties of liquids or gas into which the test liquid drop has been dispensed.

Results

The surface tension σ_1 of the used solvent DPM was determined in air. Due to the fact that DPM is very soluble in highly alkaline solvents, perfluorohexane C6F14 (d = 1.7 g/ml, σ = 11.9 mN/m) was chosen as second liquid, to measure DPM against it and calculate the non-polar components of the surface tension $\sigma_{1/2}$.

The results of measuring the total surface tension of DPM are shown in table 1.

Table 1 : Surface tension of DPM

Air (O2)	Perfluorohexan (C6F14)
σ = 28.41 ± 0.15 mN/m	σ = 8.66 ± 0.17 mN/m
Components of DPM	
σ_1^d = 21.04 ± 0.30 mN/m	σ_1^p = 7.37 ± 0.34 mN/m

Equation (2) and (3) together result in the polar and dispersed components:

The result of a relatively high polar component of 7.37 mN/m of the surface tension of DPM reinforces the good solubility of the substance in polar (highly alkaline) liquids referred to previously.

Summary

Using the video based contact angle measuring unit OCA together with the respective software module of DataPhysics Instruments, the pendant drop method provides a quick, easy and reliable way of characterizing the networking properties of a liquid.

The total surface tension is directly accessible and the polar and dispersed components can easily be calculated after determining the surface tension compared with a non-polar liquid. In the example measurement of the frequently used solvent DPM the previously unknown polar and dispersed components of the total surface tension were determine confirming the good solubility of the substance in highly alkaline liquids.