Letters

Surface energies of silicate glasses calculated from their wettability data

When a series of homologous liquids is placed on a flat solid substrate, forming small sessile drops, the cosine of the contant angle (θ) of the drops increases linearly with decreasing surface energy of the drops (γ_{LV}), with:

$$\cos\theta = a - b\gamma_{LV}. \qquad (1)$$

It has been shown that the surface energy of the substrate can be calculated from the linear correlation [1–3];

$$\gamma_{SV} = \frac{(b\gamma_c + 1)^2}{4b} \qquad (2)$$

where γ_{SV} is the surface energy of the substrate and γ_c is the surface energy of the liquid drop when the contact angle θ approaches zero. The experimental method, in principle, is fairly simple and straightforward, so that the surface energy of a solid substrate can be readily determined. The purpose of this note is to demonstrate how the surface energies of glasses can be calculated from their contact angle data.

A sessile drop of methylene iodide on soda-lime glass exhibits a contact angle of 13° and that of tetrabromoethane 9° at 20° C at an r.h. of 1% [4]. From these data b is found to be 0.00424 and $\gamma_c = 44.7$ erg cm^{-2} (Fig. 1). Substituting these values into Equation (2), the surface energy of the soda-lime glass is found to be 83.4 erg cm^{-2}. This value is not much greater than the surface energy of water at 20° C (72.8 erg cm^{-2}), thus suggesting the presence of adsorbed water. The wetting of borosilicate glass by Na–K and Hg at 20° C in vacuum [5] is shown in Fig. 2. In this case, the calculated surface energy value is 110 erg cm^{-2}, which is still not too much greater than that of water. Huang *et al.* measured the reduction in surface energy of E-glass due to water vapour adsorption to be 247 to 254 erg cm^{-2} at 20° C [6]. According to Bondi [7], the temperature coefficient of surface energy of soda-borate glass is -0.05 erg cm^{-2} °C^{-1}. It is reasonable to assume that these values are applicable to soda-lime glass. Taking the average value of 251 erg cm^{-2}, we obtain 310 ($83 + 251 - 0.05 \times 480$) erg cm^{-2} for the surface energy of soda-lime glass at 500° C, which is in excellent agreement with the value 312 erg cm^{-2} determined by Parikh [8] for soda-lime glass in the neighbourhood of 500° C in vacuum, using the fibre elongation method.

Good *et al.* [9] estimated the contact angles of Hg and Ga on baked-out glass (unspecified) in vacuum to be aprroximately 70° and 110°, respectively. Taking the surface energy of 484.5 erg cm^{-2} for Hg [10] and 735 erg cm^{-2} for Ga [11] at 30° C we obtain the surface energy value 254 erg cm^{-2} for the baked-out glass at 30° C in vacuum. This value becomes 230 erg cm^{-2} at 500° C and compares favourably with 210 erg cm^{-2} determined by

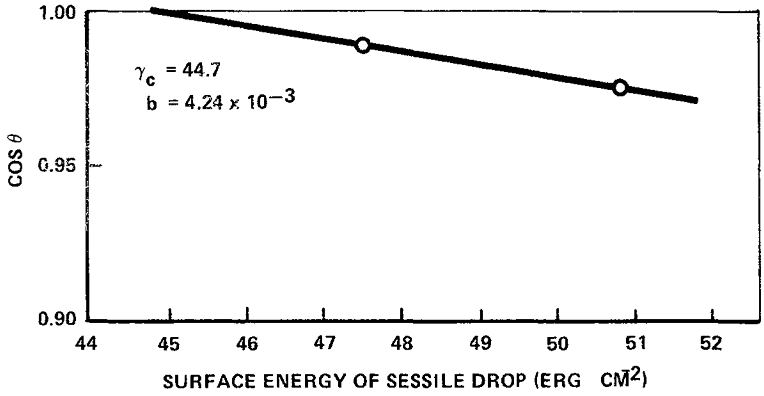

Figure 1 Wetting of soda-lime glass by methylene iodide and tetrabromoethane [4].

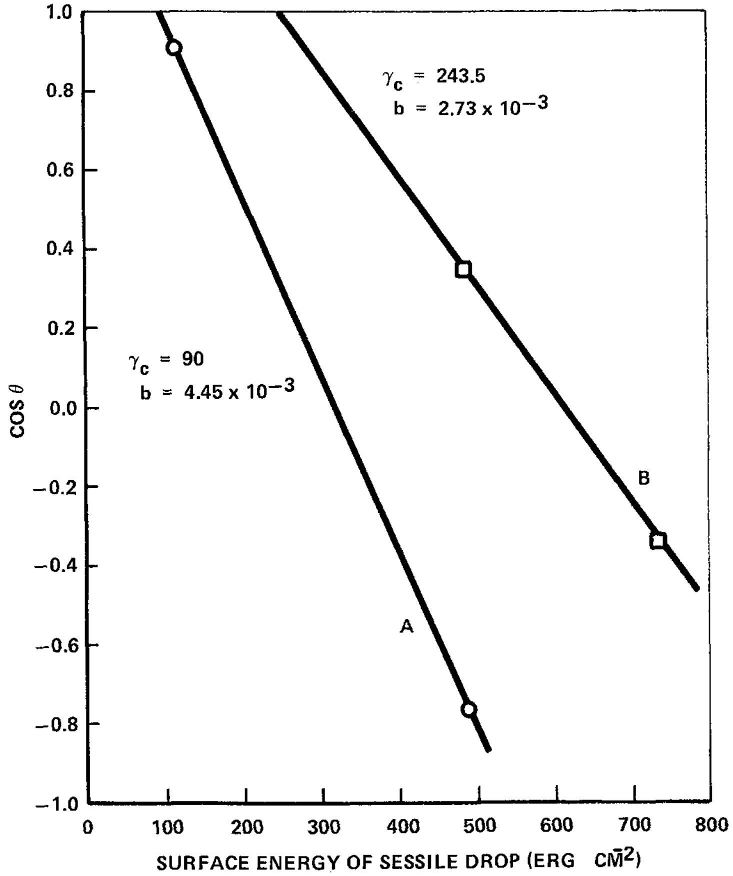

Figure 2 Wetting of borosilicate glass by Na-K and Hg (A) [5] and baked-out glass by Hg and Ga (B) [9].

Parikh [8] for lead disilicate glass at 500° C in vacuum. The results indicate that adsorbed water on glass persists even in vacuum unless it is baked-out at higher temperatues.

Admittedly the cases cited above involve only two datum points. Nevertheless the results clearly indicate that the surface energy of glasses can be calculated from their contact angle data.

References

1. S. K. RHEE, *Mat. Sci. Eng.* **11** (1973) 311.
2. *Idem, J. Amer. Ceram. Soc.* 58 (1975) 441.
3. *Idem, ibid* 54 (1971) 376.
4. E. G. SHAFRIN and W. A. ZISMAN, *ibid* 50 (1967) 478.
5. D. A. OLSEN and A. J. OSTERAAS, *J. Phys. Chem.* 68 (1964) 2730.
6. R. J. HUANG, T. DEMIREL and T. D. MCGEE, *J. Amer. Ceram. Soc.* 56 (1973) 87.
7. A. BONDI, *Chem. Rev.* 52 (1953) 417.
8. N. M. PARIKH, *J. Amer. Ceram. Soc.* **41** (1956) 18.
9. R. J. GOOD, W. G. GIVENS and C. S. TUCEK, The Contact Angle at the Gallium-Mercury Interface on Glass, in "Contact Angle, Wettability and Adhesion", edited by R. F. GOULD (American Chemical Society, Washington, DC, 1964) pp. 211–21.
10. J. J. JASPER, *J. Phys. Chem. Reference Data*, **1** (1972) 921.
11. G. L. MACK, J. K. DAVIS and F. E. BARTELL, *J. Phys. Chem.* 45 (1941) 846.

*Received 11 October
and accepted 28 October 1976*

S. K. RHEE
*Research Laboratories,
The Bendix Corporation,
Southfield,
Michigan,
USA*