

Application Report

Wetting of circuit boards

Application report: AR234e
Industry section: Electronics
Author: Dr. Thomas Skrivanek
Date: 04/2003



Drop Shape Analysis System
DSA10

Method:



Keywords: Printed circuit board (PCB), lead frame, glob top, wetting, OWRK, surface free energy

Determination of the surface free energy of electronic components

A method for evaluating their wetting and adhesive behavior with embedding compounds and adhesives

Abstract

Dispensing tasks in the electronics industry are increasing in their extent and complexity because of the use of new materials and technologies. A wide range of different boundaries is produced during the manufacture of single-chip circuits and multi-chip modules. This includes the individual steps involved in assembling the module, whether in applying an electronic component to a PCB or other carrier construction or in applying a glob top to this component. Both the wetting and adhesive behavior of the individual components between themselves play an important role. The contact angle is an easily accessible and directly observable quantity which describes the wetting and dewetting behavior of a liquid on a solid surface. Not only the surface tension of the liquid influences the size of the contact angle, but also the surface free energy of the solid and the interfacial tension which forms between the two phases. This paper provides a step-by-step description of the procedure for the determination of the surface free energy including the polar and disperse fractions of two different electronic components on a carrier. Knowledge of these quantities allows an estimation of the wetting and adhesive behavior with embedding compounds.

Introduction

The marketing success of an electronic product is strongly dependent on its reliability and customer satisfaction. The flat assemblies of electronic instruments must therefore meet the highest demands. In order to be able to guarantee that electronic components will function properly for a long time they must be protected against all possible types of environmental influences, such as vibration, impact or moisture. With wire-bonded electronic components on carriers this can be achieved by applying an embedding compound, a so-called glob top. In this case not only the wetting behavior plays a decisive role, but also the adhesive behavior of the embedding compound towards the carrier, the electronic component and the bonding wire. An effective means of obtaining detailed information in advance about the wetting and adhesive behavior between the glob top compound and, for example, an electronic component is the surface tension and contact angle measuring technique. In this way the decisive parameter, the surface free energy σ_s of a solid including its disperse σ_s^d and polar fractions σ_s^p and the surface tension of a liquid σ_l (e.g. embedding compound) can be determined. The procedure for the determination of σ_s , σ_s^d and σ_s^p is described in this paper using two different electronic components attached to a carrier as an example.

Theory

Whereas the surface tension of liquids can be measured directly (e.g. with ring or plate), the surface free energy of solids ("surface tension of the solid") must be calculated as solids are not capable of reversible elastic deformation. Since the start of the twentieth century various scientists have developed evaluation methods for calculating the surface free energy [1-8].

By measuring the contact angle θ of at least two test liquids (σ_l -, σ_l^d - and σ_l^p -values must be known) on the solid surface to be analyzed the surface free energy of the solid surface (σ_s) including the disperse (σ_s^d) and polar fractions (σ_s^p) of the surface free energy can be determined. The fact that only those interactions along the boundary in which both phases are involved are of any importance is decisive for solving wetting and adhesion problems. This means that if two liquids or a solid and a liquid are in contact then, at the phase boundary, only an interaction between the two polar and the two disperse fractions of the interfacial tension of the participating phases occurs. This is the very reason why the knowledge of the polar and disperse fractions is so very important.

Experimental part

The surface free energy according to *Owens, Wendt, Rabel and Kaelble* is to be determined together with the polar and disperse fractions by optical contact angle measurements on two different electronic components on a carrier construction. The measuring system used is the Drop Shape Analysis System DSA10DO4 from Krüss GmbH (see Figure 1).



Figure 1: Drop Shape Analysis System DSA10DO4 from KRÜSS GmbH

Water and diiodomethane are used as the standard test liquids. Surface tension values are listed in Table 1.

Liquid	σ_l [mN/m]	σ_l^d [mN/m]	σ_l^p [mN/m]
Water	72.80	21.80	51.00
Diiodo- methane	50.80	50.80	0.00

Table 1 Test liquid data according to Ström [9]

The samples to be investigated (Sample 1 and Sample 2) were measured at room temperature without any pre-treatment. For each sample three to five contact angle measurements with water and diiodomethane were made at different locations on the electronic components. As sample 1 only had an area of approx. 3 mm x 3 mm very small drop volumes were used (0.5 μ l).

Results and discussion

Figure 2 shows examples of a water drop and a diiodomethane drop on each of the electronic components.

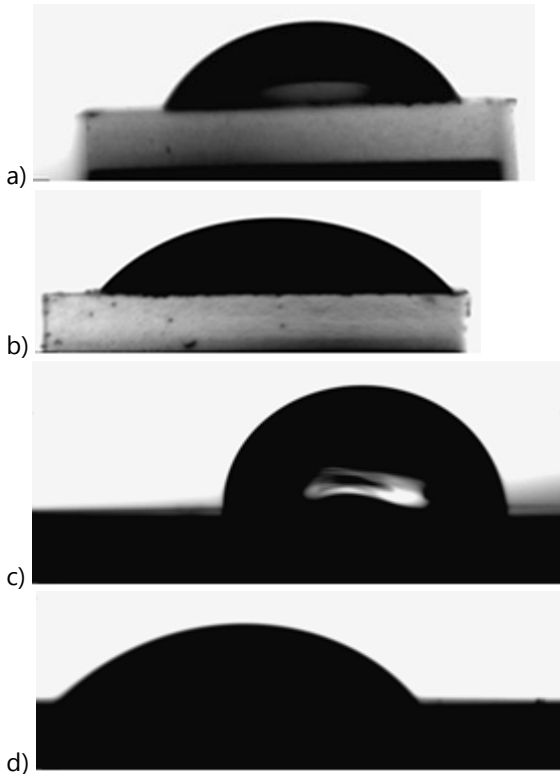


Figure 2: a) Water on Sample 1; b) Diiodomethane on Sample 1; c) Water on Sample 2; d) Diiodomethane on Sample 2.

Table 2 lists the mean values for the contact angles determined for water and diiodomethane on Sample 1 and Sample 2.

Substrate	θ_{H_2O} [°]	$\theta_{CH_2I_2}$ [°]
Sample 1	65.9 ± 3.9	48.7 ± 2.3
Sample 2	86.3 ± 2.2	45.4 ± 4.3

Table 2: Mean contact angle values for water and diiodomethane on Sample 1 and Sample 2.

Table 3 gives the surface free energies for the two electronic components and their disperse and polar fractions calculated according to *Owens, Wendt, Rabel and Kaelble*.

Substrate	σ_s [mN/m]	σ_s^d [mN/m]	σ_s^p [mN/m]
Sample 1	45.95 ± 0.81	34.97 ± 0.47	10.98 ± 0.34
Sample 2	38.93 ± 1.07	36.81 ± 0.91	2.12 ± 0.16

Table 3: Calculated surface free energies with their disperse and polar fractions according to *Owens, Wendt, Rabel and Kaelble*.

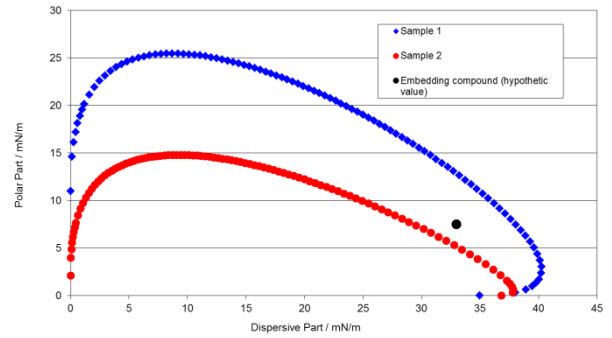


Figure 3: Wetting envelopes for the two electronic components together with their polar and disperse fractions for a hypothetical embedding compound with a surface tension of 40.5 mN/m.

Observation of Figure 2 indicates that there is very little difference between the diiodomethane drops on Sample 1 and Sample 2, whereas a significant difference between drop shapes of the applied water drops on the different electronic components can be seen with the naked eye. This fact is also demonstrated by the mean contact angle measuring data shown in Table 2. When the given error for diiodomethane on both samples is taken into account the same contact angle is obtained; however, with water the contact angles differ by at least 15°. From these results alone it is possible to make several statements about the two surfaces. As the contact angle of the completely nonpolar liquid diiodomethane is the same on both samples it can be concluded that the nonpolar fraction of the surface free energy does not differ significantly between the two electronic components. With regard to the contact angle of the very polar liquid water on the investigated surfaces it can already be stated that the surface of Sample 1 is more polar than the surface of Sample 2. If the results given in Table 3 are considered then the above conclusions can be verified quantitatively. The nonpolar fractions of the surface free energy of the two electronic components investigated differ, when the given error is taken into account, by just under 0.5 mN/m whereas the polar fractions differ by more than 8 mN/m. This means that the surface of Sample 1 is considerably more polar than the surface of Sample 2. Such significant differences in the surface free energy of two electronic components on one and the same carrier construction could mean that both wetting and adhesion problems could occur with one of the two components when applying a glob top. Which of the two components is better wetted by an embedding compound and which embedding compound will adhere better to the electronic component depends on the surface tension of the embedding compound as well as on its disperse and polar fractions. An example is used to make this clear. In Figure 3 the so-called *wetting envelopes* are shown for the two electronic components as well as a data point for a hypothetical embedding compound with made-up surface tension values ($\sigma_l = 40.5$ mN/m, $\sigma_l^d = 33$ mN/m, $\sigma_l^p = 7.5$ mN/m).

The wetting envelope of a solid fully characterizes the wetting properties of the solid surface that are to be expected with any liquids. For the calculation of this envelope (which is only possible using the evaluation method according to *Owens, Wendt, Rabel and Kaelble*) the surface free energy of the solid as well as its disperse and polar fractions must be known. The data point for the hypothetical embedding compound is inside the wetting envelope of Sample 1 and outside that of Sample 2. This means that this embedding compound will completely wet Sample 1 and incompletely wet Sample 2. As the surface tension data of the hypothetical embedding compound agrees far better with the values of Sample 1 than with the values of Sample 2, the following prediction can be made about the adhesive behavior:

The hypothetical embedding compound will have a better adhesive behavior with Sample 1 than with Sample 2.

Summary

In order to evaluate the wetting and adhesive properties of a solid toward liquids from an interfacial energy point of view the wetting envelopes, surface free energy as well as the disperse and polar fractions of two different electronic components on a carrier construction were determined according to the method of *Owens, Wendt, Rabel and Kaelble*. This was done by making contact angle measurements using water and diiodomethane as the test liquids. By using these measurements it could be shown that the surface of one of the electronic components has a considerably higher energy and is more polar than the other one. The application of one and the same embedding compound to protect the electronic components could, according to the surface energy nature of the glob top (ratio of disperse and polar fractions of the surface tension), lead to wetting and adhesion problems with one of the two electronic components.

Literature

- [1] Einige Aspekte der Benetzungstheorie und ihre Anwendung auf die Untersuchung und Veränderung der Oberflächeneigenschaften von Polymeren; Rabel; Farbe und Lack, (1971), 77./10, 997-1005.
- [2] A Theory for Estimation of Surface and Interfacial Energies, III. Estimation of Surface Energies of Solids from Contact Angle Data; R.G. Good, L.A. Girifalco; J. Phys. Chem., Jg. 64, 1960, 561-565.
- [3] Attractive Forces at Interfaces; F.M. Fowkes; Industrial and Engineering Chemistry, Vol. 56, No. 12, Dec. 1964, 40-52.
- [4] Polar and Nonpolar Interaction in Adhesion; S. Wu; J. Adhesion, 1973, Vol. 5, 39-55.
- [5] Contact Angles, Work of Adhesion and Interfacial Tensions at a Dissolving Hydrocarbon Surface; G. Ström, M. Frederikson, P. Stenius; Journal of Colloid and Interface Science, Vol. 119, No. 2, Oct. 1987, 352-361.
- [6] The Components of Surface Tension of Liquids and their Usefulness in Determinations of Surface Free Energy of Solids; B. Janczuk, T. Bialopiotrowicz, W. Wojcik; Journal of Colloid and Interface Science, Vol. 127, No. 1, Jan. 1989, 55-66.
- [7] Estimation of the Surface Free Energy of Polymers; D.K. Owens, R.C. Wendt; Journal of Applied Polymer Science, Vol. 13, 1969, 1741-1747.
- [8] Relation of the Equilibrium Contact Angle to Liquid and Solid Constitution; W.A. Zisman; Advances in Chemistry, Series 43, 1964, 1-51.
- [9] Contact Angles, Work of Adhesion, and Interfacial Tensions at a Dissolving Hydrocarbon Surface; G.Ström, M.Frederiksson, P.Stenius; J. Coll. Interf. Sci. 10, 119/2, 352-361.