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FIXING OF CAPS WITH EPOXY ADHESIVES

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1. INTRODUCTION

Ceramic substrates equipped with chips generally require a protection against humidity and mechanical damages. This protection can, for example, be achieved by fixing the substrate inside of a hermetically sealed enclosure, by covering the circuit with an insulating material, or by sticking a cap on top of the substrate.

The installation into a hermetically tight enclosure leads to technically reliable results. Compared to metal enclosures, ceramic packages have the advantage of being magneticly pure; however, larger packages are not easy to get. Unfortunately, the large metal and ceramic packages are rather expensive. For economical reasons, another way of protecting the circuit had to be found.

Embedding the circuit in insulating material (cast resin) has proved technically questionable. Even small differences in the coefficients of expansion of substrate and embedding material result in mechanical stresses when exposed to temperature changes. As a result, the fine bonding wires may be sheared off.

On the other hand, the advantages of both kinds of packaging may be combined by protecting the circuit with a cover (Fig. 1). The cover and the substrate are connected with an adhesive. Cover and substrate are made of the same insulating material (ceramic). The necessary substrate connections are soldered to the outside of the substrate in the form of small bands or pins. When compared with hermetic enclosures, the cover proves to be the more economical solution. Compared to the embedding solution, the bonding wires are, in this case, free from tensile and shearing forces.

2. SELECTION OF THE ADHESIVES

The adhesives should have the following properties:

- mechanical strength at the desired temperature range (e.g. - 65 °C to + 150 °C)
- low hermetic permeability ($L \leq 10^{-8} \frac{atm\ cm^3}{s}$)
- electric insulation ($\rho \geq 10^8$ Ohm m)
- chemical neutrality
- non-aging
- corrosion-proof
- easy workability.

In the course of the examinations a multitude of adhesives was tested. Partly the adhesives tested had been recommended by the manufacturers, others were tested as a result of being mentioned in catalogs. Only such adhesives were tested that seemed suitable for use together with semiconductors. Neither adhesives with a low temperature strength or electric conductance, nor those with an obvious content of solvents were examined.

3. TEMPERATURE TESTS

In principle, the epoxies tested proved resistant to changes in temperature. The adhesives withstand heat storages in the whole of the range specified. For example, the substrate with the

1-inch-cover is resistant to heat cycling tests and heat shock tests (e.g. 20 shocks from - 65 to + 150 °C and back again). When exposing thin layers of adhesive to heat storages, a loss of weight in the percentage range (typical is 5 % at 150 °C in 1000 h) is revealed. The vaporous substances emerging from the adhesive were measured with a mass spectrometer. The result showed that 80 % of these substances were made up of water, the rest of oxygen and nitrogen. Only traces of substances with a higher molecular weight were found.

4. HUMIDITY TESTS

All adhesives that came up to the basic requirements of low permeability and temperature range were tested for their moisture resistance. It was found that all of the adhesives tested were destroyed when exposed to high water vapour pressures. In addition, the adhesives were affected by saturated water vapour even at lower temperatures (e.g. at t = 40 °C) although at a correspondingly lower rate. It is not certain to what extent these results can be applied to unsaturated water vapour. However, it can be assumed that the destruction of the adhesive progresses at a noticably slower rate when exposed to unsaturated instead of to saturated water vapour. Nevertheless, the question of whether the adhesives are tropic-proof remains open. Prior to their use in a region with a relatively high moisture content (about 90 to 100 % relative humidity = rh) suitable adhesives will have to undergo corresponding tests (e.g. MIL-STD-202 D, method 103 B, condition D (permanent humidity at + 40 °C, 92 % rh, 1344 h). Various types of test samples were used in order to determine the resistance of adhesives when exposed to humidity. The test samples consisted of single substrates, double substrates and substrates with various covers (Fig. 2).

When exposing the adhesives to hot water vapour an increase in weight was revealed. Parallel to it, a swelling of the adhesives was observed. When examining harder adhesives it was found that the swelling process caused the substrates to bend and, finally, to crack. After increasing in weight by some percent the sticking materials lost their adhesive capacity and disengaged from the substrates. As a rule, this process involved further obvious changes of the adhesive properties: the adhesives crumbled and frequently changed colour, too. The changes could not be rectified by drying or heating up. A typical condition for destroying an adhesive layer of 2 mm is given when the adhesive is exposed to water vapour of 100 °C for a period of 32 h, or 120 °C for 8 h.

Double substrates were used for the quantitative measurement of the disintegration rate. The adhesive material located between the two glass sheets can only be destroyed from the external edges. The progress of destruction can be observed through the glass sheet. These conditions correspond to the geometry when using a cover on a substrate: two flat surfaces are connected with a thin adhesive layer. A possible attack starts from the outer edges. As expected, a discoloured seam at the outer edge of the adhesive layer can be observed as a result of the exposure to water vapour. When increasing the storage time, the seam grows evenly wider. After an extended exposure to water vapour, the center shows discolouration, too, and the two glass substrates fall apart. Upon examination of a double substrate after it was exposed to hot water vapour (Fig. 3) an interspace between the discoloured outer seam and the unchanged center can be observed. This interspace can be easily identified by a multitude of fine interference lines that change position when the substrate is pressed. The interference lines (Newton rings) are caused by the interference in a wedge-shaped layer. In this case, it is an air gap between substrate and adhesive layer. The gap is caused by the swelling of the outer part of the adhesive layer. This causes the following adhesive volume to peel off. The peeled-off adhesive is subject to more intense corrosion by hot water vapour since the corrosion can act from the outer edge and from both surfaces of the adhesive.

The advance of the moisture along the gap also confirms an observation recorded during the humidity tests: tests with a relative humidity of 92 and 100 % produced comparable results. This can be explained by a capillary condensation: in the narrow gap of only a few micrometers in height, humidity condenses even at less than 100 % rh. Thereby, the mechanism of gap formation becomes effective even without external dewing. In contrast, test samples exposed to moderate humidity conditions at room temperature remained unchanged for years.

A disintegration rate of $v = d/t$ can be determined upon measuring the width d of the destroyed outer zone. Fig. 4 shows this disintegration rate at 100 % rh. Increasing the temperature by 10 ^{O}C causes the rate of disintegration to double. When presented logarithmicly, it can be seen from the illustration that nearly parallel straight lines are produced by different adhesives. It follows, that a preliminary test at two different temperatures, for example at 120 and 100 ^{O}C, is sufficient for a first approach towards the yet unknown adhesive. Substrates with a cover confirm the results achieved with double substrates. Covers on ceramic substrates stuck 1,5 times longer that those fixed on glass substrates. The reason for this might be that the epoxy finds a better adhesion on the coarse ceramic surface than on the smooth glass. Presumably, the adhesive does not peel off so easily in the interspace. After an extended exposure to hot water vapour, drops of water appeared on the inside of the covers and glass substrates. When the exposure to hot water vapour was even more extended, the cover and the substrate fell apart. Following the exposure to hot water vapour the test samples were left to cool down and were subsequently immersed in an inert fluid of 125 ^{O}C to be tested for hermeticity. The consistence of the material was also affected by this test: even those adhesives that stood the humidity test without noticable discolouration now revealed leaks. Frequently, this test caused the cover and the substrate to separate with explosive force.

Another important property of the adhesives was observed on covers fitted on glass substrates: the property to balance mechanical tensions. When curing at high temperatures (for example at + 150 °C) particulary thin glass substrates revealed bends. This is largely due to the low pressure in the inside of the cover after cooling down. Other distortions of the substrate were noticed when the adhesive shrinks in the process of curing, and when exposure to hot water vapour causes it to swell. Sometimes, ceramic and glass substrates were even destroyed. The distortions were particularly noticable when hard adhesives were used.

5. RESULTS

The substrate with the cover fixed on top of it in the form of an inexpensive multichip passes the ambient tests teat storage and temperature cycles without any difficulties. However, regions with a particularly high constant humidity should be avoided.

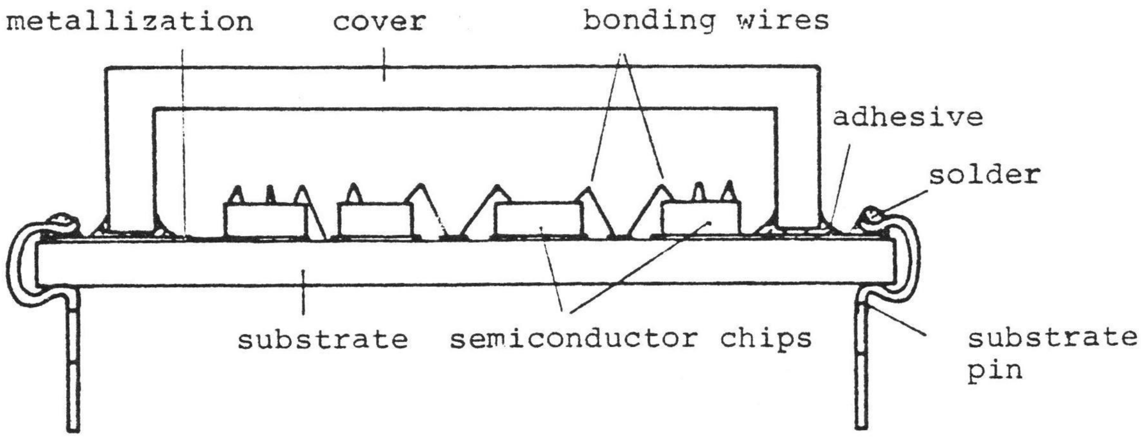
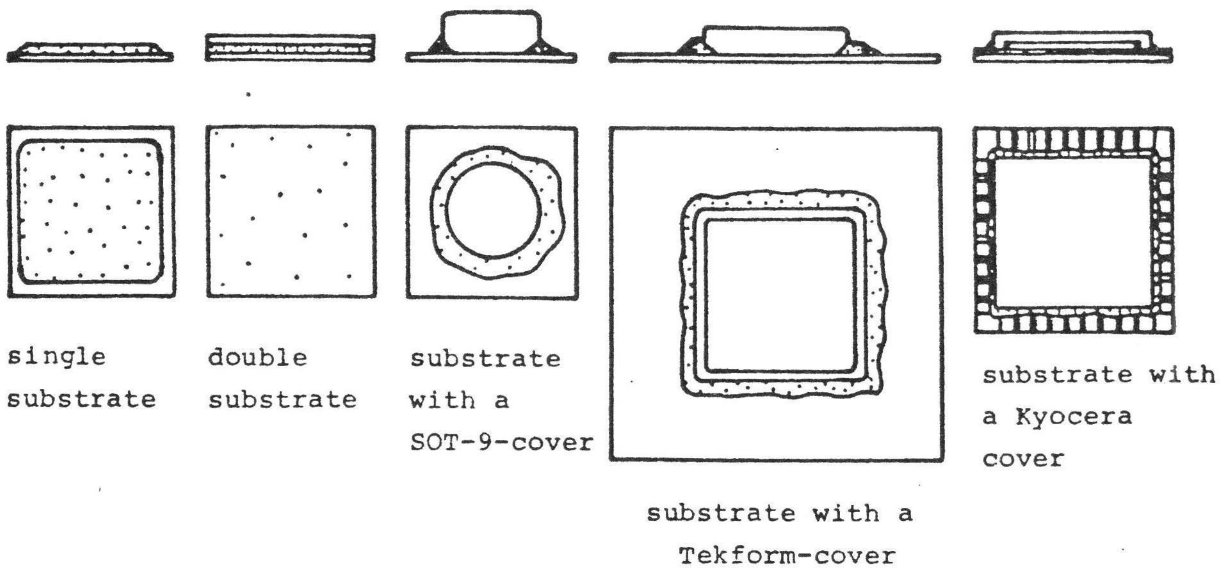
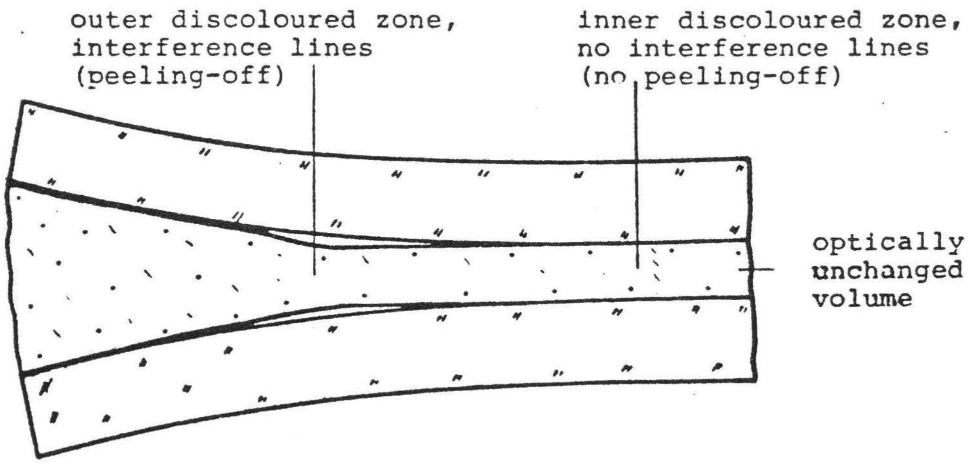


Fig. 1: Multichip circuit as a substrate with a cover



<u>Fig. 2:</u> Test samples for the moisture test



<u>Fig. 3:</u> Double substrate after exposure to hot water vapour storage; Section

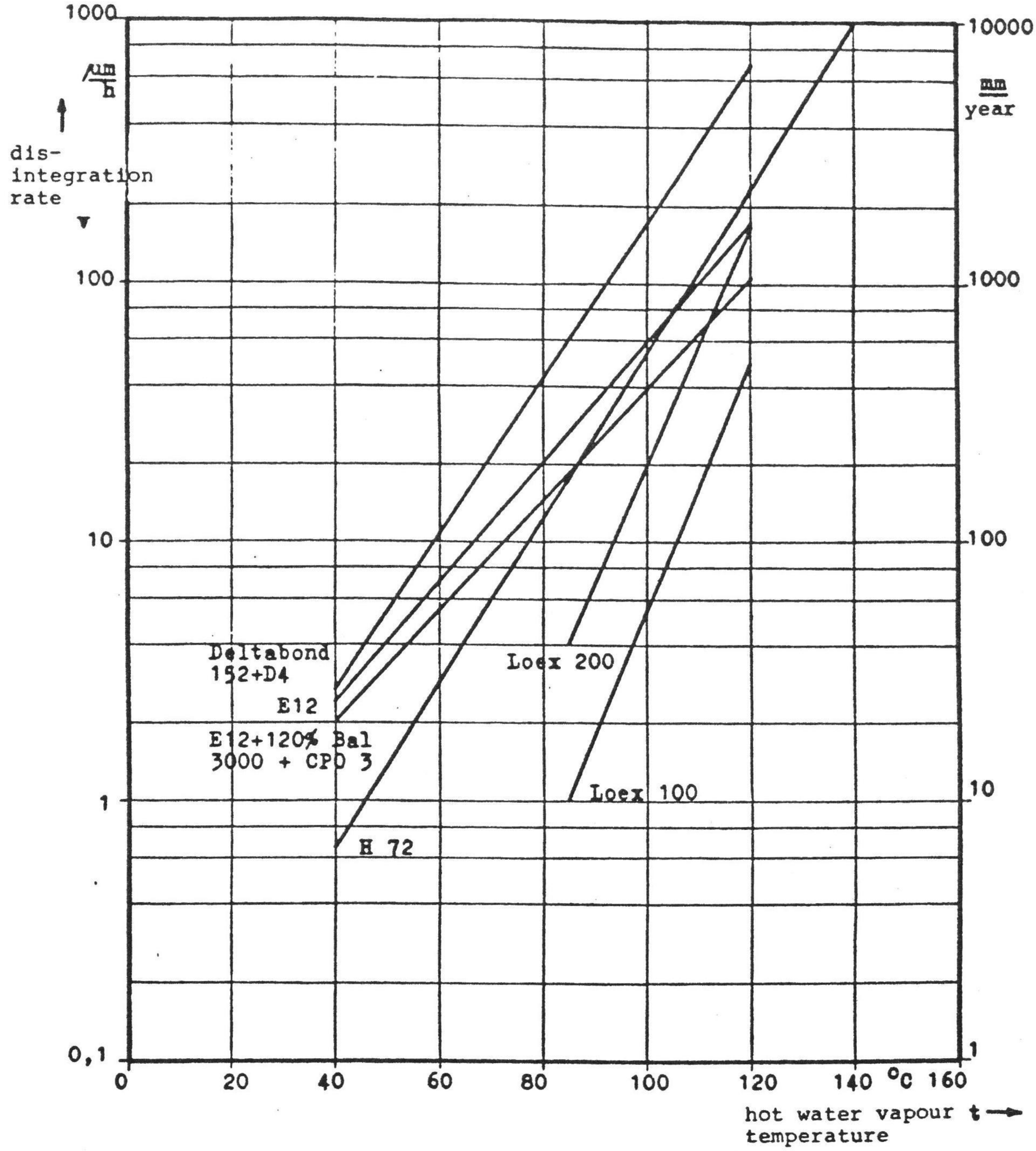


Fig. 4: Disintegration rate of adhesives in saturated hot water vapour