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Epoxy Bleedout in Ceramic Chip Carriers

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Abstract — **The use of conductive silver filled epoxies for the bonding of silicon IC chips into ceramic chip carriers and chip carrier like packages is a well established procedure in the microelectronics industry. One problem that has plagued this die attach method has been the separation and "bleeding-out" of the resin vehicle from the epoxy. At times, this resin bleed has been severe enough to interfere with subsequent wire bonding and lid sealing operations by coating the bonding fingers and seal rings of the carriers with resin. Even more aggravating has been the apparently sporadic nature of the problem. The objective of this investigation was to define the nature and cause of this resin bleeding phenomenon and then determine a practical solution for its elimination.**

INTRODUCTION

The use of silver filled conductive epoxy for die and component attach is an established practice in the microelectronics industry. A problem which has plagued this die attach method is the phenomena of resin bleedout from the epoxy. When severe, this resin separation can interface with subsequent assembly operations by coating wire bonding and lid sealing metallizations with resin. Particularly susceptible to this effect are ceramic chip carriers. The close proximity of wire bonding and lid sealing metallizations to the epoxy in this package type makes even minor resin separation a potentially serious problem. The objective of this investigation is to define the cause and effect relationships involved with epoxy bleedout. The work focuses primarily on the behavior of silver filled conductive epoxies when applied to the type of gold plated, thin film, metallized surfaces commonly found in ceramic chip carriers. The results of the experiments lead ultimately to a definition and solution of the bleedout problem in these packages.

EXPERIMENTAL PROCEDURE

An examination of production records indicated that the severity and frequency of epoxy bleedout was closely related to specific chip carrier vendor lots. Two specific chip carrier lots from two different vendors were isolated as having a particularly acute bleedout problem. The first of these lots, from vendor B, exhibited very severe bleedout. Separating epoxy resin frequently covered the entire die cavity floor and often succeeded in wicking up the package side walls, contaminating the post bonding fingers, and severely interfering with subsequent wire bonding operations. The second isolated lot, supplied by vendor A, also exhibited bleedout. The bleedout in these parts, however, was less severe, exhibiting on an average only a three to four mil halo-like spreading from the point of epoxy applications.

Initial experimental testing focused on these chip carrier lots in an attempt to answer the following questions:

1. What is the reason for the observed differences in bleedout severity between the two vendors' products?
2. What are the specific characteristics and observable mechanisms of the bleedout phenomena?
3. What are the effects of epoxy brands and epoxy formulation on the occurrence and severity of bleedout?
4. How can bleedout be controlled or eliminated?

"Bleed testing" was performed by depositing a 20 to 40 mil dot of epoxy in the center of the test chip carrier bonding area. A minimum of ten pieces were run for each sample evaluation. All parts were allowed to stand a minimum of five minutes prior to heat curing of the epoxy. All curing was done at 150°C ±1°C on an open hot plate. Careful notes were taken as to the bleeding behavior and extent, during both the standing and curing periods.

In the first stage of the experiment, only two epoxy types were used in the evaluations. These were Abelbond 773-6 and Epotek H2OE. The Abelbond material is a two component epoxy which is delivered premixed and frozen. The Epotek H2OE, also a two component epoxy, was mixed one to one by weight immediately prior to each test run. All evaluations were restricted to single epoxy lots of each vendor type. Later in the evaluations, a variety of other adhesive types were also tested for bleedout characteristics.

RESULTS AND DISCUSSION

In the initial testing, both the Abelbond and Epotek epoxies exhibited a very severe bleeding problem on the vendor B chip carriers (see Figures 1 and 3). On the vendor

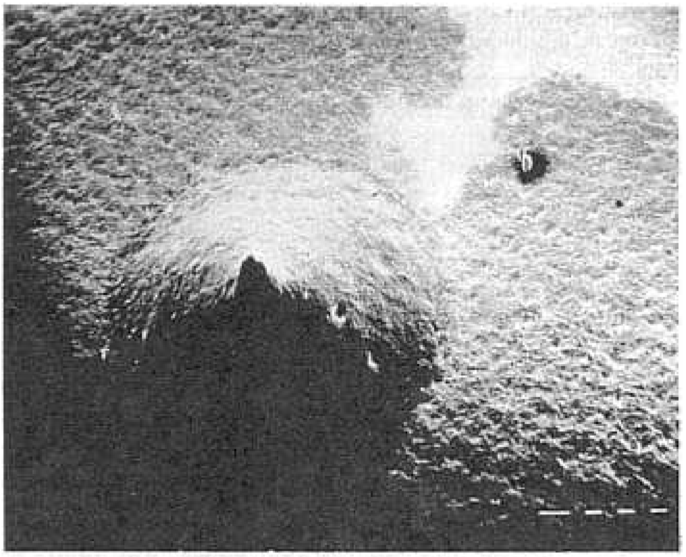

Figure 1. Typical resin bleedout on a vendor B chip carrier using H20E epoxy.

A parts, both epoxies showed either no bleeding or only a minor bleed halo (see Figure 2). There were notable differences between the two tested epoxies in the manner in which the resin separated from the original dot. Within a minute of being dispensed on a vendor B chip carrier, a darkish ring of separating resin could be seen forming around the Epotek H2OE epoxy. Application of heat during curing caused this separated material to spread rapidly radially outward. The spread reached its maximum extent after only a few minutes on the hot plate. When the Abelbond material was dispensed on a vendor B part, an immediate wetting action was noted. There were even some silver particle movement and separation observable near the dot edges. When heat was applied to this epoxy, the resin vehicle wicked rapidly outward, causing an actual physical collapse of the original dot (see Figure 3). In some samples, silver particles were actually carried away from the original dot and accumulated in the package corners.

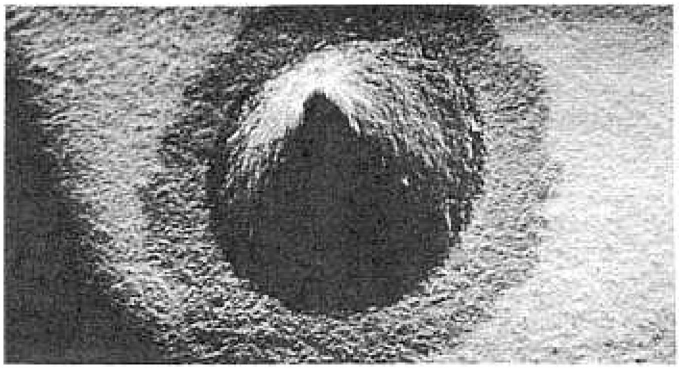

Figure 2. Worst case bleedout on a vendor A chip carrier using H20E epoxy.

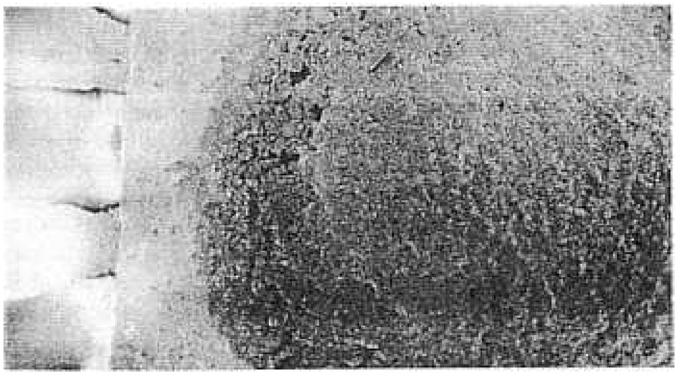

Figure 3. Abelbond 773-6 epoxy on a vendor B chip carrier. Note the spread of silver particles at the dot edge. Mag. 53X

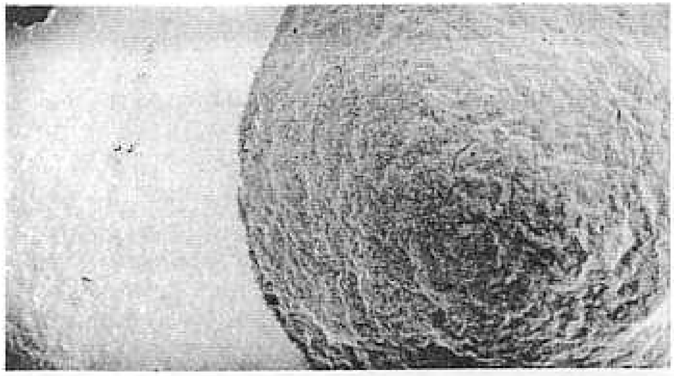

Figure 3A. Abelbond 773-6 epoxy on a vendor B chip carrier that was vacuum baked four hours at 250°C before dispensing of the epoxy. Note the absence of resin separation at the dot edge.

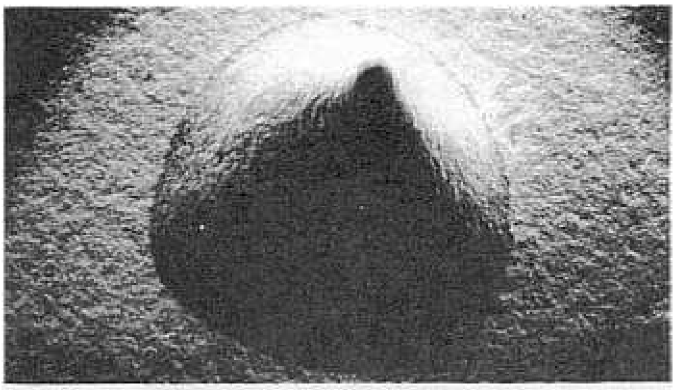

Figure 3B. H20E epoxy on a four hour vacuum baked vendor B chip carrier.

It was already evident from an examination of product records that a substantial difference in the severity of bleedout existed between vendor A and vendor B chip carrier products. Experimental testing confirmed the product records indication that vendor B chip carriers suffered the severest bleedout problem. A scanning electron microscope was used to evaluate the surface contour of each vendor's parts in an attempt to determine a reason for this observed difference.

As can be seen in Figure 4, the surface of the vendor A part was found to be relatively smooth and void free. In contrast, surfaces of the vendor B parts, shown in Figure 5, have a much grainier and obviously porous appearance. It is believed that this surface porosity promoted resin spreading through capillary transport and accounts for the observed severity and extent of bleedout in the vendor B chip carriers.

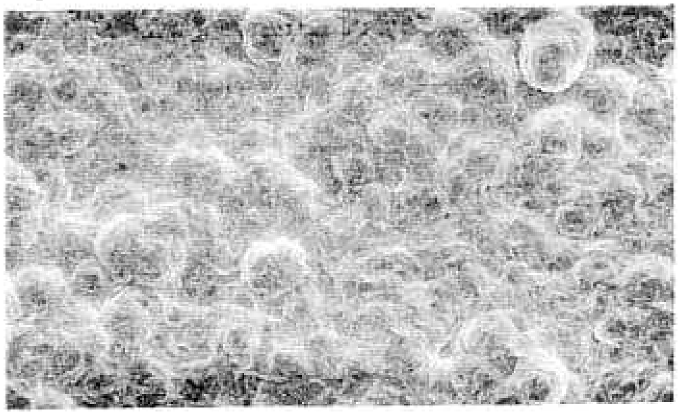

Figure 4. Vendor A bonding area surface. Mag. 1090X

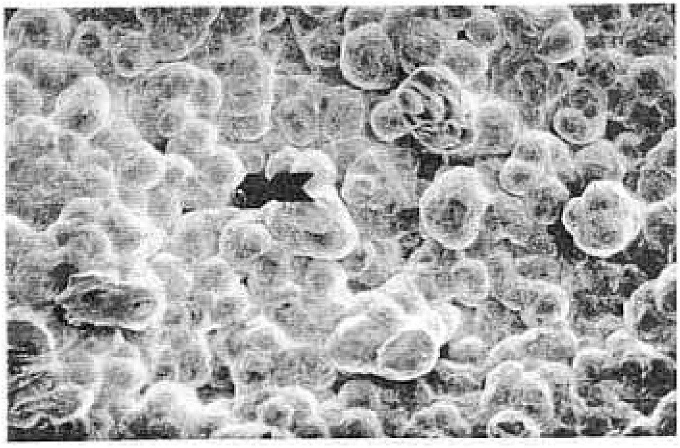

Figure 5. Vendor B bonding area surface. Mag. 1090X

Though the surface porosity of the parts appears to contribute substantially to the ultimate spread of the resin, it was not believed to be the primary causative agent in epoxy bleedout. Other lots of vendor B chip carriers have been encountered, which have had equally as porous surfaces yet exhibited little bleedout. In addition, the vendor A parts used in this study, which have nonporous surfaces, still exhibited some degree of bleedout. The observed behavior of epoxy dispensed on a bleed prone surface strongly suggests that a surface wetting phenomena is occurring. The meniscus action at the epoxy dot edges shows a definite wetting action that is absent when the same epoxy is applied to a nonbleeding surface. This effect is suggestive of a surface contaminant, which either by dipole attraction or chemical reaction, promotes the separation of lighter organic resin fractions from the epoxy.

In the manufacturing and handling processes, which the chip carriers undergo prior to being die bonded, ample opportunity for the introduction of a variety of surface contaminants exists. A particularly suspect process is the gold electroplating operation used during the manufacture of the parts. The plating baths expose the parts to a variety of organic and inorganic compounds. Some of these materials may become entrapped in the microstructure of the gold as it is deposited on the part. In addition, both the manufacturer and the end user will normally give the parts a fluorocarbon/alcohol cleaning prior to shipment or end use. These cleaning cycles offer the additional possibility of solvent residues on or in the parts.

In an attempt to detect the presence of such surface contamination, the series of tests shown in Table 1 was performed. The first test was for inorganic plating bath salts or other water soluble compounds. A group of known bleeding vendor B chip carriers was boiled in 15 megohm deionized water for one hour. These parts, along with a group of unboiled controls, were then vacuum baked for four hours at 250°C and 100 millitorr. This was initially done only to ensure that the boiled parts were free of residual water. Amazingly, when bleed testing was performed, it was found that bleedout had been eliminated in both the control and boiled samples. Evidently, the vacuum baking step had somehow acted to eliminate the resin bleedout.

The results of this experiment indicated that some type of adsorbed yet volatile surface contamination was present on the chip carriers. The vacuum baking process was investigated further by baking an additional group of vendor B parts. Once again epoxy bleedout was eliminated. Some of these vacuum baked parts were then allowed to stand in room air for 24 hours to determine whether surface absorbed moisture might be the causative factor of resin bleeding. After 24 hours, these parts still exhibit no signs of bleedout. In fact, later testing has shown that the bleeding phenomena do not return even after long periods of room air exposure.

The influence of normal production cleaning steps on the parts was next investigated. A group of chip carriers was bleed tested as received from the vendor. These parts showed a moderate amount of bleedout. Parts from the same lot were then cleaned using a common fluorocarbon/alcohol cleaning solvent. This cleaning resulted in a marked increase in the severity of the bleedout. Vacuum baking of either the as received parts or the cleaned parts eliminated bleedout in both groups. Interestingly, recleaning of the of the vacuum baked parts did not induce new bleedout. Figures 2, 3, 3A, and 3B illustrate the results obtained from the Table 1 experiments. Note the total absence of resin separation and the specific non-wetting, convex meniscus at the edge of the epoxy dot on the vacuum baked samples. This effect is particularly pronounced with the Abelbond epoxy, as shown in Figures 3 and 3A.

It was found that a combination of both vacuum and high temperature was required to eliminate bleedout. Neither a simple 250°C oven bake nor a vacuum treatment alone was effective in reducing bleedout.

The dependence of bleedout on specific adhesive formulations was also briefly investigated. A number of common conductive die attach materials were used for testing. The test results, using both vacuum baked and unbaked chip carriers, are summarized in Table 2. None of the products tested bleed on the vacuum baked chip carriers. All of the epoxy based materials showed some degree of bleedout on unbaked parts. The polyimide adhesives showed no bleeding behavior, though there was some slight separation of the solvent used in these materials on unbaked parts. However, this solvent vehicle evaporated upon curing.

CONCLUSIONS

The experimental testing leads to a number of conclusions regarding the behavior of epoxy resins when applied to chip carrier surfaces:

1. Epoxy resin bleeding in ceramic chip carriers appears to be a phenomenon strictly related to the surface condition of the part and is not due to any inherent defect in the epoxy formulations. There are indications that a contaminant is present which modifies the surface wetting characteristics in such a way as to promote a phase separation of the lighter fractions of the resin vehicle. The vendor B parts exhibited the most severe problems, due to an additional factor of capillary transport supplied by their porous surfaces. The vendor A parts also exhibited bleedout though their smoother and void free surfaces act to moderate the problem.

2. A high temperature, high vacuum bake of bleedout afflicted chip carrier has been shown to be effective in eliminating bleedout in both the vendor B and vendor A parts. The effectiveness of the vacuum baking procedure is highly indicative of the presence of either a high molecular weight and/or a highly surface adsorbed contaminant.

3. There is a definite relationship between the fluorocarbon/alcohol cleaning and the occurence of bleedout. The cleaning of vendor parts made the bleedout worse, whereas the cleaning of vacuum baked parts did not cause bleedout to reoccur. It is possible that a contaminant is being picked up during the manufacture of the parts, most probably during the gold electroplating operation. This contamination acts to promote an active adsorption of cleaning solvents, which in turn produce a surface wetting reaction with the applied epoxy.

The vacuum baking operation removes both the trace cleaning solvents and the original contaminant. Thus, recleaning of vacuum baked parts does not cause bleedout to reoccur, since solvent is no longer entrapped. An empirical conformation of these theories, through Auger or microprobe, is extremely difficult, due to the complexity of the surface chemistries involved and the micro quantities of materials present.

4. On a qualitative basis, there appears to be little difference in the bleedout resistance of the various epoxies tested. Some formulations, such as the Abelbond 773-6, exhibited signs of silver migration in addition to resin bleeding. This could be a more serious threat to device reliability than the spreading of the nonconductive resin only. However, vacuum baking of the chip carriers prior to die bonding eliminated even this bleedout.

TABLE 2

BRAND	FORMULATION	BLEED BEHAVIOR* UNBAKED	BAKED
Epotek H20E	Epoxy	Severe	None
Epotek H27D	Epoxy	Moderate	None
Epotek P-10	Polyimide	None	None
Amicon C840	Epoxy	Severe	None
Amicon CT2523	Epoxy	Moderate	None
Amicon CT2523-1	Epoxy	Severe	None
Amicon C950	Polyimide	Slight (Solvent)	None
Abelbond 773-6	Epoxy	Severe	None

*Qualitative visual criteria

AFTERWORD

Vacuum baking of chip carriers prior to die bonding has been implemented as a normal production process for over one year now. Assembly yield losses due to epoxy bleedout on properly baked parts have been reduced substantially to zero. For the treatment of large volumes of parts, process scaling experiments have found that a 15 hour, 200°C, baking schedule provides optimum results in a production environment. It has also been found to be important when using large vacuum chambers for extended periods of time to protect the parts from oil backstreaming from the vacuum pump. Molecular sieve foreline traps are available for this purpose and should be installed prior to any vacuum system operation.

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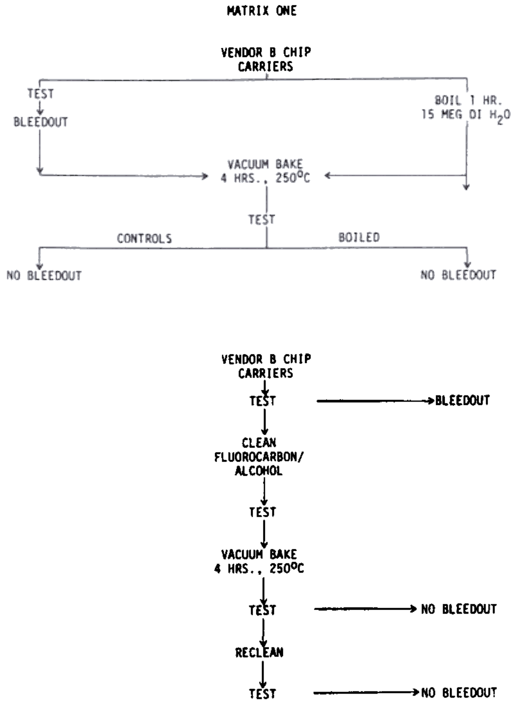
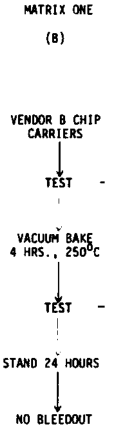
TABLE 1

(A)



(B)



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