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Precision Dispensing of Liquid Encapsulants for Smart Cards

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Roland Moreno is credited with the first patent for a Smart Card in 1974¹. Smart Cards have significantly evolved since then into major instruments of commerce in France and more recently other parts of Europe. Now that the Bank of China stating their intention to use smart cards this has have attracted a lot of attention in Asia.

A smart card consists of a plastic card with printable surfaces, a small printed circuit board (PCB) with eight contact pads on the surface which are flush with the surface of the card. The PCB has an Integrated Circuit (IC) chip bonded to the underside of the PCB. The IC is wire bonded to the PCB and encapsulated with liquid epoxy resin to form a Chip on Board (COB) module. Epoxy based encapsulation materials are used to protect the wire bonds, keep moisture/corrosive elements away from the chip and provide mechanical protection. The module is glued into a milled cavity in the card. A Glob Top process is typically used to encapsulate the IC and wire bonds. Some manufactures use post encapsulation grinding, to control the height of the module, so it will fit into the cavity in a plastic card.

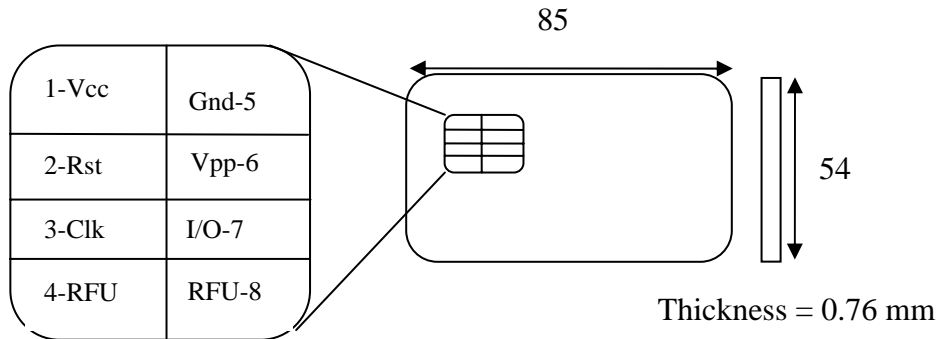
This paper will review Glob Top and Dam & Fill encapsulation processes in the production of contact smart cards. Due the exacting dimensions required for this application, our customers specified an overall height tolerance of 50 microns for the encapsulation materials. This requires exacting control over the dispensing system and materials, whilst maximizing throughput.

Smart Card Fabrication

Cards are made from several different resin materials such as PVC, ABS and polyester. PVC sheets up to 58 cm wide are used in the production of cards. At least two manufactures have a process which injection molds a card around a COB module. However this process limits the choice of card materials which can used to form a card. For reasons associated with card flexibility, cost, and several other factors PVC has become the dominant material used in card manufacturing.

The Physical dimensions for contact smart cards are defined in ISO standard 7816 – 1,2 which govern the card dimensions and contact pad locations (figure 1). Cavities for the

COB modules are milled into the body of the PVC Sheet. Cavity size and depth being determined by the IC chip size and the amount of encapsulation material surround the IC. The COB module is partially buried in the card material so that the gold plated PCB contact pads on one side of the COB module are flush with the card surface (figure 2).



Chip on Board, Module **Figure 1: Smart Card dimensions and module**

Chip on Board Module

Contact smart cards only have 5 or 6 wire bonds per die so the density of wire bonds is not a factor in the encapsulation process. The bond wires are typically aluminum wedge bonds, which have a lower profile than gold ball bonds. However the bond wires and die require protection from mechanical flexing of the card and environmental contamination when the card is handled

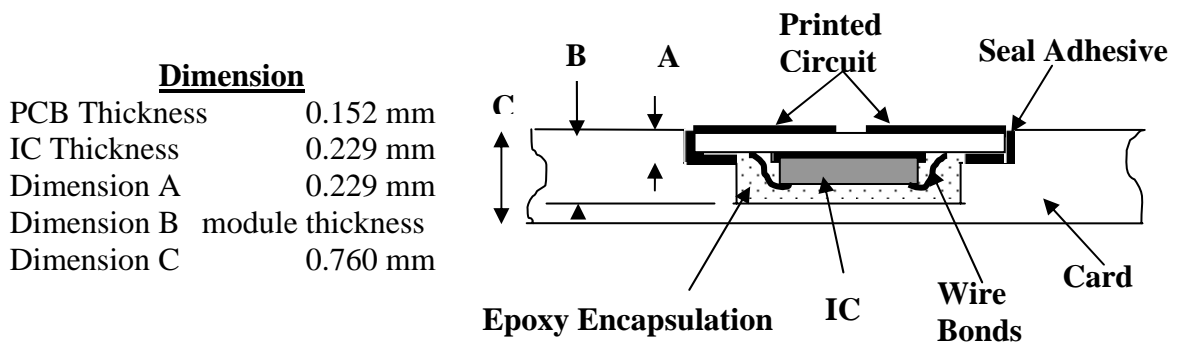


Figure 2: Smart Card Cross Section

Glob Top Encapsulation

Glob top encapsulation would appear to be the simplest method of encapsulating the IC and wire bonds. However it is difficult to obtain a uniform height of encapsulation material over the IC and wire bonds without creating a mound of epoxy. Some manufactures grind the thickness of the module to a finished value typically

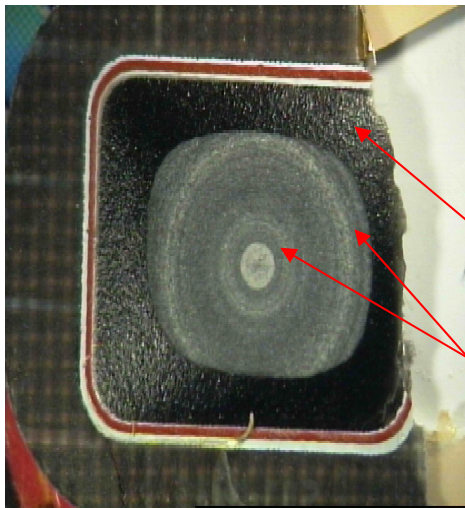
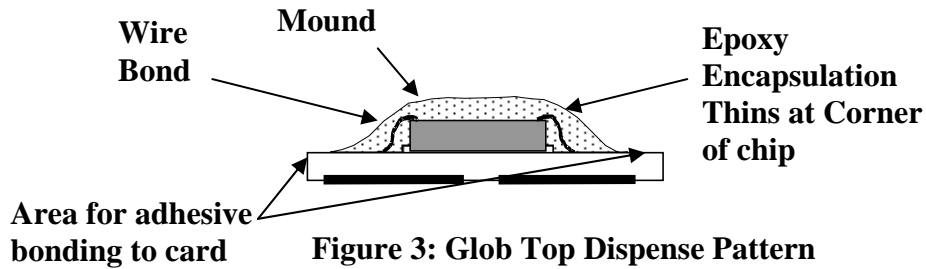


Figure 4: Glob Top encapsulation with grinding marks

of 0.63 mm. Figure 4 is a picture of a glob top ground down to fit into a card cavity. Glob top encapsulation techniques become less suitable as the IC chip gets larger or if multiple IC chips are used in one module.

Encapsulant fluid manufacturers have developed glob top materials that lower viscosity with shear thinning action from an auger pump. The fluids initially flow to cover wire bonds and quickly recover their original viscosity, to keep the encapsulant out of the Module to card bond area.

Dam & Fill Encapsulation

The Dam & Fill encapsulation method uses two different viscosity epoxy materials to provide protection of an IC device. The Dam material is a highly filled epoxy with viscosity's ranging from 500,000 to 1,000,000 centipoise. A rectangular pattern of epoxy is dispensed around an IC chip to form a dam, usually just beyond the second wedge bond on the circuit board. The height of the dam is controlled by the properties of the material that are set by the epoxy manufacture and dispensing conditions such as needle dispensing height, epoxy temperature and several other factors.

Fill encapsulation material is a similar epoxy formulation to the dam, with much less filler. The viscosity of fill fluids can range from 1000 to 50,000 centipoise. They have the ability to flow quickly under wire bonds and around the IC chip and level to a uniform height. Large flat top surfaces can be obtained, which will fit into flat-bottomed card cavities. By separating the functions of the two fluids to height control / containment for the Dam fluid and encapsulation to the fill fluid the best properties of both fluids are combined to provide an effective encapsulation method.

Damming fluids are thixotropic materials whose viscosity can drop by 50% with shear thinning action from the auger screw pump, typically used for dispensing. Single point viscosity numbers from the epoxy manufacture are not a good indicator of the fluids potential for forming a high aspect ratio dams and therefore materials need to be thoroughly characterized for use in an application ³. Five different manufactures dam materials were evaluated and the results shown in table 1. A high aspect ratio of dam width to height is preferable to minimize space used for encapsulation. Note the specific gravity of any fluid is controlled to 1% by the epoxy manufactures this allows fluid weight or line weight to be used to control machine fluid dispensing parameters. A 12 mm line length of consistent aspect ratio should always weigh the same even though the viscosity of the fluid will change over time. This can only be achieved if dispensing parameters are computer controlled using mass flow weight control system built into a feedback loop.

Table 1: Five Different Manufactures Dam Materials

Fluid	Viscosity (cps)	Aspect Ratio (Width/Height)	Specific Gravity
A	1,300,000	3.8 : 1	1.76
B	690,000	1.5 : 1	1.6
C	575,000	2.5 : 1	1.75
D	500,000	3.8 : 1	1.8
E	1,200,000	2.3 : 1	1.8

Dam Knit Points

Where Dam height is critical or cosmetic appearance is important attention needs to be placed on the knit point of the Dam, where the start and end points of the line meet (figure 5, note the fluid is shown with two different shadings to differentiate the start and end points of the same dam). On modern dispensing equipment there are over fourteen different line control functions that can be used to control a knit point, start speed, turn on delay, ramp speed, turn off delay, backtrack, over travel, to name a few which can be used to perfect a good knit point. The choice of which functions to use depends to some extent on the characteristics of the fluid. Figure six shows the results from a typical analysis of knit point on a Dam, using a laser profilometer.

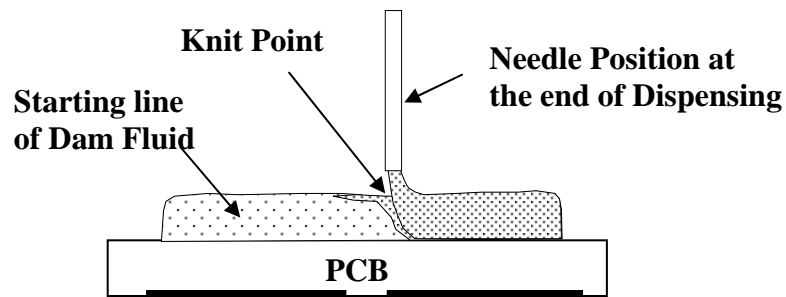


Figure 5: Knit Point of Dam

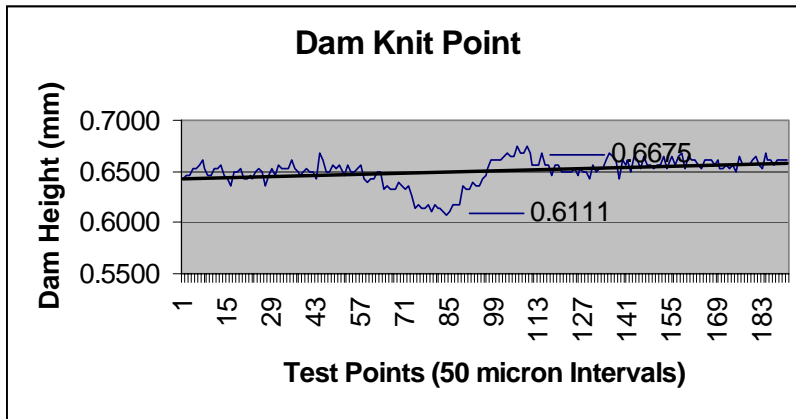


Figure 6: Knit Point Analysis (Laser Profilometer)

Dam Filling

Fill epoxy is dispensed into the Dam immediately after forming a Dam, using a dual action dispense head on the same machine or on a second machine in line. This allows the wet Dam and Fill fluids to coalesce and form a continuous coating of encapsulation material. It also minimizes any opportunity for air entrapment on the dam walls.

Due to the two different concentrations of filler particles in the Dam and fill fluids, having different coefficients of thermal expansion. It is advisable to not have wire bond wires traverse through both fluids. Filling a dam immediately after formation will minimize the dam fluid flow into the IC cavity and tighter specifications can be placed on the position of the dam.

Fill patterns for single chip devices can range from circular or rectangular spiral in or out patterns. However recently these patterns have developed to line and dot patterns as in figure seven. When multiple IC chips are used the height of each die needs to be taken into consideration. The taller the IC chip the less material

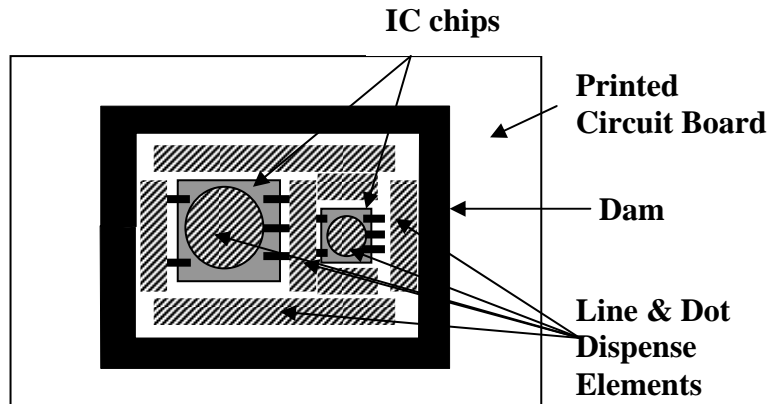


Figure 7: Fill Pattern for a Two-Chip Smart Card

will be required for encapsulation especially with a maximum height specification. If the second IC has a smaller surface area then more fluid will be required to fill in the dam around the chip than the larger die.

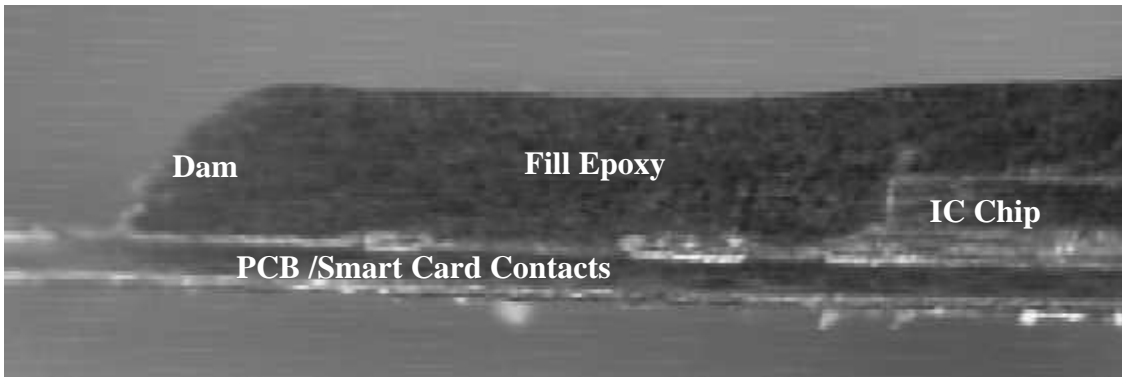


Figure 8: Section through a Dam & Fill Encapsulation, IC Chip and PCB

Figure eight is a cross section through finished smart card COB module. The blend of epoxy materials between the Dam and Fill is indistinguishable and no voids or air inclusions can be seen. The fill epoxy has a slight change in height above the first IC chip but is within the height specification of 0.53 to 0.58 mm for this customer.

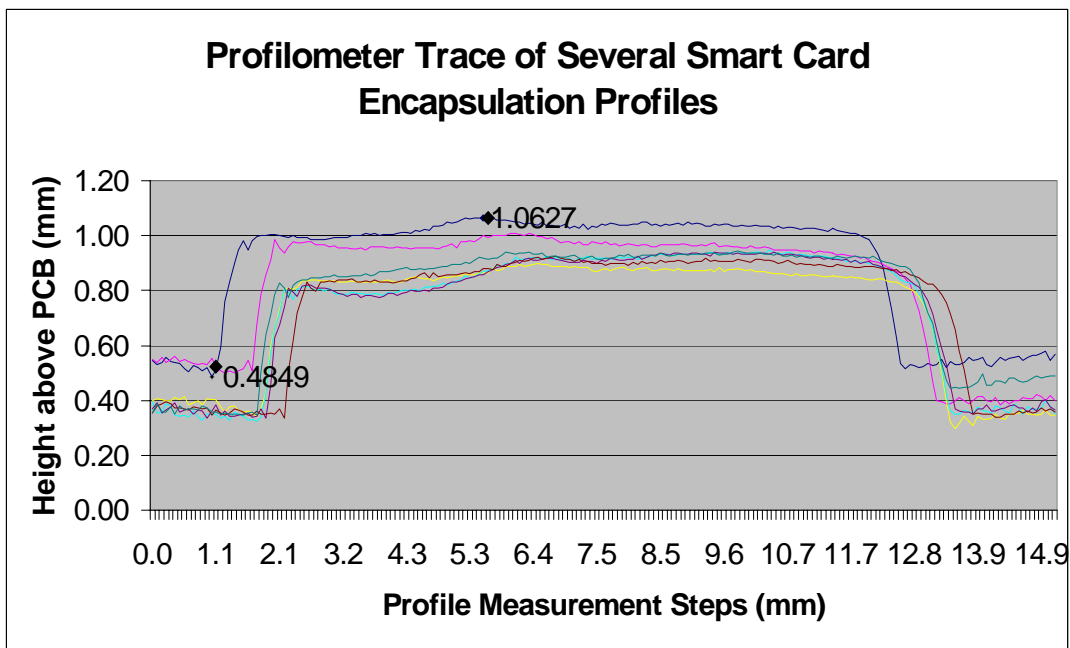


Figure 9: Profilometer Traces

Figure nine show several Laser profilometer traces over encapsulated smart cards after curing. Although the zero height of the PCB is offset for several cards in the graph the overall height is within the height specification window of fifty microns. However the

individual traces show that more fill material could have been added to the left hand side of the graph because there is a slightly lower level in this area which coincides with the smaller IC chip zone. Also note that the transition between the Dam and Fill on the right hand side of the graph shows a smooth transition. On the left hand side there is a small dip just after the apex of the Dam. Again this indicates that slightly more dam fill fluid could have been added to improve the transition between the Dam and Fill fluids.

Summary

Dam and Fill encapsulation method for smart cards has been shown to be a highly accurate method of applying protective epoxy overcoats for IC chips and wire bonds. In applications such as smart cards where tolerance specifications on the overall thickness has to be controlled to within fifty microns, it has been shown that this can be achieved with accuracy and repeatability.

In difficult transition areas of dispensing such as the knit line, modern dispensing equipment which have numerous control features on line parameters are proving that liquid epoxy materials can be dispensed with precision and consistency. When this is coupled with mass flow control methods to eliminate the effect of viscosity changes over time once a process is developed it can be put into production with assurances that it is highly repeatable. This ability to control height and still obtain adequate coverage over die and wire bonds can eliminate a grinding step in smart card manufacturing.

The smart card process, which was developed for this customer, is presently being used on an Asymtek, Century machine running at over five hundred units per hour. This throughput number could be increased considerably with newer high speed machines but it meets the price performance characteristics for this application.

References:

- 1) Smart Card Museum, www.cardshow.com/musem/ex70/y74.html, Analyses & Syntheses, 146 rue Monmartere – 75002, Paris – France
- 2) ISO Standard 7816 – 1
- 3) Dam & Fill encapsulation for IC devices, S. Adamson, C. Ness, Nepcon West 1999

