Adhesion Enhancement for Electroless Plating on Mold Compound for EMI Shielding with Industrial Test Compliance

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***Abstract* – In the manufacturing process, metal capping for EMI shielding is done during the integrated circuit (IC) assembly process, which hinders the attempt of reducing the size of electronic device and also incurs higher cost of assembly. Therefore direct deposition of metal on IC mold compound is desirable. Conventional metal plating techniques, however fail tape test. This paper studies the condition of plating metal directly onto surface of mold compound with the enhancement of novel non-etching adhesion promoter CovaBond MR™. By plating direct onto mold compound, the shielding capping task can be done in array form before the die saw process in IC manufacturing (before IC assembly), which reduce the thickness and dimension of chip and improves design flexibility of circuit board as well as reduce the manufacturing cost. The industrial test results in this paper have proven the performance of the enhanced metal plating technique**.

Key words: EMI shielding, electroless NiP, mold compound, reliability, CovaBond MR™

I. INTRODUCTION

Conventionally Electromagnetic Interference (EMI) shielding is accomplished by metal can on chip as shown in Fig. 1(a). Fig. 1(b) shows direct conformal metal plating on mold compound, which is able to create a thin and smaller dimension EMI shielding solution [1]. This provides higher flexibility on board design by reducing the need of grouping on certain area, improve chip density and reduce the total thickness of the board. In order to increase the performance of EMI shielding, a double shielding can be established as shown in Fig. 1(c), by combining plating method and metal can, which further enhance the EMI shielding capability.

Conformal shielding on mold compound has been done in market by laser roughening follow by silver paste, or using sputtering technology. The cost of conformal shielding could reduce much lower if it is done by electroless plating. However, electroless plating method is not desirable due to difficult to plate on non-conductive surface, and its poor adhesion performance.

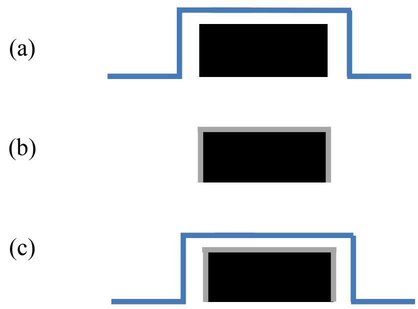


Fig. 1: Metal capping techniques: (a) Conventional metal can on device, (b) Conformal plating on mold compound helps to reduce space and height, (c) Conformal plating on mold compound combines with metal can to enhance EMI shielding effect.

II. ADHESION ENHANCEMENT AND PLATING TECHNIQUES

The key challenge to plate metal directly on mold compound is to provide adequate adhesion between metal and dielectric. Although technique of plating on plastic are quite common in fabrication process, but the same technique cannot be direct apply into mold compound. One of the reasons is the fact that mold compound is not purely organic resin instead it has high percentage of silicon oxide (normally 60-90%), which known as glass filler. Another reason is aging effect; whereby in electronic industry, aging simulation during qualification work is very critical. Device need to undergo extreme change of temperature and humidity. Normally delamination issue tends to arise thus fail in industrial standard test requirement.

Surface roughness is important to ensure the integrity of the bond between the mold and EMI shielding material. Ideal etching method should offer a better micro-roughness with high relative surface area increase (RSAI) after surface treatment. High quality micro-roughening can provide high contact area for metal plating, and reduce chemical attack between plating layer in subsequent process in manufacturing process.

One of the surface roughing techniques is using permanganate etch which can produce acceptable roughness on polymer material economically. Fig. 2(a) shows surface of mold compound where resin has been etched off by permanganate and glass filler appear on surface. However, due to resin contain in mold compound is low, permanganate etch alone is not sufficient to achieve the required roughness.

Another method we tried by performing etching on glass filler by using fluoride base chemical. The purpose of fluoride base chemical is able to attack and dissolve the glass filler, hence create roughness on the glass filler layer as shown in Fig. 2(b). In this paper, a novel non-etching adhesion promoter using CovaBond MR^{TM} from Atotech [3] is evaluated to compare to the existing techniques. CovaBond MR^{TM} is a unique wet chemical process that enables deposition of metals (e.g Cu and Ni) with good adhesion onto difficult to plate substrates such as molding resin. It employs a combination of mechanical anchoring and chemical bonding, thus enabling direct metallization with very good adhesion.

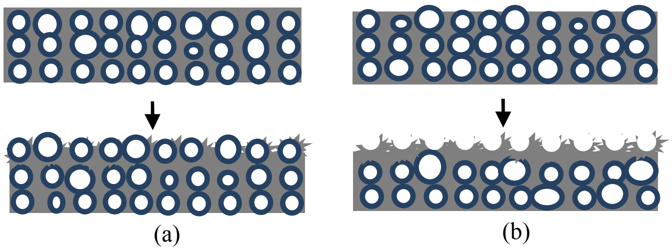


Fig. 2: Surface roughing process by, (a) permanganate etches and (b) fluoride etch.

Plating on mold compound starts with cleaning and create roughness on surface, follow by activation to enable surface to be conductive and works as catalyze to electroless nickel-phosphorous (NiP) plating etch as shown in Fig. 3.

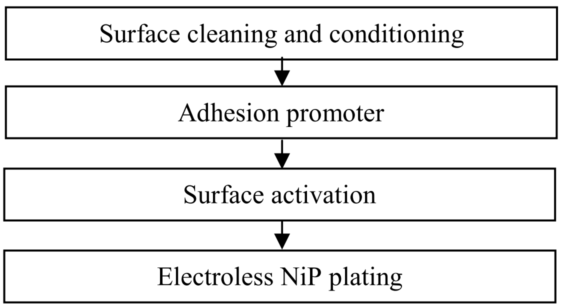


Fig. 3: Process Flow for Nickel-Phosphorous Plating on Mold Compound

III. Adhesion Mechanism

Due to of the high glass filler content and the nature of the molding resin itself, the surface of the mold compound is normally quite rough, as shown in Figure 4.

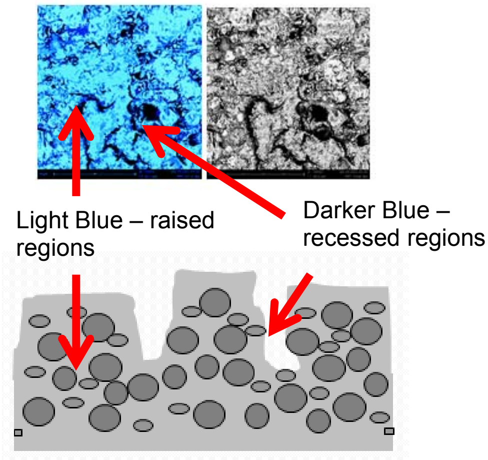


Fig 4: Structure Of mold compound

The adhesion promotion process starts with spraying the substrate with CovaBond MR^{TM} which excellently wets & fills the surface topography, including recessed areas. Later the solvent evaporates; condensation leads to a thin CovaBond MR^{TM} film. Solvent penetrates into substrate, inducing the resin surface to swell, thus increasing the available area for permanganate etching. CovaBond MR^{TM} film imparts added selectivity for the permanganate attack on the resin, thus increasing the available surface area for adhesion. Particularly the recessed regions are subject to softening and swelling, while the raised regions are protected by the CovaBond MR^{TM} film serving as a temporary and local etch resist.

Process followed by permanganate etching as illustrated in Figure 5(a) and 5(b). CovaBond MR^{TM} film completed etched from surface within ≤ 2min. Dense matrix on top of raised regions retard the etching process and induce a planarization effect. Permanganate preferentially etches in susceptible CovaBond MR^{TM} soaked recessed regions causing rougher trenches. Higher RSAI and retention of distinct recessed area/higher level area structure leads to increased adhesion. Within 5 to 15 min of permanganate etching, glass fillers get partially exposed, providing additional anchor points for electroless copper adhesion.

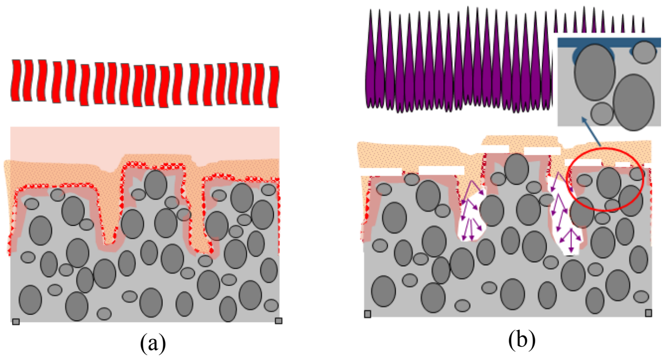
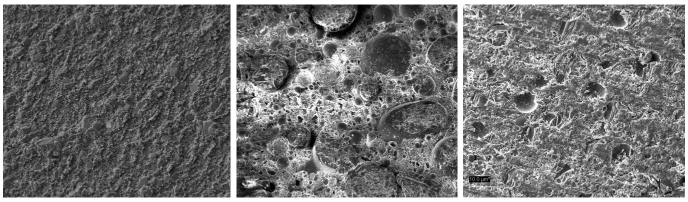


Fig 5: Covabond MR^{TM}, (a) coating and (b) oxidizing process.

IV. EXPERIMENTAL RESULTS

Fig. 6(a) shows the surface of a mold compound of a SEM photo under a magnification of 1000 times, before it is going through the surface treatment. It can be seen the surface is not severely rugged compared to Fig. 6(b) and Fig. 6(c), which are being treated with permanganate etch and fluoride etch respectively. CovaBond MR™ combines mechanical anchoring with chemical adhesion leading to better adhesion strength for similar surface roughness of permanganate etches as shown in Fig. 7.



(a) (b) (c)

Fig. 6: Surface of mold compound at a magnification of 1 k scanning electron microscope, (a) before surface treatment, (b) after permanganate etches on resin, (c) after fluoride etches on glass filler.

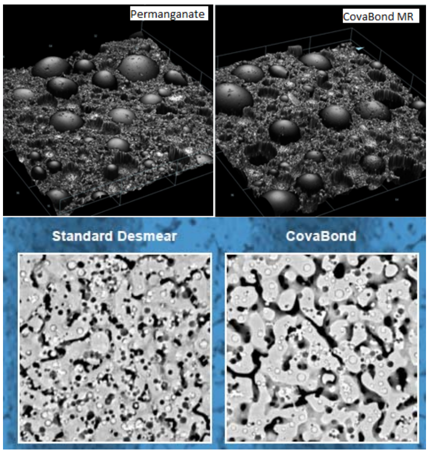


Fig. 7: CovaBond MR™ combines mechanical anchoring with chemical adhesion leading to better adhesion strength for similar surface roughness of permanganate etches

In order to understand the adhesion capability, samples are treated with different adhesion promoter, and follow by autocatalytic nickel-phosphorous (NiP) plating for 5 um thickness. Tape test based on industrial standard was carried out to test on samples and the results are shown in Table 1 with the quantified measurement of peel strength.

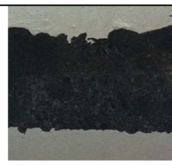
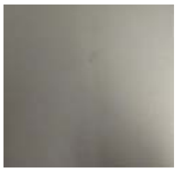
The tensile strength tester as discussed in was being used for the measurement. As NiP is fragile, copper was plated on top of mold compound. The results are shown in Table 2.

The experiment test summarize that CovaBond MR™ gives significant adhesion performance compare to others adhesion promoter. We target peel strength of above 4N/cm for industrial buy off. This reading is benchmark to peel strength requirement in the IC substrate manufacturing.

Table 1: Result of different adhesion promoter versus peel strength

No.	Test condition	Peel strength test [6]
1.	Without treatment of adhesion promoter	No test result available as sample has already blistered
2.	Permanganate etch	< 1.5 N/cm
3.	Fluoride etch	< 2.0 N/cm
4	CovaBond MR ™	4-5 N/cm

Table 2: Results of different adhesion promoter versus tape test.

Test condition	Before tape test	After tape test
Without treatment of adhesion promoter		
	Blister found immediate after NiP plating. Tape test fail.	
Permanganate etch		
	No blister after NiP plating; but the entire NiP peels off after tape test.	
Fluoride etch		
	No blister after NiP plating, tape test condition improved; only minor peel off.	
Covabond MR ™		
	No blister after NiP plating. Tape test pass.	

V. INDUSTRIAL RELIABILITY TESTS

The purpose of semiconductor device reliability testing is primarily to ensure that shipped devices, after assembly and adjustment by the customer, exhibit the desired lifetime, functionality and performance in the hand of end users. In order to comply to the electronic manufacturing requirement, some standard reliability tests have been performed. In this section, all of the aging tests will be conducted on samples produced only with CovaBond MR ^{TM}.

Tests were conducted on chip Mound on Board (MOB) as the experimental reference. Table 3 shows the results of preconditioning samples with standard Moisture Sensitivity Test Level 1 (MSL1), then followed by Pressure Cooker Test at 96 hours (MSL1 + PCT96), Pressure Cooker Test 192 hours (MSL1 + PCT192), Thermal Cycling of 500x (MSL1+ TC500), 1000x (MSL1 + TC1000) and 2000x (MSL1 + TC2000).

Table 3: Results of electrical test after varies type of aging conditions.

No.	Test condition	Electrical Resistance ,ohm			
		Average	Min	Max	Standard deviation
1	MOB (reference)	0.952	0.7	1.2	0.146
2	MSL1:Precondition	0.965	0.7	1.2	0.129
3	MSL1+ PCT96	0.978	0.8	1.2	0.112
4	MSL1 + PCT192	1.072	0.9	1.2	0.091
5	MSL1 + TC500	0.953	0.8	1.2	0.091
6	MSL1 + TC1000	0.919	0.7	1.2	0.141
7	MSL1 + TC2000	0.722	0.4	1.2	0.159

Electrical test was carried out to verify the consistency of device performance to investigate the fatigue of samples. From the electrical tests, the experimental results show that there is no significant change of electrical resistance, which indicates that no separation and minor crack occur. However, for the test on TC2000, the sample resulted in a noticeable drop of resistance, which shows that heat treatment of the NiP affecting the resistivity. It has been reported that, at a temperature as low as 150°C, resistivity decreases commonly due to the fact that it releases physically adsorbed hydrogen, which therefore increases the conductivity [4].

After the aging and electrical tests, tape test were repeated, as presented in Table 4. There is no peel off of nickel flake after all aging test. It shows that the adhesion between nickel-phosphorous and mold compound is remained strong.

On cross section investigation as shown in Fig. 8, there is no separation found between NiP and mold compound, which confirmed that Covabond MR^{TM} adhesion is able to withstand with the entire reliability test.

Table 4: Tape test after electrical test and after varies type of aging conditions.

Test condition	Tape test result
MSL1+ PCT96	Pass
MSL1 + PCT192	Pass
MSL1 + TC500	Pass
MSL1 + TC1000	Pass
MSL1 + TC2000	Pass

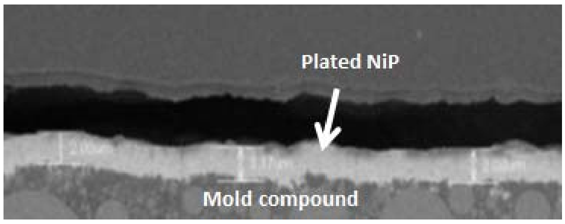


Fig. 8. Cross section view between mold compound and plated metal after TC 1000, no delamination noticed.

VI. CONCLUSION

From the experiment results, they show that CovaBond MR^{TM} enhances adhesion of electroless nickel to epoxy mold, and the process meets the high level criteria of reliability test on electronic manufacturing requirement. This conformal plating on mold compound provides alternative solution for IC packaging industry especially useful for EMI shielding capability requirement of an IC.

Acknowledgement

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