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Bonding Parameters of Anisotropic Conductive Adhesive Film and Peeling Strength

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Abstract. The effects of different bonding parameters-temperature, pressure, curing time, bonding temperature ramp and post-processing on the adhesive strengths of Anisotropic Conductive Adhesive Film (ACF) interconnection were investigated. The test results showed the adhesive strength increased as the bonding temperature increase. The curing time had great influence on the adhesive strength of ACF joints. The adhesive strengths increased as the bonding pressure increasing, but decreased if the bonding pressure was over 0.25MPa. The effects of different Teflon thickness on the pressure header and post-processing on adhesive strengths performance of ACF joints were studied. It was shown that the 90° peeling strength became deteriorated as the Teflon thickness increase. Different post-processing conditions showed that the specimens kept in 120°C chamber for 30 minutes had the best performance of the ACF interconnection. The environmental experiments of the thermal cycling (-40 - 125°C) and the high temperature/humidity (85°C, 85%RH) aging were used to evaluate the reliability of the specimens with different bonding parameters. It was shown that the high temperature/humidity was the harshest condition to the ACF bonding. The optimum bonding parameters were determined to obtain better peeling strength.

Introduction

Anisotropic Conductive Adhesive Films (ACF) is currently the primary method to interconnect liquid crystal display (LCD) Panels to external flexible circuits [1]. Intensive research and development work has been carried out in the field of flip-chip and chip-on-glass (COG) technology in order to use ACF as an alternative of soldering [2]. However, there are several drawbacks to interconnect with ACF. The contact resistance of ACF joins becomes increasingly unstable in high temperature (85°C) and high humidity (85%RH) conditions [3, 4]. Interfacial delamination of ACF bonding emerges during its application that can result in the failure of whole electronic components. Processing parameter is very important for reliability performance [5, 6].

This paper tried to investigate the effects of different bonding parameters on 90° peeling strength of ACF joint and discovered the effects on the specimens after thermal cycling (-40 - 125°C) and high temperature and humidity (85°C/85%RH) test. The optimum bonding parameters of ACF joints were given according to the test result.

Experiments

Experimental materials. A commercial Hitachi anistropic conductive film, ANISOLM AC-7106-25, was used to make the electrical interconnection between electrolysis Tin coated copper pads on a polyamide flexible circuit and ITO glass plate substrate. The ACF used in this study was 25μm in thickness and 1.5mm in width and made of insulating epoxy resin in which nickel and gold plated polymer particles were dispersed. The particles were 5μm in diameter. Epoxy resin was selected as the insulating resin and thermosetting because of its strong adhesion to various substrates and favorable melt viscosity. The specifications of ACF were summarized in Table 1.

Table 1 Specifications of the ACF

Description	Specification	Description	Specification
Film thickness [μm]	25	Pre-bonding time [s]	5
Film width [mm]	1.5	Pre-bonding temp. [^{o}C]	80 ± 10
Particle size [μm]	5	Pre-bonding pressure [MPa]	0.1
T_g [^{o}C]	145	Bonding temperature [^{o}C]	180
Conductive particle	Au/Ni coated polymer	Bonding time [s]	18
		Bonding pressure [MPa]	0.15

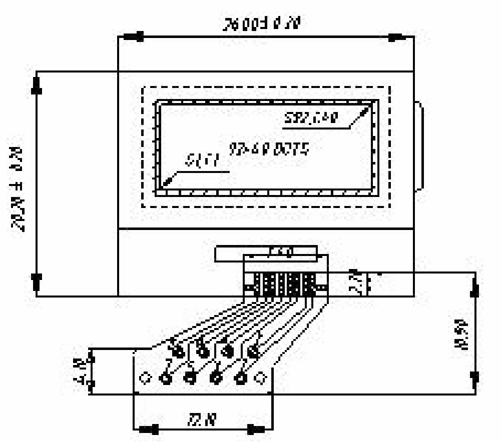


Fig. 1 Specimen dimensions (mm)

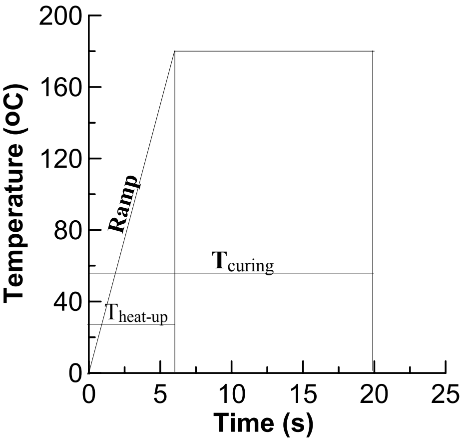


Fig. 2 Processing temperature

The ACF interconnection was a blank ITO (In_2O_3: 90%; SnO_2: 10%) deposited glass with surface resistance of 30-40Ω/sq. and flexible printed circuit (FPC) with patterned metallization I/O pads. The metal pad on flexible film consisted of approximately 35μm thick copper and electrolytically plated 2μm Tin. The bonding width of the specimen was 2.1 mm and the length was 7.4mm. Fig. 1 showed the structure and the dimensions of the specimens.

Specimen fabrication. The equipment used in the fabrication of the specimens was TCW-125 bonder. The bonding temperature, bonding pressure and curing time of the specimens can be adjusted directly by the bonding machine.

Table 2 Bonding parameters used

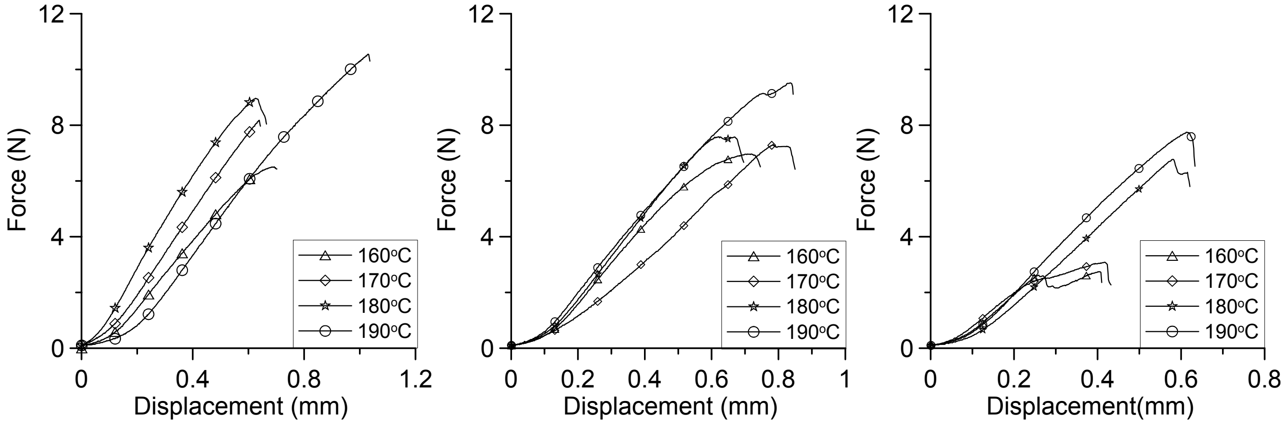
Spec.	Bonding temperatures [^{o}C]	Curing time [s]	Bonding pressures [MPa]	Thickness of Teflon [μm]	Post-processing condition [^{o}C]
A	160,170, 180, 190	18	0.15	50	25
B	180	9.9, 15, 18, 29.7	0.15	50	25
C	180	18	0.15, 0.2, 0.25	50	25
D	180	18	0.15	None, 50, 100	25
E	180	18	0.15	50	120, 25, -10

In order to level off the ACF and pressure head, the equalizing Teflon film was used between ACF and pressure head when bonding was processing. The Teflon film used in this study was none, 50μm, and 100μm in thickness respectively. Before the specimens were fabricated, the thermocouple was used to probe the bonding temperature ramp. The direct effect of the Teflon film was different bonding temperature ramp resulted, i.e. heat-up time of 6s, 9s and 12s respectively as shown in Fig. 2. Another group of specimens was with different post-processing conditions. They were kept in ambient condition (25^{o}C), calorstat (120^{o}C), and refrigerator (-10^{o}C) for half hour, respectively. Five group specimens were fabricated with different bonding parameter, different Teflon thickness and post-processing condition, as shown in Table 1.

Experimental procedure. 90^o peeling strength tests were conducted to measure the adhesion strengths. All peeling tests were carried out at a rate of 1mm/min on a Testometric Materials Testing Machines (350 AX). Peeling forces and displacement were recorded for each adhesive situation as the peeling took place. The test was run at room temperature 25^oC and humidity 50%. The peeling tests were classified as three kinds of specimens, original specimens, after thermal cycle (-40 - 125^oC) test for 1000hours(60min/cycle) (TCT), and after high temperature and high humidity (85^oC, 85%RH) test for 500 hours(HTHT).

Experimental results and analysis

Effects of bonding temperature on adhesive strength. From Fig. 3 (a), the results of the 90^o peeling test were shown that the peeling forces became larger with the bonding temperature increasing. The increasing bonding temperature influenced the rheological properties of the epoxy resin and a good interfacial wetting can been established. Thus the adhesive strengths became increased. After 1000 hours of thermal cycling test, as shown in Fig. 3 (b), the average peeling forces decreased 8.3%. The specimen with the bonding temperature of 190^oC had the largest peeling forces. After 500hours of high temperature/humidity test, it was observed that the average peeling forces decreased 40.6% as shown in Fig. 3 (c). The specimens with the bonding temperature of 160^oC and 170^oC had the worst adhesive strength, and the specimens with lower bonding temperature could not subject to the high temperature/humidity test for 500hours. Decrease of peeling strength was mainly due to the high temperature/humidity exposure, because the absorbed moisture could degrade the adhesion properties of adhesive layer. The humidity also caused hygroscopic expansion of epoxy and weakening of epoxy/contact pad adhesion. Comparing the test results of Fig. 3 (b) and Fig. 3 (c), it was found that the high temperature/humidity condition had more damage than the thermal cycling test to the adhesive strength of ACF bonding. The optimum bonding temperature was $180\text{-}200^oC$.

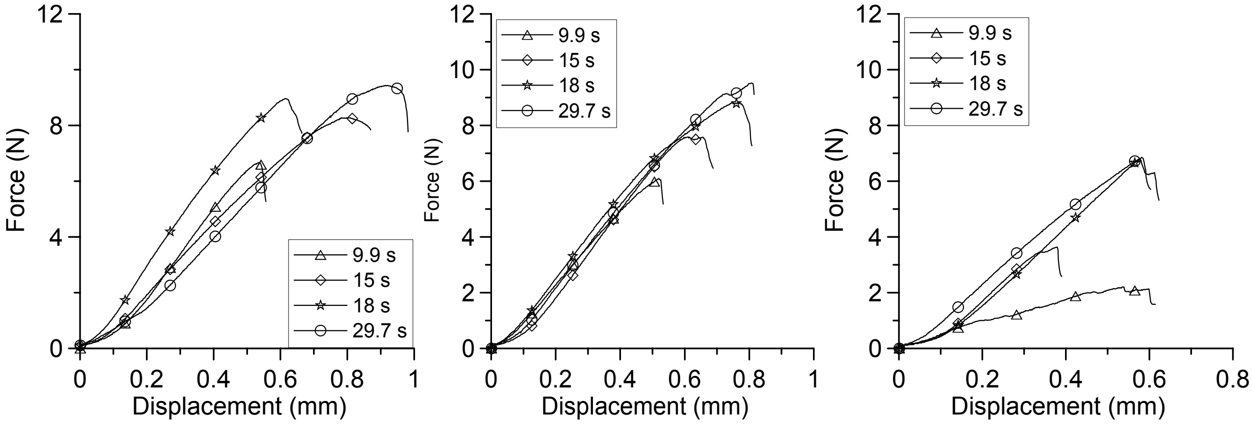


(a) Original (b) After TCT (c) After HTHT

Fig. 3 Force-Disp. curves at various bonding temperatures

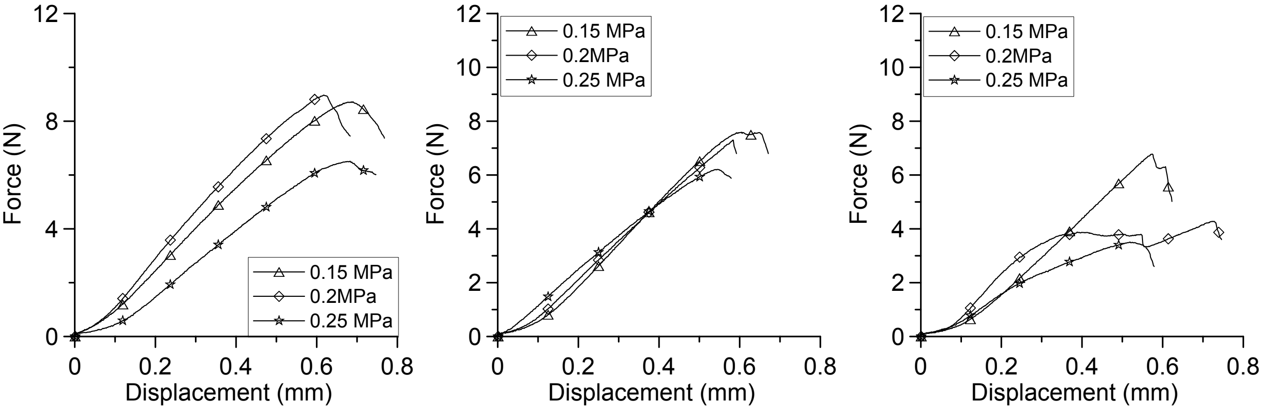
Effects of curing time on adhesive strength. The curing time had significant influence on the adhesive strength of the specimens. The peeling strength became larger with the curing time increasing as shown in Fig. 4 (a). As curing time increases, the degree of curing of epoxy-based adhesives increases resulting in stronger chemical bonding at the interface. After 1000 hours of thermal cycling test, the average peeling forces decreased 3.5% as shown in Fig. 4 (b). After 500hours of high temperature/humidity test, the average peeling forces decreased 41.7% as shown in Fig. 4 (c). The test result showed that the shorter curing time, the worse peeling strengths, but long curing time would introduce low manufacture efficiency. The reasonable curing time was 18s-25s.

Debonding occurred at the FPC metallization pad/adhesive layer interface was observed for peeling tests. The phenomenon can be explained that decreasing peeling strengths after the temperature/ humidity test was due to the oxidation of metal pad of copper on the FPC and epoxy layer by absorption moisture. The FPC itself can also absorb moisture, so the interfacial adhesive strength of FPC/adhesive layer is not stronger than that of the glass substrate/adhesive interface.



(a) Original (b) After TCT (c) After HTHT

Fig. 4 Force-Disp. curves at various curing times

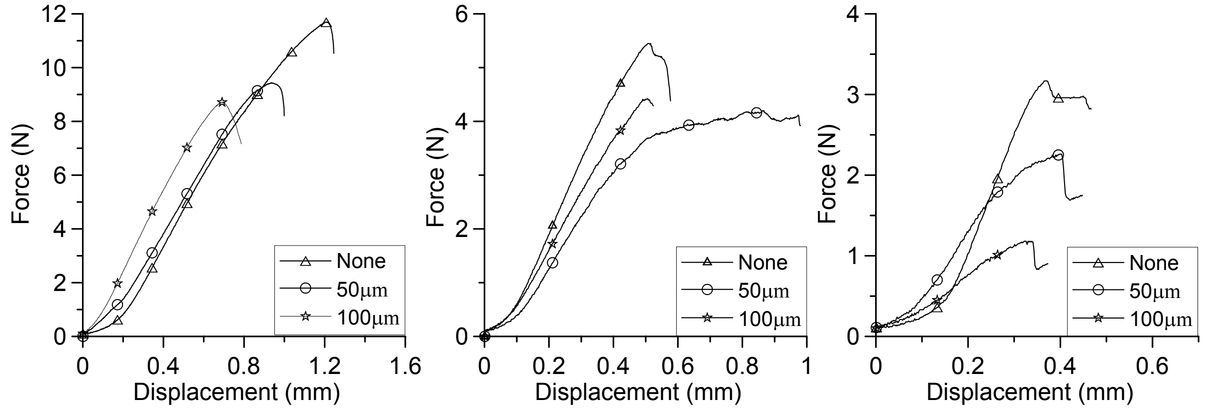


(a) Original (b) After TCT (c) After HTHT

Fig. 5 Force-Disp. curves at various bonding pressures

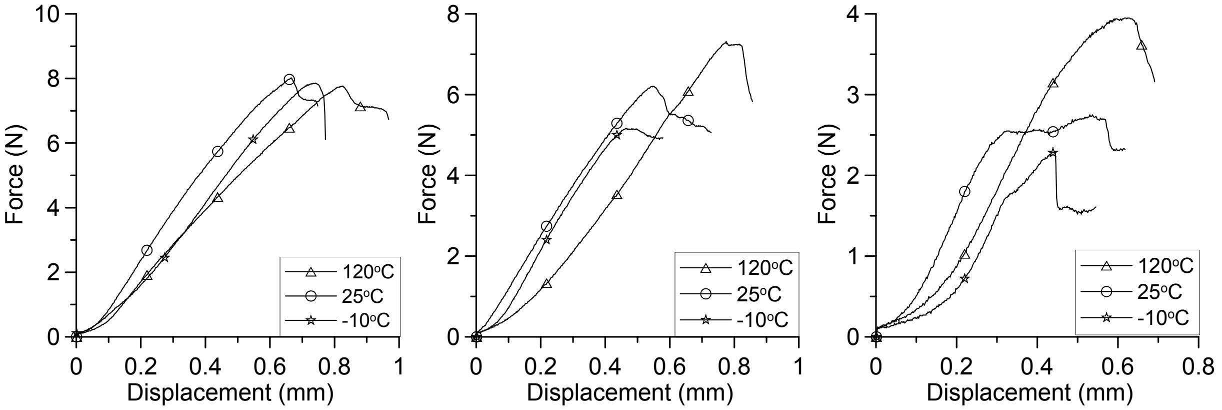
Effects of bonding pressure on adhesive strength. The bonding pressure had also significant influence on peeling strengths of the ACF interconnections. The adhesive strengths decreased with the bonding pressure increase as shown in Fig. 5 (a). Because the thickness of the ACF decreased as the bonding pressure increase which result in the adhesive strength decreased. After 1000 hours of thermal cycling test, the average peeling forces decreased 12.8% as shown in Fig. 5 (b). After 500 hours of high temperature/humidity test as shown in Fig. 5 (c), it was observed that the average peeling forces of the specimens decreased 39.9%. The excessive high bonding pressure might induce compressive stress in the epoxy adhesive and the internal stress in some local joining areas. The stored elastic compression could be released and lead to a loss of the contact area during testing which resulted in the adhesive strength decrease after high temperature/humidity test. The reasonable bonding pressure was 1.5-2.0MPa.

Effects of Teflon film thickness on adhesive strength. As shown in the Fig. 6 (a), the adhesive strength of the specimens decreased as the thickness of Teflon film increasing. The thickness of Teflon film increased not only result in the bonding temperature ramp time increased but also affect the curing time of ACF bonding as shown in Fig. 2. If the total processing time unchanged, the curing time decreased at the bonding temperature due to the ramp time increased, which can change the rheological properties of the epoxy resin, and the interconnected gap between the copper track and the ITO bump became narrow with the thickness of the Teflon film increased. The adhesive strengths of the specimens decreased after the TCT or HTHT tests as shown in Fig. 6 (b) and Fig. 6 (c). The specimen with the lowest strength was the bonding with Teflon thickness 100μm. From the curves of Fig. 6 (c), a phenomenon was found that the adhesive strength of ACF joints went down after temperature/humidity test. The adhesive strength of the bonding with Teflon thickness of 100μm cannot remain the interconnection reliability. The experiment result showed that the specimens which the bonding temperature heat-up time 12s had the lowest strength and the reliability cannot satisfy the requirement after environmental tests. Therefore, Teflon film thickness did not exceed 50μm, and the eligible bonding temperature heat-up time was from 6s to 10s.



(a) Original (b) After TCT (c) After HTHT

Fig. 6 Force-Disp. curves at various Teflon thickness



(a) Original (b) After TCT (c) After HTHT

Fig. 7 Force-Disp. curves at various cooling condition

Effect of post-processing condition on adhesive strength. After bonding of the specimen the post-processing on the bonded specimen was immediately conducted as remained in three different temperature environments (120°C, 25°C, -10°C) for 30minutes. As shown in Fig. 7 (a), the adhesive strength of the specimens with different post-processing conditions (100°C, 25°C, -10°C) was measured. The specimen that stayed in the refrigerator with -10°C had the lowest adhesive strength. The specimens with the relief temperature120 °C for 30min and then slowly cooled down to ambient temperature had higher adhesive strengths. After 1000hours of thermal cycling test, as Fig. 7 (b) shown, the adhesive strengths of the specimens all decreased slightly during the test. After 500hours of high temperature/humidity test as showing in Fig. 7 (c), the adhesive strength of the specimen staying in the calorstat (120°C) presented the best behavior. The experimental results had shown that the post-processing condition in the calorstat (120°C) for half hour was better for the reliability of ACF bonding.

Conclusions

The adhesive strengths of ACF joints were investigated using the specimens with different bonding parameters. As bonding temperature increased at range of 160°C to 190°C, increase of adhesive strengths was observed. The degree of curing of ACF plays an important role in determining the adhesive strengths of the specimens. Insufficient curing time at 15s resulted in the lower adhesive strengths. The adhesive strengths decreased with the bonding pressure increased at the range of 0.15MPa to 0.25MPa.

The high temperature/humidity test had worse effect on adhesive strengths of the ACF interconnections than thermal cycle test. The experiment results showed that the specimens bonded with different curing time were affected greatly by the temperature/humidity test. The insufficient curing time and the excessive bonding pressure both resulted in the weak ACF interconnection on the adhesive strength. The optimum temperature, pressure, and curing time ranges for ACF bonding were concluded to be at 180-200°C, 0.15-0.2MPa, and 18s-25s, respectively.

The suitable bonding temperature ramp time was from 6s to 10s and the thickness of the Teflon should not exceed 50μm to gain the better performance for ACF bonding. The specimens stored in the calorstat (120°C) for half hour and then slowly cooled down to ambient temperature showed good performance of the adhesive strength.

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