Direct Dry Film Optical Bonding – A Low Cost, Robust and Scalable Display Lamination Technology

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ABSTRACT

Rockwell Collins has developed a robust, repeatable, low cost lamination process that utilizes a "dry bond" approach (using PSA) to directly couple substrates to displays such as LCDs, OLEDs and Electrophoretic. These substrates can vary in intent and can serve as protective covers, reflection mitigation, heaters, filters, touch screens, environmental barriers, etc. The resultant assembly is very rugged; shock, impact, and vibration resistant, while maximizing optical performance. The paper discusses the dry film lamination approach and compares it to traditional "liquid" lamination technologies. A section of the paper will focus on the enhanced optical and environmental performances of Rockwell Collins dry film bonded displays. In addition, the flexibility of this technology will become apparent with further discussions of proven applications and scalability.

1. INTRODUCTION

Military, avionics, ground vehicles and automotive displays require very high optical and environmental performances [1-5], which can be achieved only by laminating additional components on displays. Even commercial grade outdoor and mobile displays require optically bonded HEA (High Efficiency Anti-reflecting) glass to improve sunlight readability. Additional heater layer is often needed for LCDs that require low temperature operation [5]. Increasing demand for touch screens also requires its coupling with displays. Many applications require vandal or boot-kick resistant glass to protect the display. Military and avionics displays also need to protect their polarizers and other optical components from humidity. All these applications require high performance, robust, optical bonding. The bonding technology should be high volume, scalable, environmental friendly, re-workable and low cost, so that it can be used in military as well as consumer applications.

Rockwell Collins primarily provides aviation and information technology systems, solutions, and services to government agencies and aircraft manufacturers. Core product offerings include leading edge display technologies which are designed to withstand punishing climatic exposures. Currently LCD [6, 7] is the preferred display technology for military, avionics and consumer applications. Rockwell Collins has made significant investment to configure these rather delicate electronic devices such that they can survive harsh environments, while simultaneously improving optical performance. Most recently, the patented lamination and ruggedization technology [8] developed for Rockwell Collins core LCD products has been offered to license into high volume commercial markets such as cell phones, TVs, laptops, tablets and e-readers [9, 10]. Key to penetrate these new high volume markets is development of a low cost, high volume, high performance lamination technology. The paper describes the Rockwell Collins Dry Film Lamination technology and how it meets all the desired attributes. Other lamination technologies, their merits and demerits are also described. The paper also compares our dry film technology with other optical bonding technologies.

2. OPTICAL BONDING TECHNOLOGIES

Optical bonding is bonding of two or more optical components together using a clear optical index matched adhesive. In its simplest form, optical bonding eliminates the air gap between the cover glass and the LCD, thus eliminating two reflective surfaces. It reduces the specular reflectance. An anti-reflective coating is usually applied to the top surface of the cover glass, along with possibly an anti-smudge (AS, hydrophobic) coating and often an anti-glare (AG) treatment. It further reduces the specular reflectance and increases the high ambient contrast. The optical bonding of many components reduces the total reflectance of the stack drastically. One major advantage of the optical bonding is the enhanced legibility of displays in high ambient lighting [5- 7, 11]. LCDs used in high performance avionics, military and outdoor applications may require additional layers such as compensation films, heater, EMI and boot kick (or vandal resistant).

Most of the commercial displays have very poor legibility and usually wash away in outdoors and high ambient lighting such as sun light. The legibility in high ambient can be increased either by increasing the display luminance or cutting the display reflectance. Increasing the display luminance beyond a limit has many adverse effects such as high power consumption, additional cooling requirement, higher cost and reduced life. Reducing the display specular and diffuse reflectances is the best approach.

Let us consider the legibility of the display (backlit transmissive passive display such as LCD or light generating active display such as OLED) in high ambient lighting where most of them have very poor performance. These displays look great in dark as long as they have sufficient luminance and contrast. For a typical good laptop display, let us take the on pixel luminance (L_{on}) as 250 nit and off segment luminance (L_{off}) as 1.0 nit. Its contrast ratio CR) can be calculated using the formula

$$CR = \frac{L_{on} + R_s x S + R_{d\text{-}on} x D}{L_{off} + R_s x S + R_{d\text{-}off} x D}$$

where R_s is the specular reflectance, $R_{d\text{-}on}$ and $R_{d\text{-}off}$ are the diffuse reflectances of the on and off segments. S and D are the specular and diffuse light components of the high ambient lighting. In dark, S and D both are zero, so the display has very high contrast ratio (250:1) and is very legible. It is well known that specular reflectance is additive from every layer. The major contribution to the diffuse reflectance of the display comes from the scattering layer such as diffuser and the amount of light reaching to such layer. Specular reflectance is almost the same in display on and off conditions while diffuse reflectance varies significantly. The amounts of diffuse and specular light also vary significantly depending on the ambient environment.

Figure 1 and Table 1 show the impact of various layers and optical bonding on the display contrast ratio (CR) with increasing level of ambient lighting. A diffuse surface reduces the specular reflectance but increases the diffuse reflectance. To make the calculations simple, we are calculating the impact of only specular light. Figure 1 shows the layer structures. Table 1A gives the specular reflectances from various layers and total specular reflectance of the stack. A typical air/glass layer reflects ~4% of the light. Same is the case with air/polarizer interface. A good HEA on glass has 0.2% specular reflectance. The quality and nature of HEA coating on top of the polarizer varies a lot (0.5 – 2.5%). Let us take 0.5% as the specular reflectance of a good HEA on the polarizer as reported by Nitto Denko. However, it has multilayer (5) HEA coating on top of an anti-glare coating, which makes it quite costly. It also produces inferior results in optically bonded stacks due to the presence of diffuse anti-glare layer. A typically good HEA on plastic or polarizer, without anti-glare layer, has ≥ 1% specular reflectance. Our dry film bonded layer reflects typically 0.035% from the glue/glass interface and 0.015% from glue/polarizer interface. Table 1B shows the calculated CR value for various light (specular) levels. All the geometries have 250:1 contrast ratio in dark. With increasing ambient lighting, the CR decreases with different rates for each of these geometries. The air gapped no enhancement is the worst and AR coated glass with our optical bonding is the best. A contrast ratio of 10:1 generates good legibility; 5:1 has reasonable readability and 3:1 has poor readability. Less than 1.5:1 may be treated as unreadable. The legibility also depends on the luminance of the character and background. At 1,000 nits ambient, the CR of air gapped no enhancement geometry goes down to 3:1 making it barely readable. The costly all the 3 surface AR geometry has ~25:1 contrast ratio, which is quite readable. The optically bonded AR top has high contrast (> 70:1) and is extremely readable. It also produces good readability (CR >10:1) even at 10,000 nit ambient, where all the geometries either fail or become hard to read. Rockwell Collins proprietary AR/AG bonded displays (with total specular reflectance of 0.15%) perform even better.

Besides the high ambient contrast, there are several other benefits of optical bonding such as reduced power consumption, longer life, shock and vibration resistance, touch screen capability, vandal and boot-kick resistance etc, which will be discussed in details in section 4.

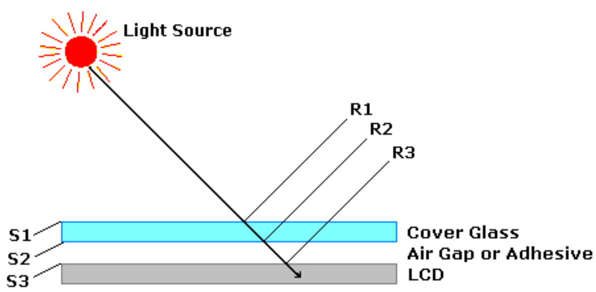

Figure 1: Reflected ambient light from an LCD with a cover glass

Table 1A: Specular Reflectances from surfaces S1, S2 and S3 with various enhancements

	No Enhancement	AR on Top	AR on All 3 Surfaces	AR on Top + Optical Bond
R1	4.0%	0.20%	0.20%	0.20%
R2	4.0%	4.0%	0.20%	0.035%
R3	4.0%	4.0%	0.50%	0.015%
Total Ref.	**12.0%**	**8.2%**	**0.9%**	**0.25%**

Table 1B: Calculated Contrast Ratio of the display (with luminances of 250 nit for on segment and 1 nit for off segment in dark) at various ambient lighting

Ambient Light (nits)	No Enhancement (TR = 12%)		AR on Top (TR = 8.2%)		AR on All Surfaces (TR = 0.9%)		AR on Top + Optical Bond (TR = 0.25%)	
	Reflected Light	Contrast Ratio	Reflected Light	Contrast Ratio	Reflected Light	Contrast Ratio	Reflected Light	Contrast Ratio
0	0	250	0	250	0	250	0	250
100	12	20.15	8.2	28.07	0.9	132.05	0.25	200.20
200	24	10.96	16.4	15.31	1.8	89.93	0.5	167.00
500	60	5.08	41	6.93	4.5	46.27	1.25	111.67
1000	120	3.06	82	4.00	9	25.90	2.5	72.14
2000	240	2.03	164	2.51	18	14.11	5	42.50
5000	600	1.41	410	1.61	45	6.41	12.5	19.44
10000	1200	1.21	820	1.30	90	3.74	25	10.58

Two main technologies used for optical bonding are liquid bonding and dry bonding. In liquid bonding many types of chemicals such as silicones, epoxies, polyurethanes and thermoplastics are used. Regardless of the type of the optical adhesive, the liquid lamination method involves assembly of the components before cure such that there must be a means for dispensing, controlling fill and flow dynamics, as well as curing of the adhesive. In the case of dry bonding the material typically exists in either fully cross-linked state for assembly such as the case with most pressure sensitive optically clear adhesives (OCAs), or in a stable sheet form that is thermoplastic which can be reflowed and adhered after assembly. Regardless of chemistry and process used, the key characteristics of adhesive include the following attributes:

- Low birefringence
- Refractive Index = 1.47-1.51
- Low moisture absorption
- Low Cost, readily available, non-hazardous ingredients
- Haze less, optically clear (high transmission) and particle/defect free
- Resistant to temperature effects; thermal soak and cycling
- Good UV, IR and life stability
- Nonreactive with glass and other optical films. It should not react with those components to change their optical, chemical and mechanical nature.
- No out-gassing, bubble formation, or latent formations after bonding
- Considerations made for repair-ability/ removal from partial assembly.
- Superior adhesion to both high and low surface energy materials.
- Suitable for glass-plastic-glass laminations; various TCE's.
- Processing Temperature for bonding < 90 ºC

Each bonding method is now discussed further.

2.1 Liquid Bonding

Liquid optical bonding technology was introduced in late 70's in LCDs and has been in use for many decades. In spite of its many weaknesses, it is still the most widely used optical bonding technology. While there are many ingredients, these materials are typically purchased as a two-part thermal cured chemistry or one-part radiation cured. In the case of a two-part system the materials must be mixed thoroughly in ratio as prescribed by the manufacturer and de-aired. Suitable standard mixing and de-airing stations are available in the industry. In addition, care must be taken such that all air and gas, generated due to mixing or chemical interactions, are removed. All the individual raw materials or the mixture should be filtered to minimize the existence of foreign material. Furthermore, proper dispensing is a must such that air entrapment does not take place. Depending on the automation level and process used, it requires development of some level of expertise by the ruggedizer. In general lamination processes using liquid adhesives are known to be labor intensive with long cycle times. Radiation curing can also be limited due to light blocking masks and uniformity of cure affecting display performance over temperature. A considerable shrinkage may take takes place during the curing of 2-part chemicals which makes it difficult to effectively control the bond-line. In addition, many liquid adhesives, especially silicones require a primer application to achieve adequate adhesion to many low surface energy substrates. Furthermore, the clean up of display and tooling are essential after lamination. This can significantly increase the cycle time, equipment cost, material and solvent cost, and can also lead to further yield loss. Many approaches using liquid bonding are currently available to serve the markets. In addition to contract services, processes are available that can be licensed. One such process is Dupont Vertak Bonding Technology that boasts superior optical, mechanical, and environmental performance [11].

2.2 Dry Bonding

The most common method of optical dry

bonding is bonding of flexible substrates such as optical films to rigid substrates such as LCDs using pressure sensitive adhesives. For rigid to rigid bonding differing techniques have been developed. A very common method used with automotive windshields, aircraft canopies and many other safety glass applications utilizes optical thermoplastic material. The process uses a tack-free sheet material that is typically rolled to or positioned against one substrate and then mechanically assembled to a second substrate. The assembly is then placed inside a vacuum bag, sealed and further exposed to pressure and temperature in accordance with a prescribed recipe. The process, well suited for many configurations, however, comes with a hefty capital investment, is somewhat labor intensive, has a lengthy cycle time and has several limitations. The thermoplastics generally have high softening temperatures and require pressures that exceed acceptable thresholds for LCD's. In addition, the optical performance is less than stellar, with inherent birefringence and lower transmission than typical optically clear pressure sensitive adhesive. There is also a new family of adhesives called UV-curing sheets that may be suitable for some rigid to rigid applications [12]. The adhesive is rolled to the first substrate and subsequently assembled in a vacuum using heat and pressure. Final polymerization then takes place using UV radiation. It is claimed that it can be used to fill gaps without air-bubbles with uniform thickness while also being able to conform to changing cross-sections (uneven surfaces). Since these adhesives are relatively new and only available in thin layers (30 - 50 µm maximum), they have not been evaluated as yet for our process.

Rockwell Collins dry film optical bonding belongs to dry bonding category. Details of this optical bonding technology and developments are given in section 3.

3. ROCKWELL COLLINS OPTICAL BONDING TECHNOLOGY AND DEVELOPMENTS

3.1 Rockwell Collins Liquid Bonding Technology

Cockpit displays started as electromechanical devices which was eventually replaced by cathode ray tubes (CRT's) and then by lighter, thinner and more efficient Liquid Crystal Displays (LCDs). Rockwell Collins began investing in LCD bonding in the late 1980's using conventional liquid bonding approaches as described in the previous sections. Well over 100 off-the-shelf adhesives were procured and evaluated as candidates over a period of time. A robust liquid bonding technology for avionics applications was developed. It was continuously used and improved for next two decades.

In the beginning stacks were very complex with many organic or sometimes inorganic compensation layers in order to improve optical deficiencies of LCDs. Therefore many of the layers were managed as "subassemblies" that were laminated uniquely for both the front and the rear of the LCD. These assemblies would then be subsequently laminated to the LCD color filter and TFT substrates. Virtually every layer for both the subassemblies and the LCD lamination used a liquid approach.

3.2 Rockwell Collins Dry Film Optical Bonding

The first significant break through at Rockwell Collins changed the process for laminating these subassemblies to a total dry film approach using pressure sensitive adhesive. This required a rigid to rigid bond to take place. The two configurations are shown in Figure 2A for LCD lamination, and 2B – 2C for front and rear subassembly lamination. With further investment of resources over the next few years this approach was expanded to subsequently remove all liquid from the lamination process and allow direct lamination to the LCD as well. See Figure 3. Before starting the process, one substrate is laminated with the optical adhesive film using the commonly known polarizer lamination techniques and machines. Our dry film bonding process, while being simple and fast, involves three key steps. First the rigid substrates are loaded into a small cavity with a means to maintain a small gap between them. Then a vacuum is induced to a desired level and held for predetermined time. The substrates are then allowed to fully contact each other while under vacuum followed by a method for applying external pressure via flexible membranes. Depending on configuration and cavity size a takt time of 26 seconds has been achieved. It is expected that further optimization of tooling and process will allow takt times less than 10 seconds.

The Dry film lamination process has been scaled up to a 65" TV and is only limited in size by current display tooling. Tooling may be quickly fabricated to support applications over 65" diagonal. There are no technical limitations to the size of the dry film lamination other than material availability.

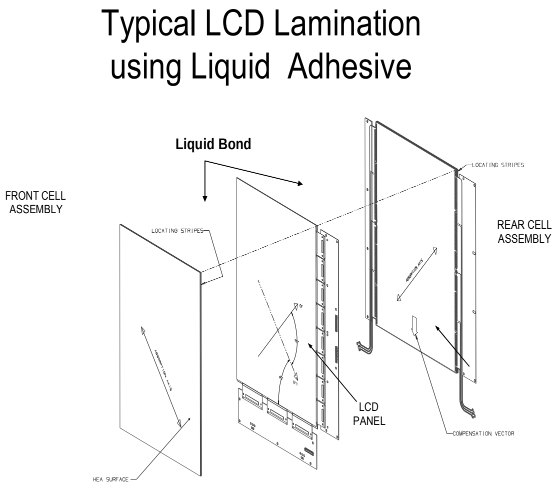

Figure 2A: Typical LCD lamination using liquid adhesive

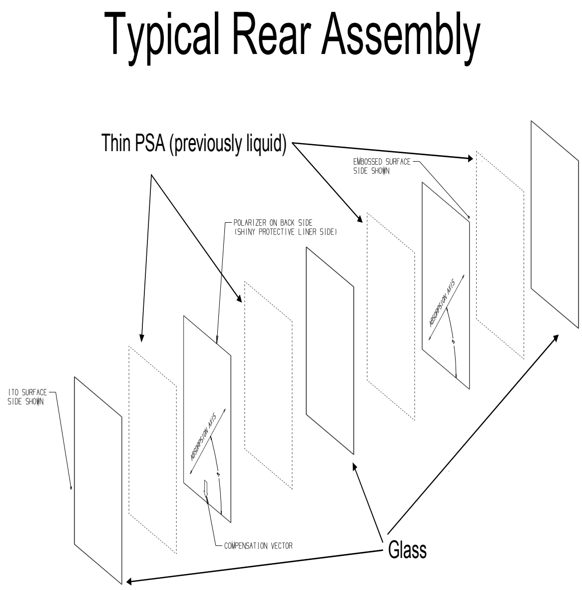

Figure 2C: Typical rear assembly stack

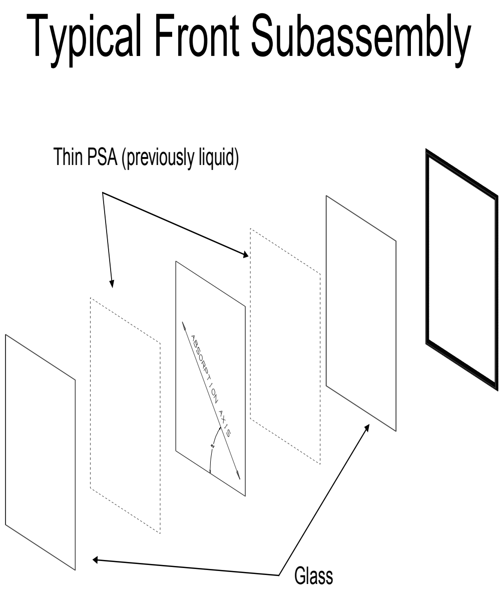

Figure 2B: Typical front subassembly stack

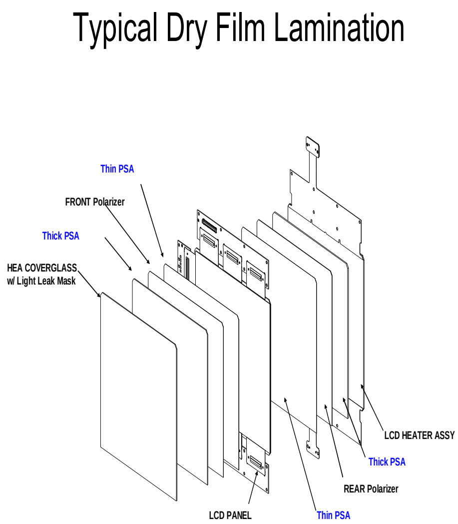

Figure 3: Dry Film lamination stack

3.3 Advantages of Rockwell Collins Dry Optical Bonding over Liquid Optical Bonding

There are several advantages of Rockwell Collins Dry Film Bonding. Some of these are listed below:

- The overall process is much cleaner. The display is laminated without residuals to clean up after bonding and the tooling remains ready for re-use.
- There is dimensional superiority compared to liquid bonding. No need to account for shrinkage, bond line control, or varying cure rates that can influence bond line and internal stress.
- The process is “green”. No wastage of raw materials. Cleaning solvents are not required.
- The process is much faster with fewer steps and less equipment.
- It is much easier to automate since the materials are solid; no mixing, de-airing or pouring.
- The process produces high yield and is also repairable, which is not the case with many liquid bonding technologies.
- There are also many performance-related benefits. The finished product exhibits excellent resistance to vibration/shock. The display stack made using our dry film bonding typically has lower deflection amplitude at resonance than those made using liquid bonding. It also has higher resonance frequency. The bonding is also more stable up to altitude over 100,000 ft. Most of the liquid bonded stacks start deteriorating just over 40,000 ft, at least temporarily.
- It is very easy to add additional layers of optical substrates to improve resistance to boot-kick or ballistic applications.

Our assessment of each of the lamination approaches for a quick comparison is given in Table 2.

*Table 2: Report Card for Performance of Various Adhesive Types for Optical Lamination**

Adhesive Type	Cost	LCD Compatibility	Adhesive Stability	Env.	Optical	Cycle Time	Bondline Control	Material Cleanliness	Tooling Cleanliness	Reworkable	User Friendly
Liquid - Silicone	B	D	C	B	B	C	D	A	C	B	C
Liquid - Epoxy	A	B	B	C	B	D	C	A	D	D	C
Liquid - Urethane	B	C	D	C	B	D	C	A	D	D	C
Dry Film - Thermoplastic	A	F	C	B	B	C	A	B	A	C	A
Dry Film - PSA	C	A-	A-	A	A-	A+	A	B	A	B	A

**Grading Judged by Authors: “A” (High Performance) through “F” (Fail)*

4. OPTICAL AND ENVIRONMENTAL PERFORMANCES OF ROCKWELL COLLINS DRY FILM LAMINATED DISPLAYS

The direct bonding of optical components brings a multitude of benefits. Materials to bond can include components such as anti-reflective glass, protective glass, touch screens, ITO heaters, EMI shields and even additional displays. These components can be bonded to the front/rear or both sides of a display or to another optical component.

One of the largest benefits to optical bonding of a display has to do with increasing it readability either through lowering reflectance, increasing contrast or increasing brightness. The increase in brightness could allow for a reduction in unit power to get to the same readability. Some examples of improved performance include data taken on the new Apple iPad and a 32” Panasonic LCD TV. The Apple iPad has a multi-touch capacitive touch screen as the front surface. By bonding an anti-reflective cover glass over it reflectance was reduced by 53%. Brightness went from 318 nits to 350 nits and contrast increased by 37 percent. Another example is a 32” Panasonic TV. This TV was ruggedized by putting an anti-reflective cover glass over the display. On half of the display the glass was directly bonded to the LCD and the other half was air gapped. The air gapped side had a reflectance of 1.46% and the bonded side had a reflectance of 0.42%. Originally the 32” TV without any cover glass had a reflectance of 2.17%.

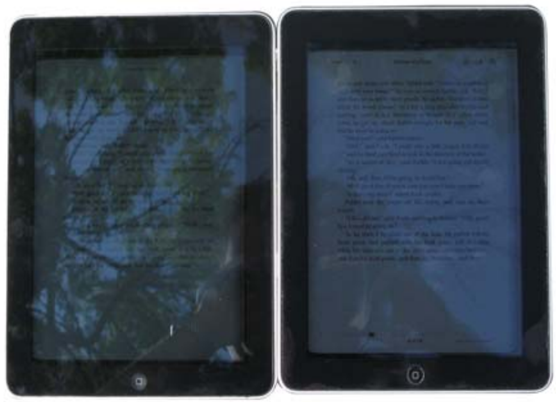

Figure 4: Example of standard iPad (left) and bonded (right) with HEA cover glass. Brightness increased 10%, contrast increased 37% and reflectance decreased 53%.

Another advantage to bonding is the protection or ruggedization of the optical components. This can be protection from environmental conditions such as humidity, fluids, foreign materials or abrasive materials. Bonding can also give protection against impacts from objects such as remotes, balls, hands etc… By bonding, the impact resistance can be greatly increased in direct correlation to the thickness of the cover glass. All of this while enhancing the performance of the display system. In addition to increasing impact resistance the direct bonding of additional rigid substrates can greatly increase the vibration performance in applications where large amounts of vibration can be seen. Any type of transportation vehicle such as cars, boats, trains etc. are good examples where additional ruggedization will provide long term reliability benefits.

Figure 5: Example of standard 32" TV with half air gapped (left) and half bonded (right) with HEA cover glass. The Specular reflectance was reduced from 1.46% to .42%.

Additional optical components that can be ruggedized would be all types of resistive and capacitive touch screens. Either front surface glass can be put on to increase optical performance or protect the front surface from damage. Rear glass can be bonded on to greatly improve resistance to impact and shattering. Some of these materials can increase performance by a factor of 10X depending on materials selected and robustness of original component.

4.1 Optical Enhancements

4.1.1 Low Reflectance

It is very important to achieve acceptable sunlight readability. Aircrews must be able to interpret the displays even when shafted sunlight is present in a cockpit. Every outdoor application is subject to reflectance problems and hence, it is imperative that each material's refractive index be carefully considered during the design phase of the project. Internal air interfaces typically contribute 4% per surface which drives the need for lamination. Overall, the acceptable level of reflectance for an entire display stack should be < 0.5% @ 30 degree incidence.

Figure 6: Example of Shafted Sunlight in a cockpit with Laminated Display

Figure 7: Top: Anti-Reflective glass dry-bonded to 40" LCD TV in direct sunlight. Bottom: Sunlight readability example – Air gapped vs. Laminated.

4.1.2 Diffuse Reflectance

Similar to the case of specular reflectance, diffuse reflectance affects the legibility of the display. In this case however, it has to do with in-plane scattering of light which can cause significant loss of display contrast. A display with a significant amount of diffuse reflectance will appear “washed-out” and the image will be hard to interpret. Top level product values usually are specified to be <0.5% of which an adhesive bond-line should not contribute more than 0.02%.

4.1.3 Internal Transmission

It is desirable to select adhesive with high visible light transmission > 95%. Transmission losses require harder driving of the backlight. This leads to an increase in operating power of the unit which in turn increases temperature, thereby affecting life. Optical transmission is intrinsically determined by the fundamental adhesive chemistry at the molecular level, and extrinsically influenced by refractive index. Any mismatch of refractive index at the bonded interface will increase specular reflectance; thereby reducing optical transmission. An example is given below:

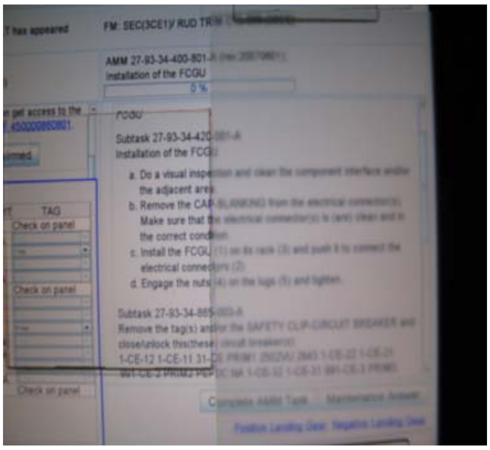

Figure 8: Left: Bonded Sample with 98.5% internal transmission. Right: Air Gapped Sample with 35.9% internal transmission.

4.2 Bonding Environmental Requirements

4.2.1 Thermal Loading & Cycling

To meet as many markets opportunities as possible the bonding must be tested over a wide range of temperature conditions. Operation over all temperature ranges are expected to produce very little change in optical performance. High temperature conditions are not expected to show defects along with temperature cycling that proves the long term robustness of the bonding technology. A typical thermal soak test is -55°C for 48 hours followed by +85°C for an additional 48 hours. In many applications, thermal cycling is also required; a composite of worse case scenarios for many customer mandated profiles is shown below.

Figure 9: Examples of two different bonding technologies after thermal cycling. Left: No yellowing (96.5% transmittance). Right: Yellowing (85.3% transmittance).

Diagnostic Used

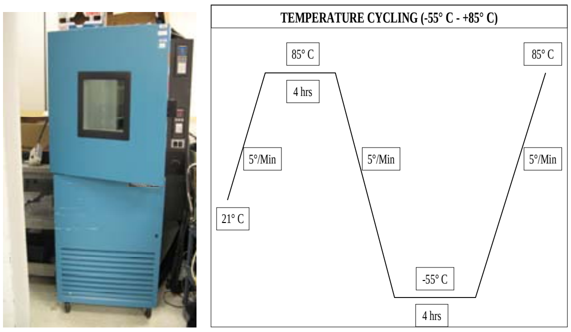

Figure 10: Top: Photo of thermal chamber. Bottom: Typical profile used to thermal cycling.

4.2.2 Humidity and Fluid Resistance

In designs where an air gapped cover glass or touch screen are used there is a good chance that humidity can be trapped between the cover glass and the display. Direct bonding will prevent this from happening by filling in the space. Since all the films will be covered with adhesive it also will protect any polarizing films that would otherwise be exposed to the environment. Accidental immersion is also an issue as people drop their devices into water such as pools or sinks. A typical humidity profile mandated by the Federal Aviation Administration is shown below.

Diagnostic Used

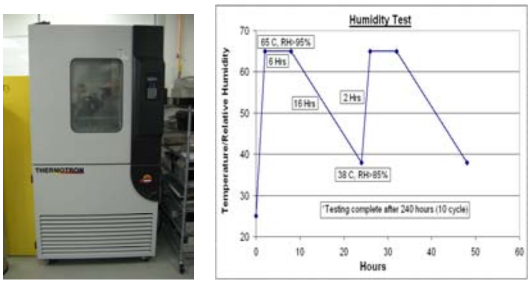

Figure 11: Left: Photo of humidity chamber. Right: Humidity cycle profile.

Example of Humidity Damage

Figure 12: Water damage behind cover glass of iPod.

4.2.3 Altitude

When bonding up components the environments that they can be used in or even they can be shipped in must be understood. Therefore one of the requirements for good bonding is being able to withstand exposure to altitude typical of aviation applications which places the lamination adhesive in tension. Many optical adhesives that are soft enough and suitable for interfacing to an LCD have poor tensile properties and can lead to temporary or permanent de-lamination. Most requirements for commercial aircraft often require survivability to 40,000 feet. However, fighter aircrafts require full performance at 70,000 ft.

Diagnostic Used

Figure 13: Photo of altitude chamber

4.2.4 Solar Exposure

Prolonged exposure to sunlight can be a common occurrence in some display applications. Degradation of the adhesive in terms of discoloring, shrinking, and reversion are not permitted.

Diagnostic Used: Xenon Compact Arc Lamp – 1000 hours direct exposure

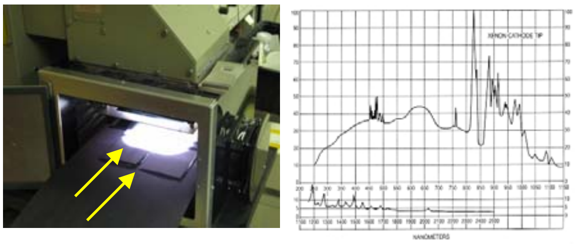

Figure 14: Left: Photo of solar simulator. Right: Spectral output of light source.

4.2.5 High Impact Testing

High impact resistance is becoming more of an issue as displays get larger but thinner and that there are more use of interface devices such as touch screens that can be mishandled. LCD's are very fragile to the touch and are easily damaged in any environment they are used in. Whether it is in a lap top, cell phone or even living room, display can be damaged by an inadvertent hit with something as benign as a TV remote. Also touch interfaces such as kiosks have requirements to not break if impacted by hands, balls and other projectiles.

There are many methods for testing impact resistance. One Military generally accepted test requires a 45 lb mass striking the center of a display at 3.8 ft/s. The contact area at impact cannot exceed 0.5 in^2. The display is to be impacted six times without changing location of impact, followed by a close examination of the product.

Diagnostic Used

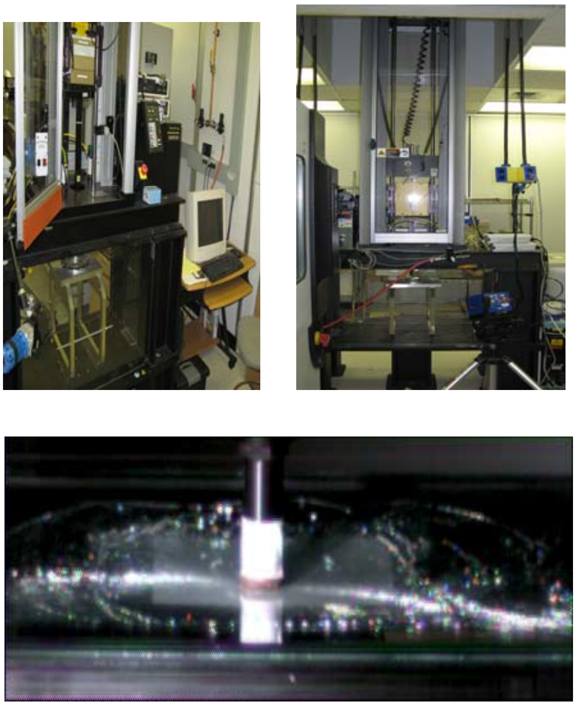

Figure 15: Upper Left & Right: Photos of impact tester. Lower: Snapshot showing impact on touchscreen.

CONCLUSION

The importance of being able to bond optical components with displays has been around since the polarizers started getting bonded on LCDs in 70's. Now with the proliferation of both displays and other optical components that are being used everywhere there is not only a need to bond and protect these components but also enhance their optical and environmental performances. Bonding technology such as Rockwell Collins Direct Dry Film technology offers the benefits of automation, scalability, re-workability while being highly cost competitive with other technologies. The paper also shows that our dry film bonded display stacks pass and exceed all the optical and environmental requirements of even toughest applications.

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