Optimized Inspection Strategies for Cell and Module Inspection

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Introduction

The cathode ray tube display market is a mature, high yield, low cost industry. It has implemented visual inspection of its components and final products. The technology evolved from human alignment/inspection to a combination of fully automated and vision system assisted alignment. Final and component inspection became fully automated.

LCD cell and module visual inspection has traditionally been done by humans (HVI). Humans had the requisite processing speed and resolution to inspect notebook and monitor sized panels. HVI drawbacks were the lack of uniformity over time and between operators. In addition, data retention was sparse and manually entered.

Automated inspection (AVI) has recently been implemented at a variety of manufacturers. Although the goal may be to eliminate human inspection, at present, all the manufacturers still use HVI as well. The AVI is used a screening inspection, with rejected panels going to repair or human inspection for final disposition.

Yield comparisons from semi to LCD

Similarities between LCD and semiconductor manufacturing exist at many points. The array fab is in essence a large semiconductor fab with similar processes and yield strategies. Another similarity is the use of repair in DRAM and LCD. Finally, both markets have mature commodity products and leading edge, ASP decaying segments. Yield strategies in mature commodity products center on low cost manufacturing and maximizing steady state yield while ASP declining products require fast fab startups.[1,2].

The differences in the two industries are striking. They are summarized in the table below. Yield in LCD fabs is dominated by random, particulate driven effects. In semiconductors, the yield is driven by systematic, process integration issues. In LCD's binning by defect level allows a wide range of defect level to be shipped. Raw yield (zero defect panels) can be quite low, depending upon product mix and fab maturity. Shipped yield is usually over 90%. The difference is binning. In semiconductors, any binning is parametric, such as microprocessor speed, but the chip only works with zero defects.

Another difference is the cost structure of the products. The cost of a semiconductor chip is mostly associated with the amortized fab costs[3]. This means that the cost of the chip increases as the chip progresses through each manufacturing step. LCD's cost is mostly materials. Of these materials, the majority is the backlight unit and IC drivers which can be recovered at final inspection. In addition, panel repairs can be made. Killer (line) defects can often be repaired and bright dots can be converted to less objectionable dark dots.

A final difference is in brand premiums. Semiconductors in general have low brand premiums for standard products. Pricing differences are associated instead with specialized designs or parametric performance. Brand premiums are extremely valuable in the LCD industry. The difference between 32" premium brand and generic brand TV's is almost 50% in the USA.[4] This means that there must be extremely high capture rate at the final inspection stages. If bad products slip into the market, the brand reputation can be ruined and the premium destroyed.

Inspection Requirements

Any inspection system has three main jobs:

1. Detection
2. Classification
3. Binning

Of these, detection is paramount. A high capture rate is necessary to ensure that the panels do not acquire any additional costs if they are to be scrapped. Also, defects can often be repaired if caught early enough. Conversely, a low false rate is important to minimize wasted disposition and repair time. To allow Go/No Go scheduling after inspection, a detection rate of at least 95% is required for all defects, including mura.. The costs associated with lower detection can be large. Looking at polarizer loss alone, the cost of ownership is dominated by yield loss if the detection rate is at 80% for a single HVI inspection point. For the higher detection rate of AVI, the cost of ownership is dominated by the capital and labor costs. Figure 1 details this.

Classification has two levels. The first, simpler level is to characterize the defects to allow binning. Examples are classification of dark vs. bright, line vs. dot, and adjacent vs. widely spaced defects. The second level is to allow root cause assignment. Classification and location accuracy to the RGB sub-pixel is required. In addition, adjacent sub-pixels and dot defects adjacent to line defects must be located and classified. Root cause needs to be assigned such as gate to common short, ITO-ITO short, data line open, LCD fill bubble, etc. to optimize repair and to aid in process control.

Binning optimizes profit. A fab can have many customers, each having different binning criteria. It quickly becomes impossible for human operators to optimally bin panels. They instead just use “repair everything” strategies. Automated systems can quickly go through thousands of permutations to disposition a panel with the minimum amount of repair and the maximum profit.

Cell Inspection is typically done after cell assembly before polarizer attach. Any defects are sent to review/repair. If the module factory is offsite, an additional inspection is done after polarizer attach and before cell shipment to ensure that there are no polarizer defects. Additionally, if repair is possible after polarizer attach, the pre-polarizer inspection can be skipped. If the module fab is on site and cell repairs have been done following a cell assembly inspection, the after polarizer inspection can be eliminated.

Module inspection is done at two points. The first is after driver IC attach. This inspection is readily automated as the drive probing is simple and typical defects are line type (missing contact) with extremely high capture rates. The automated system can easily identify the exact missing contact to repair. Leading fabs are implementing AVI at this step.

The second inspection is done after aging and final assembly. This inspection is critical, as any escapes will go to the consumer. Multiple levels of HVI are used for this inspection, sometimes aided by AVI. Cascaded HVI inspections by multiple operators ensure the highest possible capture rate. Although the capture rate of a single HVI is much lower than AVI, cascaded HVI can achieve very high performance levels as shown in the figure 2. Cascading only AVI, because of the high repeatability of AVI, has little benefit. HVI also allows inspection of non-active areas (bezel, etc) before shipment. The false rate must be very low as rejected panels are lost revenue.

Inspection Tradeoffs

The first inspection tradeoff is to determine how many inspection points will be included. The table below summarizes the recommended points. Depending upon repair capability and/or module location, one inspection can be eliminated.

Product Mix

The product mix of a fab is dictated by the generation (glass size). The later the generation the larger the size of the target products. Each fab has a target mix of products centered around the target sizes. In practice, this mix can be skewed up or down by order fluctuations. If the mix goes to smaller size panels more inspection systems are required to serve the greater number of panels. The difference between the target mix and worst case for typical product mixes is shown in the graph below. For lower generation fabs the difference is minimal. For higher generation fabs the difference can be substantial.

Summary

Inspection in the back end of the LCD is moving from human based to automated. This is driven by the desire to eliminate human operators and the need to have repeatable, reliable data for fab optimization. The number of systems required varies by the fab module location, product mix, and repair capability.

[1] Competitive Semiconductor Manufacturing: Final Report on Findings from Benchmarking Eight-inch, sub-350nm Wafer Fabrication Lines" , Univ. of Berkeley, http://esrc.berkeley.edu/csm/csmab.html#C52
[1] "Yield Management in LCD Factories"Info Display Magazine, November 2005
[1] "It's a Flat but Non-linear World",David Barnes, DisplaySearch USFPD, March 2006
[1] "TV Flash Reports", DisplaySearch, 2004-2006

Table 1 – Yield Comparison

	Semiconductor	*LCD*
Yield	Systemic, process integration Defect free Binning by performance	Random, particulate Repair to acceptable Binning by defects
Cost	Amortized fab costs	Materials
Price	Parametric,/functional	Brand

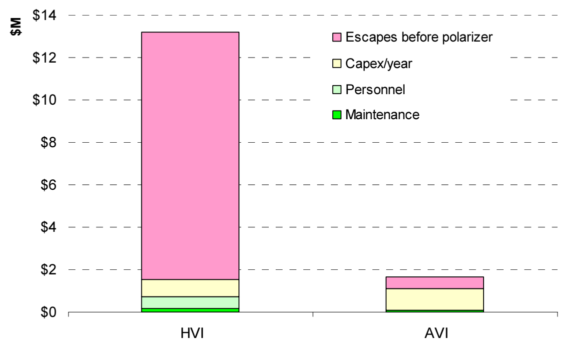

Figure 1 -- Costs, HVI vs. AVI

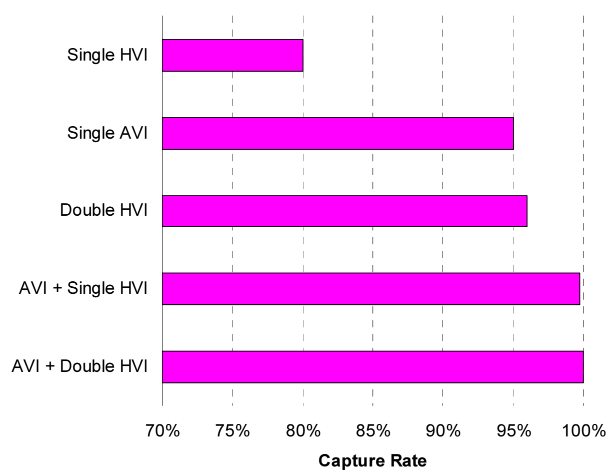

Figure 2 - Capture Rate Comparison

The table below summarizes inspection requirements for cell and module.

	Detection	Classification	Binning
Cell Assembly	>95% Dot/Line/mura <5% False	Location to sub-pixel Root cause	Go/No go Auto repair disposition
Polarizer attach	>95% Dot/Line/mura <5% False	Location to sub-pixel Root cause	Go/No go Auto repair disposition
Driver IC attach	>99% line <5% False	Location to driver lead	Auto repair disposition
Final module	>99% dot/line/mura <1% False	Root cause	Go/No go

Table 2 - Inspection Requirements

	Module on site	Module off site	Repair after polarizer possible	*No repair after polarizer*
Cell assembly	X	X		*X*
Polarizer attach		X	X	
Driver IC attach	X	*X*	*X*	X
Final assembly	X	X	X	X

Table 3 - Recommended Inspection Points

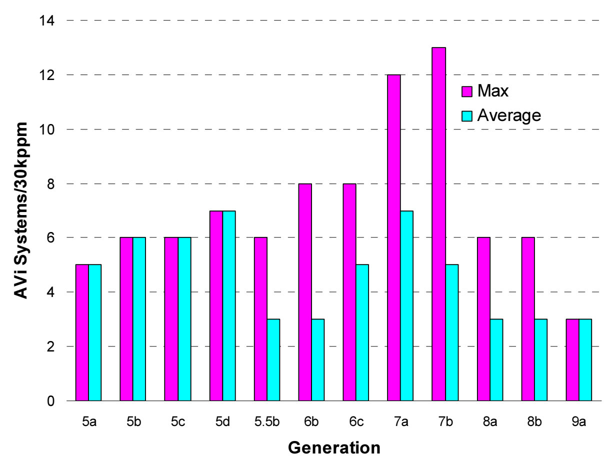

Figure 3 - Product Mix vs. Required Cell AVI