LIQUID CRYSTAL **FLAT PANEL DISPLAYS**

MANUFACTURING
SCIENCE &
TECHNOLOGY

WILLIAM C. O'MARA

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Table of Contents

INTRODUCTION

CHAPTER ONE

LARGE AREA LIQUID CRYSTAL DISPLAYS	1
1.1 Computer Displays	3
1.1.1 Desktop Computers	3
1.1.2 Portable Computers	3
1.1.3 Engineering Workstations	7
1.1.4 Computer Display Summary	7
1.2 Television Displays	9
1.2.1 Portable TVs	9
1.2.2 Projection Displays	10
1.2.3 High Definition TV	11
1.2.4 Video Camera Viewfinders	11
1.3 Automotive Applications	11
1.4 Other Applications	12
1.5 Liquid Crystal Display Technology	13
1.5.1 Types of Liquid Crystal Display	16
1.5.2 Passive vs Active Addressing	21
1.5.3 Workstation B/W Display	23
1.5.4 Polymer Dispersed Displays	24
1.5.5 Automotive Display	26
1.6 Active Matrix Devices	27
1.6.1 Two Terminal Devices	28
1.6.2 Amorphous Silicon Transistors	31
1.6.3 Polysilicon Transistors	35
1.6.4 Comparison of Device Performance	39
1.6.5 Ferroelectric Polymer	43
1.6.6 Printed Transistors	45
1.7 Display Manufacturers	47
1.7.1 Japan	47
Current Suppliers	48
1.7.2 USA	48
Xerox	48
Department of Defense Initiatives	48

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

IBM	48
Advanced Display Manufacturers	50
Others	51
1.7.3 Rest Of World	51
Europe	51
Korea	53
Other Asian Firms	53
References	54

FIGURES

1-1 Portable and laptop computers.	3
1-2 Active matrix liquid crystal display screen size in recent years	5
1-3 Pixel count versus display diagonal size for flat panels	6
1-4 No. of pixels & display diagonal for high information content displays	7
1-5 Basic liquid crystal polymer molecule.....	14
1-6 Principle of operation of a twisted nematic liquid crystal display	15
1-7 Transmission versus voltage curves for TN and STN materials.....	18
1-8 Schematic representation of passive and active matrix color LCD's.	22
1-9 Polymer dispersed liquid crystal projection TV system	24
1-10 Structure of the dispersed liquid crystal droplets.....	25
1-11 Projection display using polysilicon thin film transistors	28
1-12 Amorphous silicon PIN diode.....	29
1-13 MIM diode structure	30
1-14 Double pixel design for MIM diode.	30
1-15 Cross-section view of three TFT configurations	32
1-16 Aluminum gate a-Si TFT	33
1-17 Light leakage in TFT structure	33
1-18 Plan view of TFT structure with light shield.	33
1-19 Hitachi TFT array equivalent circuit.....	34
1-20 Relative cost of silicon TFT processes	42
1-21 Data rate of driver circuits for complex TFT displays.....	43
1-22 Construction of ferroelectric matrix active device.....	44
1-23 LCD panel structure with ferroelectric matrix device	44
1-24 Comparison of photolithography and printing for imaging on FPD's.	46
1-25 Photoresist application by offset printing	46
1-26 Polysilicon transistors made by offset printing and photolithography ...	47

TABLES

1-1 Classification of Portable Computers	4
1-2 Japanese Large Flat Panel Displays	8

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

1-3 Japanese LCD TV and VCR Displays	10
1-4 Calculation of S for various values of N_{max}	17
1-5 Requirements for Vertical TN LCD Display	19
1-6 Types of Liquid Crystal Displays	20
1-7 Processing and Relative Cost of Active and Passive Displays	31
1-8 TFT Array Process and Specifications	31
1-9 Resistivity of Metals	35
1-10 Comparison of a-Si and poly-Si TFTs	37
1-11 Polysilicon Fabrication Methods and TFT Properties	38
1-12 Comparison of TFT, PIN Diode, and MIM Diode Displays	40
1-13 CMOS poly-Si TFT and a-Si:H TFT Comparison	41
1-14 AMLCD Drive Circuit Types	42
1-15 Characteristics of Ferroelectric Liquid Crystal Display	45
1-16 Liquid Crystal Display Status in Japan	49
1-17 Advanced Display Manufacturers Association Members	50
1-18 US Liquid Crystal Display Activity	51
1-19 European LCD Activity	52
1-20 Liquid Crystal Display Status in Korea	53
1-21 LCD Manufacturing in Asia	53

CHAPTER TWO

DISPLAY MANUFACTURING PROCESS	57
2.1 Color Filter Manufacturing.....	58
2.1.1 Glass Substrate Preparation	58
Glass Fabrication	58
Cutting, Beveling, Polishing	59
Annealing	61
Cleaning	63
ITO Deposition	66
2.1.2 Color Filter Process	70
Black Matrix Definition	71
Dye Method	71
Pigment Method	71
Electrodeposition	72
Printing	73
Overcoating	73
ITO Deposition	73
2.2 Active Matrix Display Manufacturing	74

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

2.2.1 Thin Film Transistor Manufacturing	74
Plasma CVD & Sputtering	75
Photolithography	77
Etching	78
Transistor Processes	79
2.2.2 In Process Testing	84
Optical Inspection	84
Electrical Inspection	85
Functional Inspection	85
2.2.3 Defect Repair	85
2.3 Display Assembly	86
2.3.1 Orientation Film Deposition and Rubbing	86
2.3.2 Seal Printing	87
2.3.3 Spacer Placement and Sealing	90
2.3.4 Liquid Crystal Injection	90
2.3.5 Inspection and Test	91
2.3.6 Polarizer Attach	91
2.3.7 Die Attach	94
2.3.8 Backlight	97
2.4 DISPLAY MANUFACTURING	98
2.4.1 STN Display Manufacturing	98
2.4.2 Color Filter Manufacturing	100
2.4.3 Equipment for Color Filter Manufacturing	101
2.5 AMLCD Factory	101
2.5.1 Throughput and Productivity	101
2.5.2 Manufacturing Cost and Yield	103
Yield vs ASP	103
Manufacturing Cost Model	105
Manufacturing Yield Model	106
AMLCD Factory	108

FIGURES

2-1 Schematic outline of the display manufacturing process	57
2-2 Fusion process for glass sheet formation	58
2-3 Thermal expansion of Corning 7059 glass	62
2-4 Thermal shrinkage of NA 35 glass: heat treatment time & temperature	62
2-5 Cleaning methods evaluated by contact angle measurement	66
2-6 Sputtering voltage, deposition temperature, and ITO film resistivity	69
2-7 Plasma-assisted electron beam evaporation equipment	70
2-8 Color Filter Formation	72

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

2-9 Active Device Formation	76
2-10 Photoresist adhesion by side etch for various precoating processes.	78
2-11 Cross-section view of three TFT configurations	79
2-12 Assembly, Packaging & Test	88
2-13 Automated flat panel assembly line	89
2-14 Variations in external pressure & spacer size lead to cell gap variations. ...	91
2-15 Active matrix liquid crystal display cross section.	93
2-16 Packaging configurations in flat panel displays.	94
2-17 Number and pitch of leads for flat panel displays.	95
2-18 Connection of TAB tape to flat panel leads w/ anisotropic conductive paste. ...	96
2-19 Schematic of backlight arrangement with light pipe.	97
2-20 Factory layout for passive matrix LCD manufacturing	98
2-21 Simulated yield curves: defect densities in TFT manufacturing	104
2-22 Cost components of flat panel display production.	106
2-23 NEC two story AMLCD fabrication facility layout	109

TABLES

2-1 Glass Substrates for Flat Panel Display Manufacturing	60
2-2 Glass Substrate Specification for Active Matrix Display	63
2-3 Proposed Substrate Standard Sizes for Flat Panel Displays	64
2-4 Cleaning Processes for Flat Panel Displays	65
2-5 DI Water Quality and Substrate Particle Count	66
2-6 Types of Color Filters for LCDs	71
2-7 Color Filter Process Comparison	74
2-8 Process Flow Chart for Inverted-Staggered Back Channel Etched TFT ..	80
2-9 Inverted-Staggered Trilayered TFT Process	81
2-10 Process Flow for Normal Staggered TFT	82
2-11 TFT Array Process and Specifications	83
2-12 Defects in LCD TFT Array Manufacturing	84
2-13 Causes of Defects in Assembled Flat Panel Displays	92
2-14 Clean room Conditions for STN Process Line	99
2-15 Production Lines for Large Liquid Crystal Displays in Japan	99
2-16 AMLCD Equipment Productivity and Price	102
2-17 AMLCD Production Equipment Categories	102
2-18 In-Process Inspection and Repair Equipment List	103
2-19 Assembly and Die Attach Equipment	104
2-20 TFT Array Yield Summary (No Repair)	107

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

CHAPTER THREE

MATERIALS FOR FLAT PANEL DISPLAYS	113
3.1 Glass Substrates.....	113
3.2 ITO Sputtering	114
3.2.1 ITO Powder and Thin Film Properties	116
3.3 Other Sputtering Materials	117
3.4 Color Filters	118
3.4.1 Dye Method	119
3.4.2 Pigment Dispersion	121
3.4.3 Electrodeposition	124
3.4.4 Electromist	125
3.4.5 Overcoat	126
3.4.6 Two Color Approach.....	126
3.5 Process Chemicals & Gases	126
3.6 Photoresists	129
3.7 Photomasks	129
3.8 Orientation Films	130
3.8.1 Polyimide Orientation Films	131
3.9 Spacers.....	135
3.10 Sealing Materials	137
3.11 Liquid Crystals	138
3.11.1 Other Liquid Crystal Materials	142
3.11.2 Polymer Dispersed Displays	144
3.11.3 Polymer Network Displays	146
3.12 Polarizers/Compensation Films	146
3.13 Die Attach/Connector Materials	149
3.14 Display Backlighting	152
References	157

FIGURES

3-1 CIE Chromaticity Diagram for color filters	121
3-2 Resistance to fading of dyed and printed color filters	121
3-3 Comparison of spin-coated and printed filter element.....	122
3-4 Transmittance of green pigment material / function of particle size	123
3-5 Schematic of electrodeposition process for color filters	125
3-6 Synthesis and structure of aliphatic soluble polyimide.....	132
3-7 Glass fiber spacer size distribution.	137
3-8 Typical liquid Crystal	138

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

3-9 Nematic phase	139
3-10 Cholesteric phase	139
3-11 Smectic phase.....	139
3-12 Structure & properties of difluorobenzene derivatives.	143
3-13 Trans-4-n-pentylcyclohexyl (PCH-5) derivatives.	143
3-14 Structure of polarizer film for LCD	147
3-15 Polarizer film structures	147
3-16 Transmittance vs polarization efficiency	148
3-17 Heat seal connector construction	151
3-18 Usage ratio of TAB ICs	151
3-19 IC bonding methods in chip on glass packaging	153
3-20 Construction of WedgeLight™ backlight	154
3-21 Spatial brightness uniformity of WedgeLight™	155
3-22 Flat fluorescent lamp structure	156

TABLES

3-1 LCD Glass Supplier Matrix in Japan	114
3-2 ITO Film Properties	115
3-3 Characteristics of ITO Targets	115
3-4 Glass Substrates for Liquid Crystal Displays	117
3-5 Specifications for High Density ITO Target	118
3-6 Properties of Color Filters	119
3-7 Test Conditions for Color Filters	119
3-8 Alternative Methods of Color Filter Formation	123
3-9 Solubility of Cleaning Chemicals	127
3-10 Particles in Electronic Chemicals	127
3-11 DI Water Quality	128
3-12 Measurement of Cleaning Efficiency	128
3-13 Alignment Film Material Requirements	131
3-14 Comparison of Polyimides for Orientation Film Applications	134
3-15 Plastic Spacer Size Variation	136
3-16 Plastic Spacer Thermal Expansion Coefficient.....	137
3-17 Parameters Specified in Liquid Crystal Formulations	140
3-18 Relation Between UV Exposure and Turn On Voltage	145
3-19 Polarizing Film Structures	148
3-20 STN Display Cost	155
3-21 Comparison of Backlight Technologies.....	156

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

CHAPTER FOUR

MANUFACTURING EQUIPMENT	159
4.1 Substrate Cleaning	159
4.2 Photoresist Application/Baking	160
4.2.1 Spin Coating	160
4.2.2 Roll Coating	160
4.2.3 Conveyor Ovens	160
4.3 Photolithography	160
4.3.1 Steppers	161
4.3.2 Mirror Projection	162
4.4 Etching/Stripping	164
4.4.1 Wet Etch Equipment	164
4.4.2 Plasma Etching/Ashing	164
4.5 Thin Film Deposition	165
4.5.1 Sputtering	165
4.5.2 Chemical Vapor Deposition	167
4.5.3 Plasma CVD	170
4.5.4 LPCVD and APCVD	173
4.5.5 Thermal Processing	174
4.5.6 Ion Implant/Doping	175
Phased Linear Scanner	176
Ion Flux Doping	177
4.6 Test Equipment	179
4.6.1 Visual and Functional Test	179
4.6.2 Optical Imaging	180
Optical Image Processing Equipment	182
Digital Image Processing Equipment	184
4.6.3 Electrical Evaluation	184
Transfer Admittance	185
IBM Test Set	186
4.6.4 Voltage Imaging	189
4.7 TFT Repair	189
4.7.1 Laser Cutting	190
4.7.2 Laser-Assisted Deposition	191
4.8 Assembly	192
4.8.1 Polymer Printing	192
4.8.2 Assembly/Final Test	194
4.8.3 Die/PCB Attach	198
References	199

TABLE OF CONTENTS

LIQUID CRYSTAL FLAT PANEL DISPLAYS

FIGURES

4-1 Mirror projection schematic diagram	163
4-2 Example of PECVD system for thin film deposition	170
4-3 Deposition chamber cutaway schematic	171
4-4 Cross section of PEVD electrode	171
4-5 Plan view of phased linear scanner showing two substrates	177
4-6 Cross-section view of linear scanner end station	177
4-7 Ion bucket source and deposition chamber schematic	179
4-8 Optical pattern filtering for defect imaging	182
4-9 Transfer admittance testing	186
4-10 Schematic diagram of voltage imaging of a TFT array	189
4-11 Laser connect and disconnect alternatives	190
4-12 Laser connect and disconnect using polysilicon	190
4-13 Polymer printing schematic	193

TABLES

4-1 Canon MPA-2000 Specifications	163
4-2 Nextral NE550 RIE System Specifications	165
4-3 Dry Etch Systems	166
4-4 Ulvac SDT-VT In-line Sputtering Systems	167
4-5 CVD Systems and Suppliers	168
4-6 Anelva In-Line Plasma CVD Systems	171
4-7 Amorphous Silicon Deposition	172
4-8 Nextral ND 400 PECVD System Specifications	173
4-9 LPCVD Silicon Films (Leybold LC350 Reactor)	174
4-10 Watkins-Johnson SiO ₂ Deposition System	174
4-11 KLA Acrotec 6000 Parameters	185
4-12 Spin Coating vs Print Coating	194
4-13 L-400 Rubbing Machine	194
4-14 Villa Precision GS 110 16 L Scriber Specifications	195

CHAPTER FIVE

5.1 Materials Suppliers	201
5.2 Materials Supplier Listing	205
5.3 Equipment Suppliers	208
5.4 Test, Inspection & Repair Equipment Suppliers	213
5.5 Equipment Supplier Listing	215
INDEX	221

INTRODUCTION

We live in the silicon age, and the quintessential item that defines our world is the computer. Silicon chips power the computer as well as many other products for work and leisure, such as calculators, radios, and televisions. In the forty years since the transistor was invented, the solid state revolution has affected the lives of almost everyone in the world. Based on silicon, solid state devices and integrated circuits have revolutionized electronics, data processing, communications, and the like. The computer, especially the personal computer, would be impossible without silicon devices. Only one computer was ever built using vacuum tubes, and the tubes had to be constantly replaced because they generated too much heat and burned out. Silicon devices allowed for reliable switching operations in arrays of hundreds and thousands of discrete devices. As a result, the very substantial industrial base that existed for producing vacuum tubes disappeared - with one exception. That exception is, of course, the CRT, which is evident in televisions, computer displays, and a host of other information display terminals. Until recently, there was nothing that could take its place, and it seemed that the CRT would remain as the electronic medium for all except the simplest displays.

The CRT is about to go the way of the other vacuum tubes. It's dead, but doesn't know it yet. Just like the transistor revolution, it will be a few decades before you need to go to a museum to see this other kind of vacuum tube, but the end is coming. The instrument of the CRT's demise is again the silicon transistor, in a new, thin film form. In this form, thousands of transistors can act as a switch array for liquid crystal displays, LCDs, providing picture quality equal to that of the CRT. Liquid crystal displays have been with us for more than 20 years, for watches, calculators, and other small displays. But the technology for large displays with high information content is quite recent. There are various kinds of display technologies besides LCDs, and various kinds of switching schemes besides the silicon transistor. However, this combination of liquid crystal and thin film transistor, termed active matrix liquid crystal display, AMLCD, technology, appears to be the path to complex, colorful displays for computer and other applications.

The silicon materials technology for the AMLCD thin film transistor actually had its beginnings in the solar cell investigations of 1975-1980. While the US and

INTRODUCTION

LIQUID CRYSTAL FLAT PANEL DISPLAYS

Europe poured millions of dollars into crystalline silicon for solar cells, the Japanese developed amorphous silicon deposited by chemical vapor deposition. While the US sponsors of solar research thought about paving Arizona with solar cells for power generation, the Japanese made small cells, put them in calculators, and threw away the wet-cell battery. That same silicon technology is now used for thin film silicon transistors, hundreds of thousands on a glass plate, that replace the scanning electron beam of the CRT.

This book describes the construction, operation, and manufacturing of flat panel displays, emphasizing the AMLCD type. Many of the manufacturing processes are akin to integrated circuit processes, and will be familiar to IC process engineers. These are described in some detail as well as the other operations for display manufacturing. Emphasis is on current manufacturing practice and trends in manufacturing that will impact the equipment and materials. Separate chapters are devoted to the manufacturing equipment and to the materials.

This book concentrates on large liquid crystal displays to the exclusion of other types. These other types include electroluminescent displays, plasma displays, vacuum fluorescent displays and electrochromic displays. Their manufacturing technologies and applications are certainly interesting, but someone else will have to do them justice. In terms of their applications, these latter displays are mainly for niche applications. The LCD display is the mainstream.

The emerging AMLCD industry has the look of inevitability about it, something that is going to happen sooner or later. Of course, lots of people are going to speed lots of time, money and brainpower making it happen. Some of us worry that the engineering and manufacturing won't happen in the US, and therefore won't provide jobs for those of us who are looking for work. Unfortunately, it isn't clear how to correct this situation, or even that things would be much better if it could be corrected. Hopefully, motivated people and organizations will find useful information here if they do decide to build a factory.

What is striking about the new technology is how nicely it fits the bill for the next advance in computing, the portable, and assists in the proliferation of that device. Probably we need more computers and other electronic devices, and we do love our gadgets. But, in the end, what we seem to be pointed towards is just more and different and better kinds of television. Is this progress?

INTRODUCTION

LIQUID CRYSTAL FLAT PANEL DISPLAYS

It is a pleasure to acknowledge the assistance of many of the people at the Semiconductor Equipment and Materials International (SEMI) trade organization in gathering the data for this book. In particular, the people who assisted in every way during my three month stay in the SEMI office in Tokyo, Japan, were very helpful. These include George Moore, Steve Nakayama, Yoshi Kohuo and many others. It was a pleasure to work in their company.

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