# Appendix D

## TFT-LCD Manufacture

Glass Panel

| Process Step | Equipment | Material/Chemical | Notes |
|---|---|---|---|
| Fusion Method | | barium borosilicate, aluminoborosilicate; 0.7mm thick | e.g., Corning 7059: 49% $SiO_2$, 10% $Al_2O_3$; 15% $B_2O_3$; 25% BaO; 1% other |
| Mix | | | |
| Melt glass | | | |
| Fine | | | |
| Condition | | | |
| Flow glass | | | |
| Draw glass | | | |
| Cut glass | band, wire, or circular blades | | |
| Bevel/chamfer/heat glass | | | |
| Grind (may be eliminated) | | sand, garnet, corundem, silicon, carbide, boron carbide, or diamond | |
| Polish (may be eliminated) | | | |
| Chemical finishing | | potassium nitrate | |
| Clean (physical) | brush, scrub, ultrasonic, or megasonic | | |
| or Clean (chemical) | | organic solvent; neutral detergent; or chemical clean; and water | |
| or Clean (dry) | ultraviolet ozone; plasma oxide; plasma non oxide; or laser | | |
| Anneal (back panel only) | | | 350-400°C |
| | | | |
| Float method | | barium borosilicate or aluminoborosilicate; 0.7mm thick | e.g., Corning 7059: 49% $SiO_2$, 10% $Al_2O_3$; 15% $B_2O_3$; 25% BaO; 1% other |
| Mix | | | |
| Melt | | | |
| Fine | | | |
| Flow glass | molten tin bed | float on bed of molten tin in chemically controlled atmosphere | |
| Cool glass | | still on molten tin | |
| Cut glass | | | |
| Bevel/chamfer/heat glass | | | |
| Grind (may be eliminated) | | | |
| Polish (may be eliminated) | | | |
| Chemical finishing | | potassium nitrate | |
| Clean (physical) | brush, scrub, ultrasonic, or megasonic | | |
| or Clean (chemical) | | organic solvent; neutral detergent; or chemical clean; and water | |
| or Clean (dry) | ultraviolet ozone; plasma oxide; plasma non oxide; or laser | | |
| Anneal (back panel only) | | | |

Front Panel Pattern-TN

| Process Step | Equipment | Process Material | Ancillary Material | Notes |
|---|---|---|---|---|
| Clean glass | Ultrasonic clean/spin rinse dryer | | IPA, water, nitrogen | |
| Deposit ITO | PVD | | Indium tin oxide | |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Bake photoresist | Oven | | | |
| Etch ITO | Plasma etcher | | $Cl_2$; HBr; He; $O_2$ | Wet etch: HCL |
| Strip photoresist | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Deposit black matrix material | Sputter | Chrome | | Alternative: black resin & photo process |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Bake | Oven | | | |
| Etch Cr | Wet bench | | | |
| Strip photoresist | Wet bench | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Inspect | | | | |
| Apply (R) color filter material | Extrude/spin or slit/spin coater | 0.8-2.0 um acryl epoxy resin, Sbq-PVA | Same as process material | Pigment-dispersion method, 99% TFTs |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | Negative resist; extra strip not required |
| Apply (G) color filter material | Spin coater | Pigment-diffused acryl epoxy resin | Same as process material | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Apply (B) color filter material | Spin coater | Pigment-diffused acryl epoxy resin | Same as process material | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Planarize | Coat | Polyimide | | |

| Process Step | Equipment | Process Material | Ancillary Material | Notes |
|---|---|---|---|---|
| Deposit alignment layer | Roll coat | Polyvinyl alcohol; polyesters; poly- siloxanes; polyamic acid solution | | |
| Bake | Oven | | | |
| Rub | Rubbing machine | | | |
| Inspect | Microscope | | | |
| Test | | | | |

Rear Panel Pattern-TN

| Process Step | Equipment | Product Materials | Ancillary Materials | Notes |
|---|---|---|---|---|
| Clean bottom glass | Ultrasonic or brush | | IPA, nitrogen, water | alkali-free likely future material |
| | | | | |
| Inspect | | | | |
| Deposit gate metal | PVD | One of the following: Al, Al + barrier, Al + metal, Al alloy | | Ti/Al/Ti possible future metal layers |
| Coat photoresist | Spin coater | | Polyimide | 90- 95% wasted on traditional spin coater |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | NMP | |
| Clean | Spin rinse dryer | | Water | |
| Bake photoresist | Oven | | | |
| Etch gate metal | Plasma etcher | | | or wet etch + clean |
| | | | Al: $C1_2$+$BC1_3$/$C1_2$ | |
| | | | Al+barrier: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| | | | Al+metal: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| | | | Al alloy (Zr, Cu, Nd, Y): $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| Strip photoresist | Developer | | NMP | |
| Clean | Spin rinse dryer | | Water | |
| Inspect | | | | |
| Deposit dielectric material | PECVD | $SiO_2$ or SiN | | |
| Deposit channel material | PECVD | a-Si | | |
| Deposit etch stop layer | PECVD | SiNx | | |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | NMP | |
| Clean | SRD | | Water | |
| Bake photoresist | Oven | | | |
| Etch SiNx | Plasma etcher | | $CHF_3$; $CF_4$ | |
| Etch a-Si | Plasma etcher | | $CF_4$; $O_2$ | |
| Etch SiNx | Plasma etcher | | $CF_4$; $O_2$ or $Cl_2$ | |
| Strip photoresist | Developer | | NMP | |
| Clean | SRD | | Water | |
| Deposit ohmic contact material | PECVD | Doped Si (n-type: As,P) | | |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |

| Process Step | Equipment | Product Materials | Ancillary Materials | Notes |
|---|---|---|---|---|
| Develop | Developer | | NMP | |
| Clean | SRD | | Water | |
| Bake photoresist | Oven | | | |
| Etch doped a-Si | Plasma etcher | | $C1_2$ or $CF_4$+$O_2$ or $SF_6$+HCL | |
| Strip photoresist | Developer | | NMP | |
| Clean | Spin rinse dryer | | Water | |
| Deposit ITO | PVD | Indium oxide/tin oxide | | |
| Anneal | Oven | | | |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | NMP | |
| Clean | SRD | | Water | |
| Bake photoresist | Oven | | | |
| Etch ITO | Plasma etcher | | $Cl_2$+ HBr; He; $O_2$; $CH_4$+$H_2$ | or wet etch + clean |
| Strip photoresist | Developer | | NMP | |
| Clean | SRD | | Water | |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | NMP | |
| Clean | SRD | | Water | |
| Bake photoresist | Oven | | | |
| Etch n+ a-Si (contact) | Plasma etcher | | $Cl_2$ | |
| Deposit source/drain metal | PVD | One of the following:<br>Al, Al + barrier, Al + metal, Al alloy<br>Ti, Mo, Cr, W, MoTa, or MoW | | |
| Coat photoresist | Coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Oven | | | |
| Develop | Stepper | | | |
| Clean | Developer | | NMP | |
| Bake photoresist | Spin rinse dryer | | Water | |
| Etch metal | Plasma etcher | | Al etch: $C1_2$+$BC1_3$/$C1_2$ | or wet etch + clean |
| | | | Al+barrier: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| | | | Al+metal: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| | | | Al alloy (Zr, Cu, Nd, Y): $Cl_2$; $BCl_3$; $N_2$; $CF_4$ | |
| Strip photoresist | Developer | | NMP | |
| Clean | SRD | | Water | |
| Deposit passivation layer | PECVD | SiNx | $CF_4$+$O_2$ | |
| Coat photoresist | Coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Oven | | | |

| Process Step | Equipment | Product Materials | Ancillary Materials | Notes |
|---|---|---|---|---|
| Develop | Proximity printer | | | |
| Clean | Developer | | NMP | |
| Bake photoresist | SRD | | Water | |
| Etch SiNx | Plasma etcher | | $O_2$, $N_2$, He, $SiF_6$, $CHF_3$ (mixture) | |
| Strip photoresist | | | NMP | |
| Clean | SRD | | Water | |
| Deposit alignment material | Roll coater | Polyimide, 500 to 1000 A | | |
| Bake | Oven | | | |
| Rub | Rubbing machine | | | |
| Electrostatic discharge | | | | |
| Test | SRD | | Water | |

Front Panel Pattern-IPS

| Process Step | Equipment | Process Material | Ancillary Material | Notes |
|---|---|---|---|---|
| Clean glass | Ultrasonic clean/SRD | | IPA, water, nitrogen | |
| Deposit black matrix material | Sputter | Chrome | | Alternative: black resin & photo process |
| Coat photoresist | Spin coater | | Polyimide | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Bake | Oven | | | |
| Etch Cr | Wet bench | | | |
| Strip photoresist | Wet bench | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Inspect | | | | |
| Apply (R) color filter material | Extrude/spin or slit/spin coater | 0.8-2.0 um acryl epoxy resin, Sbq-PVA | Same as process material | Pigment-dispersion method, 99% TFTs |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | Negative resist; extra strip not required |
| Apply (G) color filter material | Spin coater | Pigment-diffused acryl epoxy resin | Same as process material | |
| Bake | Oven | | | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | Spin rinse dryer | | Water | |
| Apply (B) color filter material | Spin coater | Pigment-diffused acryl epoxy resin | Same as process material | |
| Expose | Stepper | | | |
| Develop | Developer | | TMAH | |
| Clean | SRD | | Water | |
| Deposit alignment layer | Roll coat | Polyvinyl alcohol; polyesters; poly-siloxanes; polyamic acid solution | | |
| | | | | |
| Bake | Oven | | | |
| Rub | Rubbing machine | | | |
| Inspect | Microscope | | | |
| Test | | | | |

Rear Panel Pattern-IPS

| Process Step | Equipment | Product Materials | Ancillary Materials |
|---|---|---|---|
| Clean substrate | Brush, disk, US, or MS | | |
| Inspect | | | |
| Deposit light shield metal | PVD | Cr | |
| Coat photoresist | Coater | | Positive photoresist |
| Bake | Oven | | |
| Expose | Stepper | | |
| Develop | Developer | | NMP |
| Clean | Spin rinse dryer | | Water |
| Bake | Oven | | |
| Etch Cr | Plasma etcher | $Cl_2$;$O_2$ | |
| Strip | Plasma asher | $Cl_2$;$O_2$ (or wet bench) | |
| Clean | Spin rinse dryer | | |
| Inspect | AOI | | |
| Deposit dielectric | CVD | $SiO_2$ | |
| Deposit source/drain metal | PVD | One of the following: Al, Al + barrier, Al + metal, or Al alloy | |
| Coat photoresist | Coater | | |
| Bake | Oven | | |
| Expose | Stepper | | |
| Develop | Developer | | NMP |
| Clean | Spin rinse dryer | | Water |
| Bake | Oven | | |
| Etch | | | Al etch: $C1_2$+$BC1_3$/$C1_2$ |
| | | | Al+barrier: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| | | | Al+metal: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| | | | Al alloy (Zr, Cu, Nd, Y): $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| Strip | | | NMP |
| Clean | | | Water |
| Create island | | SiNx, a-Si, n+ a-Si | |
| Coat photoresist | | n+ a-si | |
| Expose | | | |
| Develop | PVD | | |
| Clean | | | |
| Bake | | | |
| Etch island | Plasma etcher | | $CF_4$; $O_2$; $Cl_2$ |
| Strip | | | |
| Clean | | | |
| Inspect | | | |

| Process Step | Equipment | Product Materials | Ancillary Materials |
|---|---|---|---|
| Deposit gate electrode | CVD | Al, Al+barrier, Al+metal, or Al alloy | |
| Deposit pixel electrode | CVD | Al, Al+barrier, Al+metal, or Al alloy | |
| Deposit common electrode | CVD | Mo, Ta, MoTa, MoW, Al/Cr, or Ti/Al/Ti | |
| Coat photoresist | Coater | | |
| Bake | Oven | | |
| Expose | Stepper | | |
| Develop | Developer | | |
| Clean | Spin rinse dryer | | |
| Bake | Oven | | |
| Etch metal(s) | Wet bench | | Al etch: $C1_2$+$BC1_3$/$C1_2$ |
| | | | Al+barrier: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| | | | Al+metal: $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| | | | Al alloy (Zr, Cu, Nd, Y): $Cl_2$; $BCl_3$; $N_2$; $CF_4$ |
| | | | Ti: $Cl_2$; $CF_4$ |
| | | | Mo: $Cl_2$; $O_2$; $SF_6$ |
| | | | Cr: $Cl_2$; $O_2$ |
| | | | W: $Cl_2$; $O_2$; $SF_6$ |
| | | | MoTa: $Cl_2$; $O_2$; $SF_6$ |
| Clean | Spin rinse dryer | | |
| Strip | Developer | | |
| Clean | Spin rinse dryer | | |
| Deposit alignment layer | Roll coater | Polyimide, 500 to 1000 A | |
| Bake | Oven | | |
| Rub | Rubbing machine | | |
| Electrostatic discharge | Spin rinse dryer | | Water |
| Test | | | |

Display Cell Assembly

| Process Step | Equipment | Process material/chemical | Notes |
|---|---|---|---|
| Apply seal | Screen printer | Epoxy resin, acrylic resin, etc. | |
| Cure | Oven | | |
| Apply spacers | Spacer sprayer | Divinylbenzene-type resin or silica | |
| Inspection | Microscope | | |
| Align and assemble plates | | | Each glass plate 1.1 mm thick |
| Cure | Oven | | |
| Scribe and break | | | 400 different types exist; more than one used |
| Inject liquid crystal | Vacuum/injection system | Polycyclic aromatic/halogenated hydrocarbon; cyanobiphenyl; phenylcyclohexane compound | 0.8 mg/cm$^2$ |
| Seal | | Epoxy resin, acrylic resin, etc. | Sealing LC-injection hole |
| Cure | UV light source/oven | | |
| Clean | | | |
| Attach front polarizer | Laminator | Polyvinyl alcohol-iodine | .2 - .3 mm cellulose triacetate; cellulose acetate butyrate-protective layer |
| Attach rear polarizer | Laminator | Polyvinyl alcohol-iodine | .2 - .3 mm cellulose triacetate; cellulose acetate butyrate-protective layer |
| Clean | | | |
| Inspect/test display | | | |

Display Module Assembly

| Process Step | Process material/chemical | Notes |
|---|---|---|
| Attach row drivers | PWB, TAB (polyimide film, sealing resin) | |
| Attach column drivers | TAB (polyimide film, sealing resin) | |
| Attach backlight | Glass fluorescent material, 20ppm Hg (notebook computer) | |
| Inspect | | |
| Clean circuit boards | | |
| Test | | |
| Attach controller | TAB (polyimide film, sealing resin) | |
| Attach passive components | | |
| Attach packaging hardware | | |
| Attach interconnects | | |
| Test unit | | |