

Flat Panel Display Manufacturing

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TFT Array Process Architecture and Manufacturing Process Flow

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2.1 INTRODUCTION

Liquid crystal display (LCD) technology has evolved over the years and presently holds a dominant position in the flat panel display market. Amorphous silicon (a-Si)-based thin-film transistor LCDs (TFT-LCDs) were developed to adopt large glass substrates. a-Si TFT-LCD grew rapidly in the 1990s through the adoption in laptop and notebook PC displays. The size of the glass substrates has been continuously enlarged to improve productivity. Since the a-Si TFT-LCDs have cost competitiveness as well as scalability, they are currently being used from small-size mobile devices to large size TV screens.

Recently, as the display resolution in both mobile devices as well as in large-size TVs has been continuously increasing, it is necessary to develop next-generation TFTs with higher electron mobility, electrically stable, and uniform performance. Smartphones, which are the fastest-growing products among mobile devices, require resolutions up to WQHD (2560×1440) or even higher. In addition to resolutions, the mobile devices require reduced power consumption by increasing the transmittance of each pixel on the TFT-LCD backplanes and low-voltage driving. The maximum aperture ratio of the pixel can be obtained by using fine design rule, minimizing the storage capacitor and TFT sizes. To achieve that, high-resolution photo-lithography, high-mobility TFTs and self-aligned TFT structure are required.

The conventional a-Si TFT structure has large parasitic capacitance and low electron mobility. With a-Si TFT backplane, it is impossible to handle the high-resolution mobile LCD displays. Even worse, the bias stability of the a-Si TFT is not good enough for use in active matrix organic light emitting diode (AMOLED) display. Alternatively, poly-silicon (poly-Si) TFT with thin gate insulator and self-aligned structure is the ideal backplane solution for producing high-resolution and low-power consumption TFT-LCDs as well as AMOLED displays. Poly-Si has an electron mobility about 200 times higher than a-Si, due to its crystalline atomic structure (Figure 2.1) [3]. For the mass production of poly-silicon TFT-LCDs, it is necessary to develop low-temperature manufacturing techniques for compatibility with alumina borosilicate large glass substrates, rather than costly and small-sized quartz wafers. The development of excimer laser annealing (ELA) for the crystallization of the a-Si precursor was a breakthrough for the use of glass substrates, enabling the mass production of low-temperature poly-silicon (LTPS) LCDs. The high mobility of LTPS brings many benefits to TFT-LCDs. The dimension of LTPS TFT is smaller than the a-Si TFT, which directly leads to higher aperture ratio pixels and narrower panel border width. The high aperture ratio reduces backlight

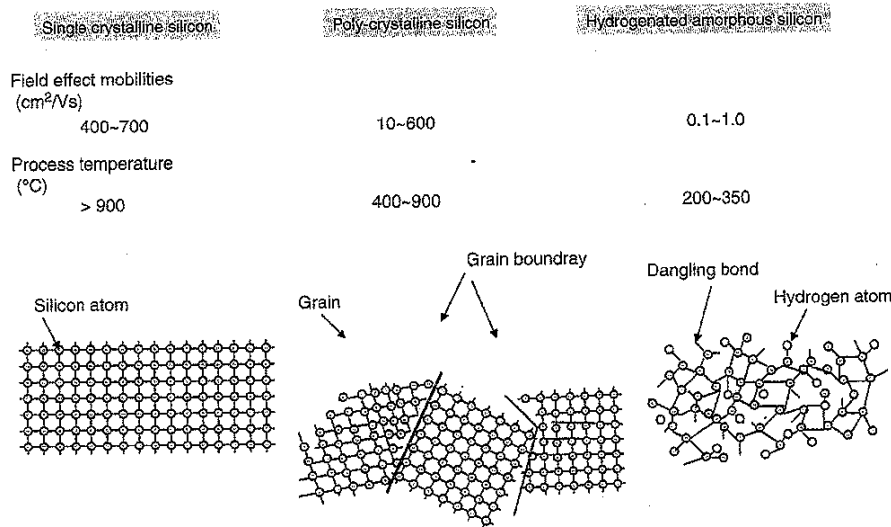


Figure 2.1 Comparison of single crystalline, poly crystalline, and hydrogenated amorphous silicon.

power consumption. The small TFT size further reduces the driving power consumption because the electrode overlapped parasitic capacitance becomes smaller. In addition, LTPS enables much higher pixel density without increasing the bezel form factor compared to a-Si because LTPS allows integrating the gate drivers and the data multiplexing circuits on the glass substrate [3]. This circuit integration capability enables the interconnections within small area.

Presently, the LTPS demand is significantly increased due to the requirement of high-resolution displays for smartphones. In addition, the AMOLED display is considered the next-generation display technology after TFT-LCD because it has higher optical performance, lower power consumption, and thinner form factor than LCD. The OLED pixel is operated by electric current, whereas liquid crystals in LCDs are driven by electric voltage. For high-resolution mobile AMOLED displays, LTPS TFTs are thus the primary choice since high electron mobility and high device stability are required. It is expected that, eventually, when the OLED material cost is reduced through mass production and the production yield is matured, the production cost of mobile OLED displays can be lower than LTPS based TFT-LCDs and the OLED displays dominate the mobile display market.

In 2004, the amorphous oxide semiconductor (OS) indium-gallium-zinc-oxide (IGZO) was introduced as a new TFT channel material [2]. Since then, many groups started research and development of OS materials for display applications. IGZO has relatively high carrier mobility and low leakage current while using a-Si like manufacturing processes. OS TFT's potential for high pixel density, low power consumption, and high-performance display-integrated touch screen in display applications were reported [2, 3]. Mass production of IGZO technology has already started for high-resolution TFT-LCD applications, although the volume is not yet comparable with conventional silicon-based backplane technologies. Furthermore, there are possibilities to use other OS materials for display TFT applications besides IGZO. For example, the potential use of Hf-In-Zn-O, which has higher mobility than IGZO, was reported by another group [4]. Since the manufacturing process of OS TFTs is compatible with a-Si infrastructure, the production cost of OS TFT is lower than the LTPS while offering reasonable electron mobilities. Thus, OS TFT is regarded as a good candidate for AMOLED TV backplanes as well [5].