Micro LED Technology and Platform Trend

Sam Chen[1], HaoMin Ku[1], Chingen Huang[1], TzuLing Yang[1] and Jimmy Shen[1]

Unikorn Semiconductor, Li-hsin 5th Rd., Hsinchu Science Park, Hsinchu 300, Taiwan

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Abstract

Over the last decade, the focus of Micro LED technology development has expanded from selective mass transfer for large display application to monolithic bonding for augmented reality. In particular, in recent years, the development of monolithic Micro LED has attracted significant interest for use in metaverse application. Micro LED promises a new generation of AR display with improved performance in terms of higher brightness, lighter, better reliability, etc., compared to current display technology. However, Micro LED must overcome manufacturing challenges from epitaxy, COW (chip on wafer), heterogeneous integration, and full color solution. In this paper, the focus will be on how COW platform satisfies various selective mass transfer types and monolithic type architectures. In addition, this paper will introduce the key technology development trends for different platforms and highlight the challenges in realizing mass production of Micro LED.

INTRODUCTION

In recent years, the development of Micro LED display has attracted significant interest and commercial investment for various applications and has already been commercialized for large display marketing in the past two years. Just like the Organic Light Emitting Diodes (OLED), Micro LED offers high contrast, high dynamic range and wide viewing angles. Furthermore, it also provides higher brightness, lower power consumption and longer lifetime. To realize the Micro LED technology for large display, the mass selective transfer is the most popular option, utilizing either stamp or laser lift off (LLO) processing. In this paper, we will discuss these two COW platforms for different mass selective transfer methodologies in large display. [1]

Besides large displays, Micro LED is also popular in augmented reality (AR) application. Although there are various solutions available in this field, e.g. Micro OLED, LCoS, DLP, and LBS, only Micro LED can offer light-weight, high transmittance, and stylish designs for AR glasses. [1] The use of AR glasses in close proximity to the eyes pushes AR applications to use the highest pixel densities available. Micro LED smaller than 1.5μm are needed to satisfy the 60 pixels per degree (PPD) angular resolution demand in AR glasses. To realize the Micro LED technology for these displays, the heterogeneous integration between III-V compound semiconductor and Si CMOS device is one of most important topics. Furthermore, achieving good efficiencies in Red with shrinking Micro LED size is still a big challenge. In this paper, we will discuss bumping material and various III-V compound semiconductor systems, e.g. GaN on sapphire, GaN on Si and AlGaInP on sapphire. Additionally, we will demonstrate a 0.12-inch single color display utilizing the heterogeneous integration between GaN on Sapphire and Si CMOS device.

MICRO LED ECO-SYSTEM

Many companies have some pieces of the Micro LED product, but no one has all of them. Unikorn can provide a COW foundry service, including both epitaxy wafer and wafer processing. Various IDM or panel companies can fabricate the COC (Chip on Carrier) by utilizing mass selective transfer or direct bonding technologies with pitch size matching the panel pixel size. Then the panel companies can use this COC to bond these Micro LEDs on the TFT glass, PCB or Si CMOS IC. The Micro LED eco-system is illustrated in Fig. 1. [1]

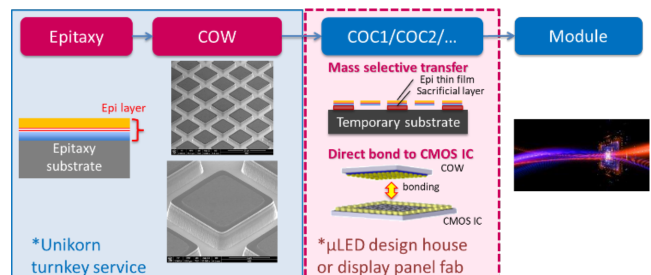

Fig. 1 Micro LED eco-system

COW PLATFORM

The COC process could be utilized several times (from COC1 to COC2, etc.) for transfer process with different transfer technologies. The two different COW platforms for large display application are Flip Chip Micro LED (FC Micro LED) with n/p electrode on the bottom and TRansparency Micro LED (TR Micro LED) with transparent electrode on the top lighting area. Fig. 2 shows these two COW platforms recommended for large display Micro LED. In order to conduct easier mass selective transfer, the InGaN (for blue, green emission) and AlInGaP (for red emission) Micro LED are both on the sapphire substrate allowing post processing for three different colors. However, the red Micro LED

epitaxy is done on GaAs substrate. The blanket red epi from GaAs is transferred onto the sapphire substrate by utilizing a glue bonding technology, and this glue material can also be LLO for post COC processing

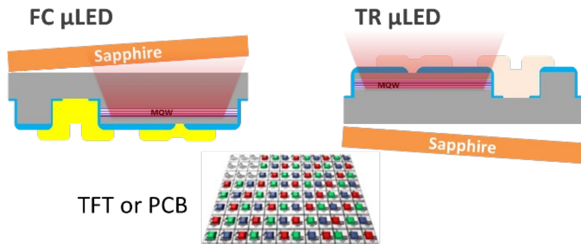

Fig. 2 Unikorn's COW Platforms for large display

For AR application, some IDM or panel companies utilize the direct bonding process for Micro LED and Si CMOS devices. A MetaVerse Micro LED (MV Micro LED) process is developed to satisfy this application. This COW's material includes InGaN (for blue, green emission) / AlInGaP (for red emission) on sapphire and InGaN on Si (for blue, green, red emission).

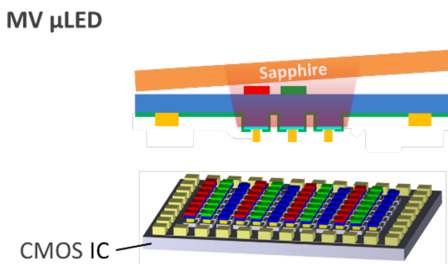

Fig. 3 Unikorn's COW Platform for AR display

Micro LED chip shrinkage is one of the most important challenges from large display to AR display. Currently, 34x58µm to 15x30µm FC/TR LED can be manufactured for large display and pitch 4µm MV Micro LED for AR display. Although thin film protection technology is not discussed in this paper, it is utilized in the COW platform for reducing surface defects, improving external quantum efficiency, and increasing product reliability. When available, Au or Sn alternative bumping material will provide additional flexibility for post bonding processing in the panel fab.

0.12 INCH AR DISPLAY DEMOSTRATION

Unikorn demonstrated a new 0.12-inch micro-display with a pixel density exceeding 6,500 PPI and a blue light brightness of 200,000 nits, using MV Micro LED platform. This display was developed in collaboration with Ennostar and Hon Hai Precision Industry Corporation [2]. Hon Hai is in charge of the Si CMOS IC and display driver, and Ennostar group is in charge of epitaxy, wafer processing, heterogeneous integration between MV Micro LED device and Si CMOS device. The pitch of Micro LED is 4µm. The Micro LED mesa size is 2.5µm and pad dimension is smaller than 2µm.

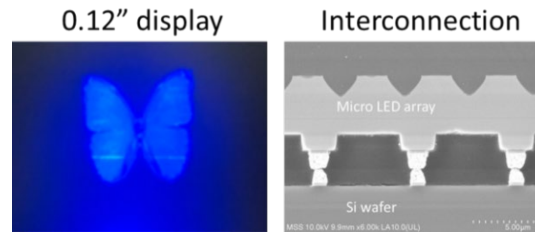

Fig. 4 Touch Taiwan Demonstration

This 0.12-inch display utilized Au to Au interconnection with cross section as shown in Fig. 4. In order to satisfy the full color AR display within 60 PPD, the bonding accuracy was better than 0.5µm. Unikorn will develop the copper bumping for hybrid bonding in next MV Micro LED platform. For the Cu bumping development, Unikorn cooperates with Professor Meng-Chyi Wu's Lab of National Tsing Hua University (NTHU and the Emerging Technology Application program of Hsinchu Science Park Bureau, National Science and Technology Council [3]).

CONCLUSIONS

Three different COW platforms of Unikorn and the 0.12-inch AR display demonstrations are presented in this paper. Each COW platform has its own suitable mass selective transfer or direct bonding COC.

The large display market is already commercialized. For AR display to commercialize, the key challenges to overcome are chip shrinkage and heterogeneous integration between III-V compound semiconductor and Si CMOS device. This work shows progress for both of those efforts.

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