GaN-based Monolithic LED Micro-arrays

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LED array displays made with individually packaged devices has been widely used for various applications. In recent years, different techniques are exploited to fabricate monolithic passive addressable LED arrays [1][2][3][4]. The array dimensions and pixel brightness in conventional passive addressable LED arrays were limited by the loading effect in the same row or column. Therefore, a new addressing scheme and fabrication technology are needed to improve the operating effectiveness of monolithic LED arrays.

In this paper, we report an 8×8 active matrix light emitting diode (AMLED) array. The AMLED array is composed of 8×8 pixels, each of which has dimensions of 300μm×300μm and a 50μm pitch. A standard multiple quantum well (MQW) blue LED wafer grown on a sapphire substrate was used for fabrication of the LED micro array. Silicon dioxide (SiO_2) masks were used for Inductively Coupled Plasma (ICP) etching. The LED wafer was etched all the way down to the sapphire substrate. Rows of the array were defined and isolated in this step. SiO_2 mask and ICP were used again to define the mesa structure of each LED pixel, with individual device size of 300×300μm^2. A thin Ni/Au (5/5nm) current spreading layer was deposited onto the p-GaN surface by electron beam evaporation. Annealing in the atmospheric ambient at 570°C for 5 minutes was performed. Then, a Ti/Al/Ti/Au (30/120/10/30nm) multi-layer metal was evaporated to form the n-contact and as reflective layer on the p-contact simultaneously. Finally, Silicon dioxide passivation was applied onto the wafer. Openings in the SiO_2 were defined and Ni/Au (500/30nm) contact pad was formed in the opening for flip-chip bonding.

The active matrix (AM) panel which consists of 64 control circuits was fabricated with standard complementary metal-oxide-silicon (CMOS) process. Each circuit is composed of one capacitor and two PMOS transistors (1C2T) so as to control the current flowing through each pixel.

After the CMOS process, a TiW/Cu (30/500nm) seed layer was deposited by sputtering and photo-resist AZ4903 was coated and patterned by photolithography. A think Cu layer (8μm) and solder layer (22μm) was deposited by electrical plating. After reflow in the annealing furnace, solder bumps were formed in ball shape. The LED micro array wafer was thinned and diced. After flipping the diced LED micro array onto the AM panel, the AMLED array was finished.

We have demonstrated a monolithic high-resolution active matrix programmed LED micro display by using flip-chip technology. The display has the advantages of high brightness, good luminance uniformity and individual controllability. This work shows that integration of GaN-based LEDs with the mature Si manufacturing technology is viable and different lighting systems on a chip can be developed using similar technology.

References

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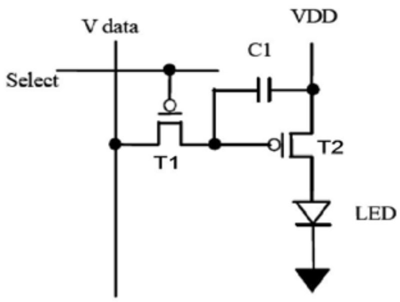


Fig. 1. Schematic (a) of AMLED pixel circuit

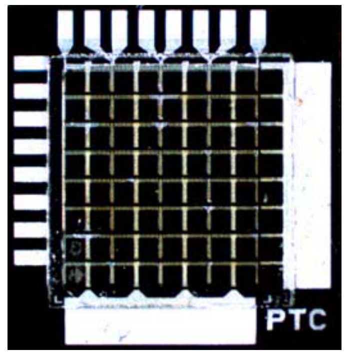


Fig. 2. Micro-photo of AMLED array after flip-chip process

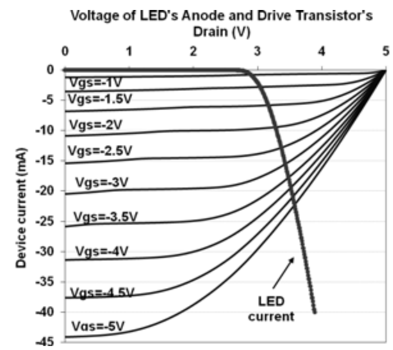
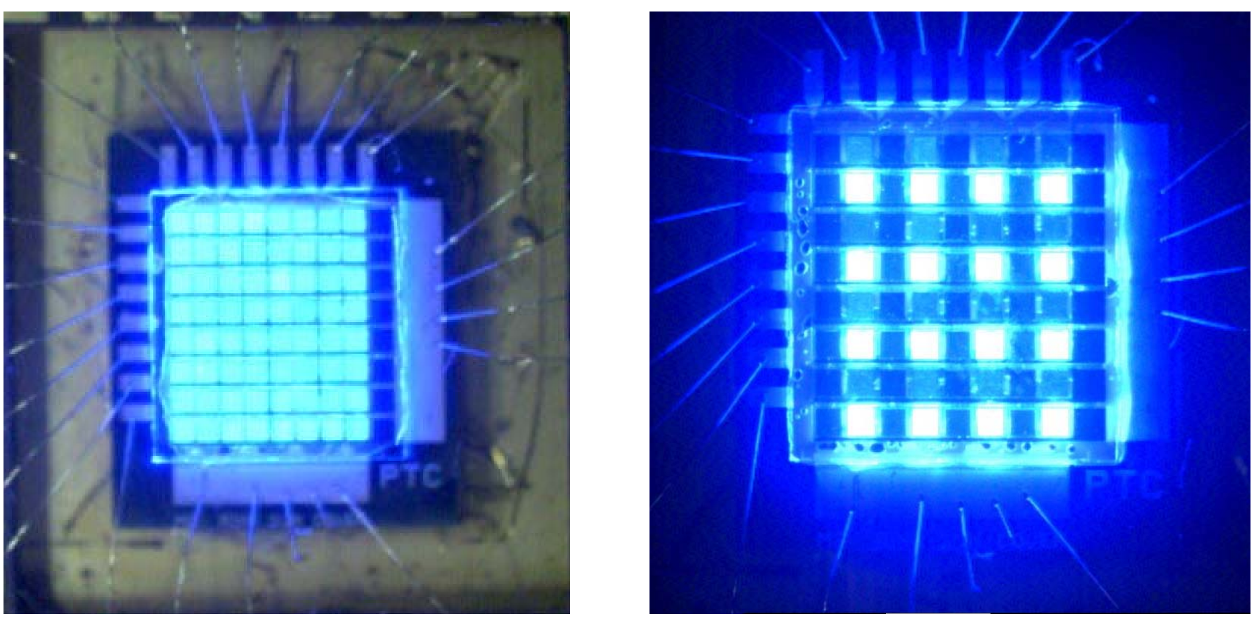


Fig. 3. Operation points of LED pixel and drive transistor



(a) **(b)**

Fig. 4. AMLED array was lighted up totally (a) and individually (b)