

Flexible High-Definition Carbon-nanotube Display

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Since the carbon-nanotube (CNT) has been discovered in 1991 [1], lots of research has been triggered towards the application due to its exceptionally intriguing properties. For example, the metallic CNT can carry the highest current density of any known material, theoretically as high as $10^{13}\text{A}/\text{cm}^2$, and measured as high as $10^9\text{A}/\text{cm}^2$ [2], two order of magnitude larger than copper. Due to its extremely low turn-on fields and high current densities, CNTs has already been proved as one of the most promising electron field emitter in 1995 [3,4]. The most popular example is the flat panel display, where a continuous or patterned film of nanotubes provides a larger number of independent electron beams. One important prerequisite to using carbon nanotubes as electron emitters in the flat panel display is to be able to apply them in patterns onto the substrates. This can be realized either by producing the nanotubes and subsequent patterning on the substrate or by growing the nanotubes directly on a substrate pre-patterned with a catalyst. Samsung research group lead by Choi in 1999 has demonstrated a 4.5in display by first method, which is shown in Figure 1 [5].

Lots of research has also been done about the growth of CNTs on patterned substrate [6-11]. But one common feature is that the substrate is stiff silicon or glass. Flexible display is the next generation display, and it requires every component be flexible. The current flexible display is organic light emitting display (OLED), in which the substrate and screen are transparent polymeric thin films. The recent review article is reference [12] by Xu in 2005.

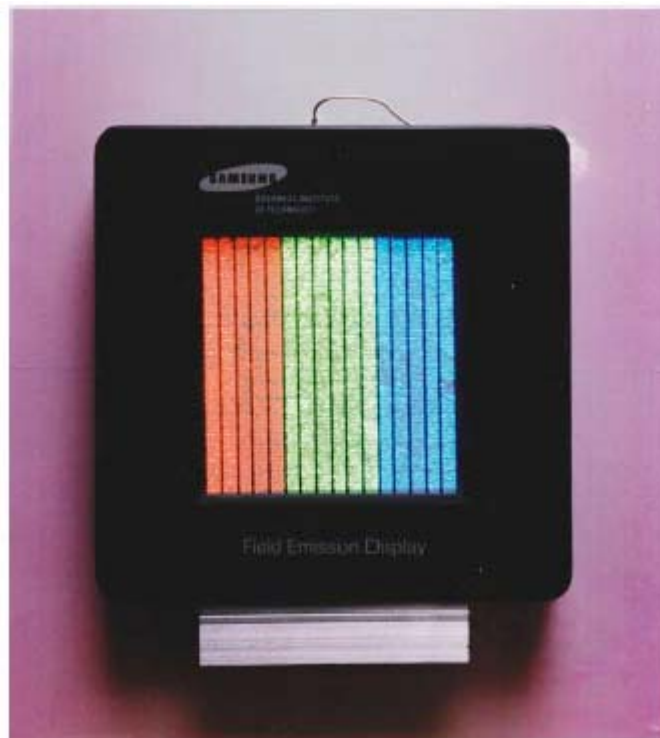


Figure 1. Single wall carbon nanotube field emitter display in color mode. (Ref.5)

Based on the two current technologies, i.e., field emission display and light emission display, we propose the model for the flexible, high-definition carbon nanotube display, as shown in Figure 2. The working mechanism is as follows: the CNT cathodes emit the electron beams to the phosphor in the vacuum, and every beam corresponds to one pixel in the screen. The color of pixel is controlled by the intensity of each beam, which in turn is controlled by the voltage. The CNT bundle is just about 1micron wide. Well patterned, fine CNT bundles can make high resolution display. And also the heat dissipation is very low, so the temperature is very low at the cathode. And because the intensity could be very high, hence the contrast is sharp. It brings bright, vivid colors as traditional CRT, but doesn't need high voltage and high heat generation. It can be viewed in very wide angle, and so exceeds the LCD.

Aside the benefits, there are some concerns to make this device work. One of the obvious problems is that if the front and back substrates are flexible, and there is a vacuum in the middle, the ambient pressure will crush the two plates towards each other, which could crash the CNT cathodes. Based on this consideration, we propose two modifications, which are shown in Figure 3. In Figure 3(a), there is no vacuum, so the cathode and anode just contact each other, like in OLED. Then we needn't worry the bending inward, and also the macroscopic rolling wouldn't damage or disorder the CNT alignment. In Figure 3(b), we use soft lithography to make the trenches and pillars, then grow the CNT in the trenches. So the CNTs are protected by the pillars. If the pillars are uniformly distributed in the whole plane, then the front and back substrates won't crash inward under the ambient pressure.

For the reference, Figure 4 shows the patterned CNTs bundle. Nice picture from reference 13.

Note: now there are some feasibility considerations. First, can the CNTs grow in the patterned trench on compliant substrate? second, does it need the vacuum between cathode and anode? How large can the whole structure be bent? And other concerns are our work for next weeks.

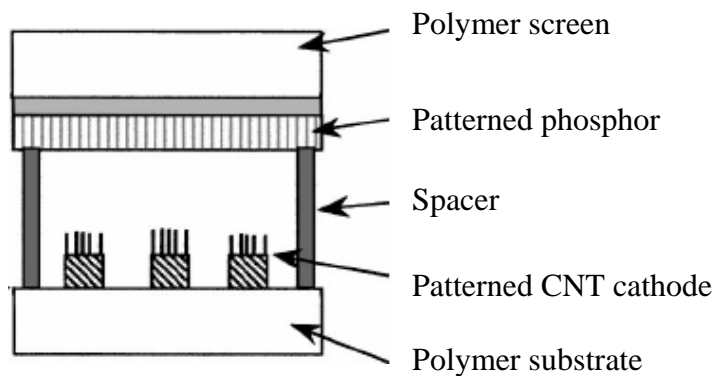


Figure 2. Schematic of flexible CNT display.

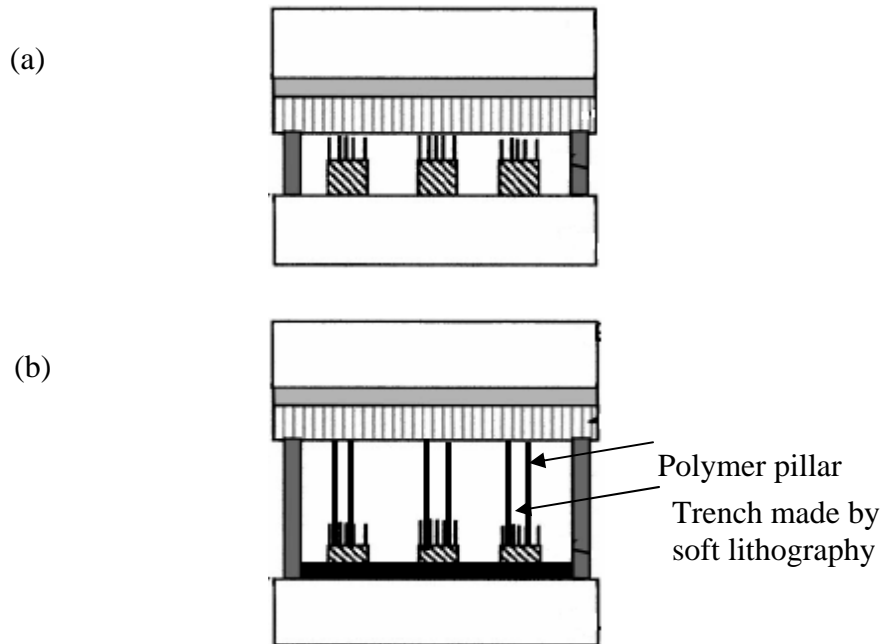


Figure 3. (a) Cathode and anode contact each other. Electrons emitted out from CNTs directly on phosphor screen. (b) Trenches and pillars are made by soft lithography, and then the CNTs are grown in the trenches. And so the whole structure is uniformly supported pillars.

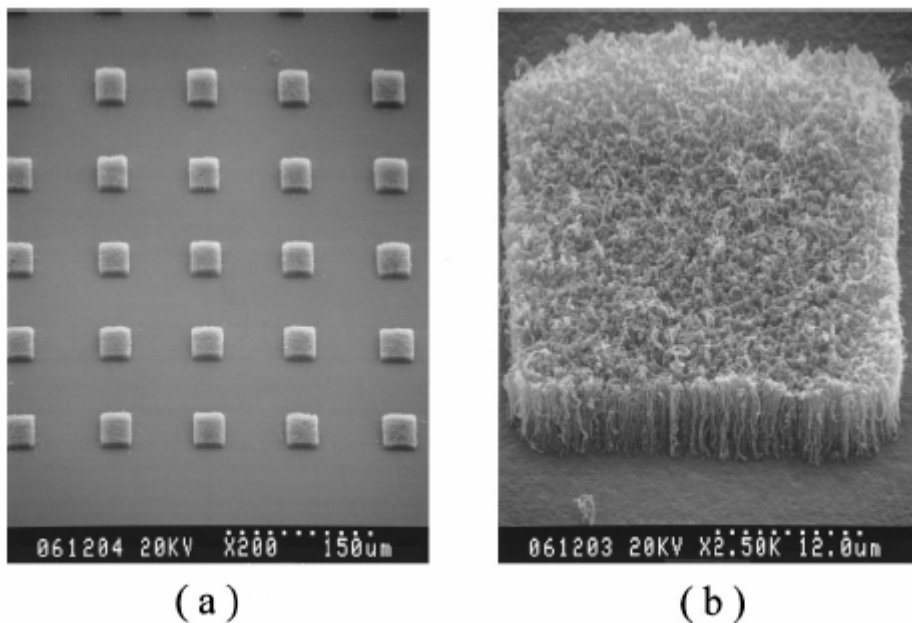


Figure 4. SEM micrographs of self-oriented and well-aligned carbon nanotubes grown on patterned Fe thin film-coated Si substrates. (a) On the left hand side, SEM image of carbon nanotube blocks grown on 30 mm by 30 mm Fe catalyst pattern at a pitch distance of 125 μm . (b) On the right-hand side the SEM image shows that carbon nanotubes in a block are well aligned to the direction perpendicular to the substrate surface. (ref.13)

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