FIELD EMITTER ARRAYS APPLIED TO VACUUM FLUORESCENT DISPLAY

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ABSTRACT

In this paper we describe recent progress in the development of a thin vacuum-fluorescent display utilizing a matrix-addressable array of groups of Spindt-type field-emission cathodes^{1,2}. The array consists of a matrix having 100 lines/inch in one direction and 300 lines/inch in the other. Each picture element (pixel) in the matrix is made up of an array of emitter tips sharing a common, individually addressable base electrode (one of the 100 lines) and three separately addressable control or gate electrodes in the orthogonal direction (one for each of the basic colors: red, green, blue). Each color element has about 100 emitter tips. The current emitted from the array is averaged over the 100 tips, and good uniformity of emission from color element to color element and pixel to pixel can be obtained, because of the averaging effect.

The phosphors used are standard phosphors developed for the cathode-ray-tube (CRT) industry. They are deposited on a glass faceplate that has been coated with a transparent conductor, indium-tin oxide (ITO), and are lithographed into thin lines of alternating red, green, and blue to correspond with the width and spacing of the three color gate electrodes on the cathode matrix. The phosphor lines on the faceplate are aligned with the gate electrodes, and spaced 100 μm from the cathode matrix by miniature pillars that are placed at the four corners of each pixel. The pillars are 50- μm square and 100- μm tall, and are spaced at 0.010-inch centers; with this geometry, the pillars are in sufficient numbers to support the load generated by atmospheric pressure on the wafer and faceplate, and the spacing between the cathode arrays and the phosphor-coated faceplate is sufficiently close that proximity focusing of the emitted electrons can be used effectively.

In the present state of development, we are able to fabricate arrays of full-color pixels in a 3.38-inch-square array with 100-pixels/inch resolution on a 5-inch-diameter silicon wafer. The wafer is thermally oxidized so that the matrix array of cathodes is isolated electrically from the wafer. At present, the oxidized silicon wafer is merely a clean, flat, and smooth substrate. However, it is obvious that it will be advantageous to have the portion of the wafer not occupied by the matrix available eventually for drive electronics and logic circuitry. To test the concept, a phosphor-coated faceplate with a pumpout tube attached was carefully aligned with and bonded to a 3.38-inch-square cathode matrix on a 5-inch-diameter silicon wafer. The faceplate was sealed around the perimeter so that it was vacuum tight and then it was pumped out.

A dc voltage of about +200 V was applied to the ITO layer on the faceplate, a selected emitter line was biased with a negative voltage up to near the threshold of emission (about -75 V), and a small positive voltage (about +20 V) was applied to the gate electrodes to produce a total current of 250 μA of emission to the phosphor (about 2 nA per emitter tip). It is important to note that with this addressing scheme, an entire line is illuminated rather than a single pixel as is the case with a standard CRT. Thus, with 338 pixels in a line (3.38 inches with 100 pixels/inch) we can produce 338 times more brightness than can be achieved with a CRT under the same conditions.

The green phosphor (ZnO:Zn) was uniformly bright along the entire length of the line, and was very visible in white ambient light that diffusely reflects from the phosphor-coated plate with an apparent brightness of 200 fL. The red and blue phosphors were rare-earth oxides, and when deposited and lithographed in this way are much less electrically conductive than the ZnO:Zn. As a result, they were not nearly so bright as the green phosphor, because they required much more than 200 V to overcome the effects of charging. Phosphor thickness and the selection of binder materials are factors that can be varied to minimize this problem.

When viewed with the unaided eye the green line was uniformly bright along its entire length and surprisingly free of the flicker that one associates with field emission. This is a consequence of the averaging of emission from many emitters, and the close packing of the emitters so that individual emitters cannot be resolved with the unaided eye. When viewed with a microscope, the individual emitters can be observed and an occasional flicker can be seen.

These preliminary results have shown that a high-resolution, three-color high-brightness vacuum fluorescent display based on a matrix-addressable array of Spindt-type field emitters and proximity focusing is feasible. Work will be continuing to improve color uniformity and vacuum processing and to develop driver electronics.

REFERENCES

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2. C.A. Spindt, C.E. Holland, and R.D. Stowell, "Recent Progress in Field Emission Cathode Array Development," *J. de Physique, Colloque*, Compendium C9, Supplement to Vol. 45, No. 12 (December 1984).