Prototype

New MOSFETs Lead to Micro Vacuum Tubes

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Integrated-circuit technology has long since driven vacuum tubes from electronic circuits, but now that same technology is ushering in a new use for the tubes. However, unlike their older counterparts, these new vacuum tubes are constructed on the micron level (one micron is one millionth of a meter), can be integrated up to a density of 107/cm², and operate at voltages that are about one order of magnitude lower than their predecessors. Also, the tubes no longer use thermal cathodes (filaments), but instead use ultra-miniature cold cathodes, called field emitter tips (microtips) and fabricated by IC technology, as a powerful electron source.

This new technology, called vacuum micro-electronics, is expected to produce high-performance vacuum microdevices. Of course, vacuum microelectronics are hardly likely to replace silicon ICs, but they may well bring about an epoch-making change to the cathode-ray tube (CRT), which is still used in TVs and has not changed in principle since its inception. (As most people know, the cathode-ray tube is a vacuum tube in which a beam of electrons is projected on a fluorescent screen to produce a luminous spot at a point on the screen.) Vacuum-microelectronics technology can reduce the size of CRTs to the micro level and integrate them on a glass in numbers equal to the number of pixels (the small, discrete elements that together constitute an image on a television screen). That approach creates a new flat-panel display called a field-emission display (FED), which is thinner, brighter, and consumes less power than liquid-crystal displays (LCDs).

However, to make the FED possible, it is critically important to overcome the drawbacks apparent in conventional microtips such as instability and poor uniformity in emission-current characteristics. Those drawbacks originate in the field-emission mechanism itself and are therefore very difficult to overcome.

That's where a new MOSFET could play a vital role. In 1996, researchers at Japan's Electrotechnical Laboratory (ETL), part of that country's Agency of Industrial Science and Technologies, developed a metal-oxide-semiconductor, field-effect-transistor, structured Si tip (Si-MOSFET tip). In that structure, which is shown in Fig. 1A (for contrast, a conventional Si tip is shown in Fig. 1B), a cone-shaped Si tip doped to n-type is made just on a drain of the MOS-

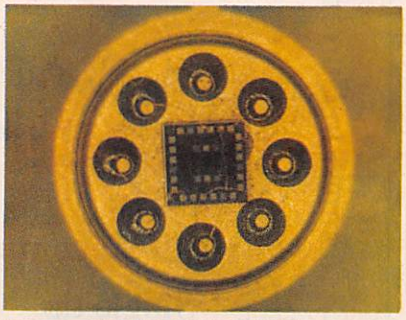


FIG. 2—TO MEASURE THE emission characteristics, the Si-MOSFET tips were mounted on a commercial TO-5 header.

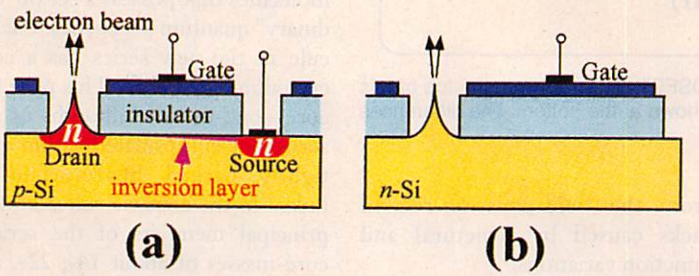
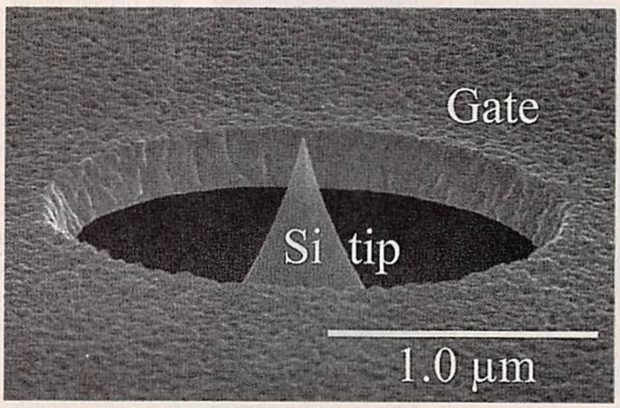


FIG. 1—THE NEWLY DEVELOPED Si-MOSFET tip is shown in A, while a conventional Si tip is shown in B.



HERE'S A LOOK at the new Si-MOSFET gate as seen through an electron microscope.

*Courtesy LOOK JAPAN, August, 1997

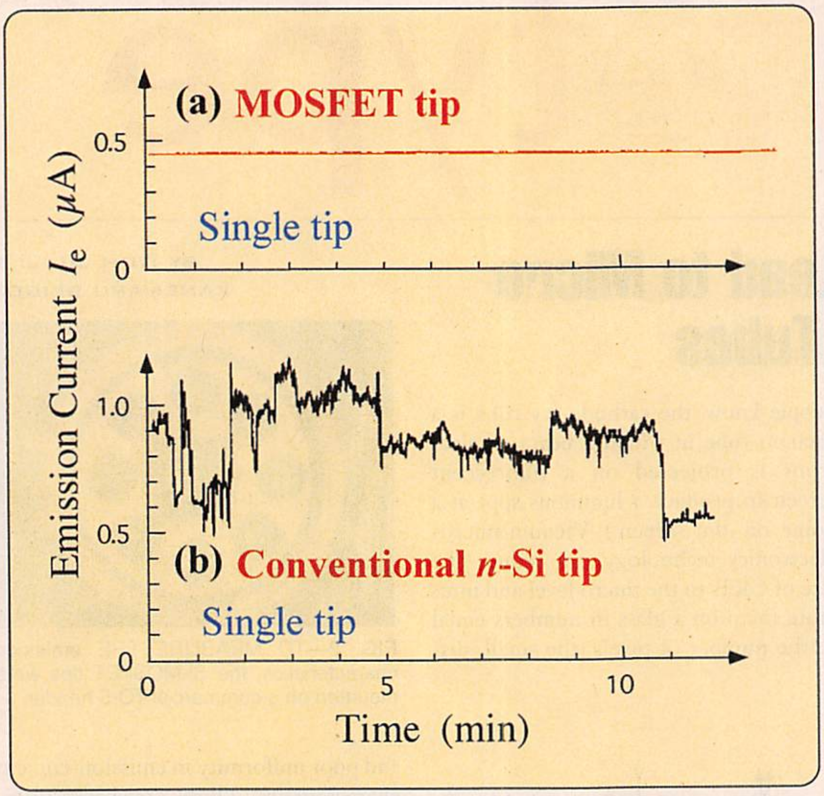


FIG. 3—THE EMISSION CURRENT of the new Si-MOSFET tip is shown at the top of this figure, while the current from a conventional Si tip is shown at the bottom. The differences in the stability are striking.

FET. The gate plays two roles at the same time: one role is that of a conventional extraction gate, the other is that of an FET-gate, controlling the drain current supplied from the source to the tip through the inversion layer (n-channel). Thus the emission current is precisely controlled by the drain current and is free from the field-emission-related drawbacks caused by structural and work-function variations.

To measure emission characteristics, the MOSFET tips were mounted on a commercially available TO-5 header (see Fig. 2), and installed in a UHV (ultra-high vacuum) chamber evacuated to a pressure of 10^{-7} Pa. A glass plate coated with (conductive and transparent) ITO film and phosphor (ZnO:Zn) was placed about 30 mm away from the tip and biased to 2 kV to observe the luminescent pattern.

Emission-current stability of the single tip was measured using an X-T recorder. As shown in Fig. 3, the new MOSFET tip showed excellent current stability compared to that of a conventional n-type Si tip. The cathode luminescent pattern was also very stable (Fig. 4) and did not change for a long period. That effect has not been observed with any conventional microtips, making the MOSFET tip a promising cold cathode for vacuum microdevices such as the FED.

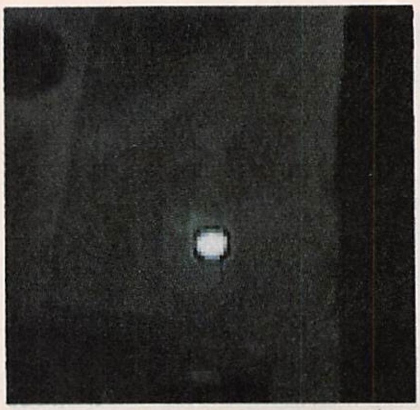


FIG. 4—THE CATHODE LUMINESCENT PATTERN showed excellent stability.

The Si-MOSFET-tip is superior to any other FET-combined tips so far proposed because of its simplicity in structure and ease of fabrication. Those advantages are born of the fact that the gate plays the roles of a conventional extraction gate and of an FET gate controlling the drain current. Based on the above principle, it is possible to extend the basic structure seen back in Fig. 1A to a multi-gate MOSFET structure, which could make low-voltage, flat-panel, field-emission displays possible, and practical. EN

"Extraordinary" Quantum Properties

An interdisciplinary team of researchers at the Georgia Institute of Technology has isolated a new series of highly stable and massive gold-cluster molecules that possess a set of "extraordinary" quantum properties. Each molecule in the new series has a compact, crystalline gold core. This pure metallic core—one-to-two billionths of a meter across—is encapsulated within a shell of tightly packed hydrocarbon chains linked to the core via sulfur atoms. The principal members of the series have core-masses of about 14-, 22-, and 28-thousand protons, which correspond to about 75, 110, and 145 gold atoms, respectively.

Gold is important technically not only for its inertness—once made, the crystals are immune to corrosion—but also for its highly stable surfaces. "The main fascination of very small metal crystals, and the foundation for their envisioned use in future electronics, arises from the fact that their construction electrons are quantized both in their number—charge quantization—and in the states they can occupy—energy quantization," stated Dr. Robert L. Whetten, Professor of Physics and Chemistry at Georgia Tech. "In crystals larger than a few nanometers, these effects can only be observed and used at very low temperatures, such as that of liquid helium, near absolute zero. The new series of nanocrystals are both sufficiently small that these effects are prominent even at ordinary tempera-