On this 60th anniversary of the first issue of EDN, we look back to 1956 when the vacuum tube was at its maturity and transistors were about to begin their domination. The vacuum tube features of fast speeds, virtual distortion immunity and high gains were no match for the higher reliability, smaller size and far lower power dissipation.

NASA Ames Research Center applied for a patent on its gate-insulated vacuum channel transistor. A tiny cavity is etched in phosphorous-doped silicon using standard silicon semiconductor processing. The cavity is bordered by three electrodes, comprised of the familiar source, gate and drain.

The source and drain are separated by 150 nm with the gate atop the pair. When a voltage is applied across the source and drain, electrons flow across the cavity from source to drain and their flow is controlled by the gate. The 150 nm gap allows electron flow without collisions, so that the electron travels and average length of 1 um mean-free path (The distance of an electron hitting a gas molecule) before it will hit anything. The vacuum is the superior medium since there are no scattering with atoms of the semiconductor in a vacuum.

So let’s forget about Moore’s Law size and density limitations and focus upon the benefits of the faster and more efficient device called the vacuum channel transistor. High voltage, high power heating elements are no longer needed in the small vacuum gap spacing which enable electrons to be emitted across only by the power of the applied electric field.

Let’s compare the conventional MOSFET to the vacuum channel transistor. See Figure 1.
Figure 1: The representation of (a) a conventional MOSFET on a bulk substrate, and (b) a back-gated vacuum channel transistor on a Silicon-on-insulator (SOI) substrate. (Image courtesy of Reference 1)

The physics behind the vacuum tube is done with Fowler-Nordheim (FN) tunneling, a form of quantum tunneling. Future design improvements in gap size and cathode geometry may lead to terahertz frequencies. Amazing. The NY Times also has a recent article on this regarding CalTech efforts in this area.

Please share your thoughts and comments with our audience.

References

1. Nanoscale Vacuum Channel Transistor, Jin-Woo Han and M. Meyyappan, Center for Nanotechnology, NASA Ames Research Center, IEEE Conference on Nanotechnology, August 2014
Also see:

- EDN's 60th Anniversary Collection
- Fleming patents vacuum tube, November 16, 1904
- Obtain a gain of 450 from one vacuum tube