Carbon Nanotube Vacuum Field Emission Transistor Design for Large-Scale Manufacturing

Background

The global semiconductor market, which includes transistors among other components, was valued at $418 billion in 2018 and is projected to reach $575 billion by the end of 2022. The use of carbon nanotubes in next generation transistors is also on the rise. Over the same time period, the global carbon nanotube market is expected to increase from $4.5 billion in 2018 to $8.4 billion in 2022.

Most present-day electronics are made with solid-state transistors constructed of semiconducting materials, such as silicon. This solid-state technology largely replaced the prior use of vacuum tubes in electrical applications because of advantages in size, reliability, ruggedness, power consumption and cost. However certain specialized vacuum tubes are still used for applications where a high frequency needs to be generated at a high power. X-ray generators, microwave ovens, satellites and radio stations all use specialized tubes. The continued need for these applications and the advent of nanotechnology have led to advances in miniaturizing vacuum tubes to create vacuum field emission transistors (VFETs). However, the ability to manufacture VFETs on a large scale remains a significant obstacle to their widespread adoption.

Research and Development Status

Inventors from the Department of Engineering Physics at the University of Wisconsin-Platteville have created novel transistors by incorporating etched carbon nanotubes into a planar design that is compatible with existing fabrication techniques. In previous studies by others, aligned carbon nanotube transistors have been demonstrated to achieve saturation current that is 1.9 times higher (at an equivalent charge density) than those that are silicon-based. In the optimal embodiment of this invention, carbon nanotubes are aligned and feature precise gaps that act as channels to allow the efficient transport of electrons without the need for a vacuum. The anticipated output of this approach will be nanoscale transistors that resist heat and radiation and operate at low voltage and high frequency.

To address current challenges with large-scale VFET manufacturing, this technology offers three advantages – the carbon nanotubes can be prefabricated using methods that are already in place, the selective etching process for creating electron channels uses conventional integrated circuit techniques, and the planar design can integrate with existing wafer-based manufacturing methods.

An experimental VFET using this technology has been fabricated, and collection of electrical measurement data is in progress. Steps toward refining the fabrication process and creating a functional prototype are underway.

Applications

- Semiconductors and transistors
- Aerospace/satellites
- Military
- Medical sensing
- Diagnostics
- Telecommunications
- High frequency and high-power applications

Key Benefits

- Nanoscale technology allows transistors to be made smaller
- Higher switching speed transistor due to vacuum electron medium
- Less susceptible to radiation than solid-state technology
- Heat resistant allowing operation at higher temperatures
- High frequency operation (terahertz)
- Ease of fabrication – compatible with wafer-based techniques currently used for semiconductor electronics

Intellectual Property

A U.S. patent application is pending for this technology. For more information, please contact Jennifer Souter at jennifer@wisys.org or by phone at 608-316-4131.

Development and Commercialization Needs:

WiSys is currently seeking strategic partners in the next generation transistor industry that are interested in further optimizing the design for large-scale manufacturing, ultimately providing a path to market for its commercialization.