Electron Impact Ionization and Field Ionization of Gas through Double-gated, Isolated, Vertically Aligned Carbon Nanofiber Arrays

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The goal of this project is to fabricate double-gated carbon nanofiber field emission and field ionization arrays, which can be utilized as an ionizer in a micro gas sensor. This device can help reduce the power consumption and the size of the conventional gas sensor. To achieve this goal, the double-gated isolated VACNF device is designed so that the electric field is maximized at the tip and the shielding effect from the neighbor is minimized while it is capable of handling a large breakdown voltage during the field emission and field ionization operations. Using a photoresist-based fabrication process, two types of devices were fabricated: (1) CNF with tip in-plane with the gate and (2) CNF with tip 0.9µm below the gate. Both devices have the following physical characteristics: (a) The tip height is about 4µm, (b) the gate diameter is 1.7µm, and (c) the focus diameter is 4.2µm. Figure 1 shows a scanning electron microscope (SEM) picture of a complete double-gated isolated vertically aligned carbon nanofiber (VACNF) array with tip 0.9µm below the gate.

Using the device shown in Figure 1, electron impact ionization and field ionization methods of ionizing gas molecules were performed. The electron impact ionization uses a strong electric field to emit electrons followed by collisions between the energetic electrons and neutral gas molecules, resulting in ionization. A linear relationship was obtained between the chamber pressure and the ratio of the ion current and the electron current, as shown in Figure 2. The field ionization is a gentler process in comparison to electron impact ionization. Instead of electrons tunneling from the tip to the vacuum under a high field (as in field emission), in field ionization, electrons tunnel from the gas molecules into the tip, thereby ionizing the gas molecules. It results in molecular ionization and a simpler mass spectrum due to less fragmentation of molecules.

Δ Figure 1: An SEM picture of a complete isolated VACNF array with tip 0.9µm below the gate.

Δ Figure 2: The linear relationship between the pressure and the ratio of the ion current and the emission current in electron impact ionization.