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Carbon Nanotube-Based Schottky Diodes for High-Frequency Applications

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Both multi-walled nanotubes (MWNTs) and single-walled nanotubes (SWNTs) are being employed in the development of high-frequency (tens of GHz to a few THz) sensors and sources. For sources, vacuum micro-tube oscillators and amplifiers are being developed using arrays of MWNT bundles as high-current-density electron sources, and for sensors, detectors are being developed using high cut-off frequency SWNT-Schottky diodes.

In the CNT-Schottky diode development, we have produced devices with Pt or Pd Ohmic contacts and Ti Schottky contacts using angled evaporation technique. The devices demonstrate rectifying behavior with large reverse bias breakdown voltages of greater than -15 V. These devices inherently exhibit high series resistances, in the order of hundreds of kOhms, which are believed to be arising from the contact pads. In order to employ these devices in high frequency circuits it is imperative that the series resistance is brought down to enable matching circuit development. We are using both multi-tube device approach as well as annealing technique to achieve this decrease. In the first approach multiple SWNTs are grown in parallel in a single device, and the metallic tubes are burnt-out selectively. In the latter, the devices are rapidly annealed in inert gas atmosphere inside a tube furnace. The recent devices have shown ideality factors in the range of 1.3 to 1.5 at low biases, which constitutes their operating range, but we still face significantly high series resistance. We have noticed that prolonged storage deteriorates these devices. Again, annealing was seen to restore/improve the device performance. Modeling of these diodes as direct detectors at room temperature at 2.5 terahertz (THz) frequency indicates noise equivalent powers (NEP) potentially comparable to that of the state-of-the-art gallium arsenide sold-state Schottky diodes, in the range of 1E-13 W/rt.Hz. Details of these results, alternate device fabrication schemes, and high frequency detection performance will be presented.