Submillimeter and terahertz sources based on Carbon Nanotubes

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Abstract:

Advances in manufacturing technology for microstructures are allowing new opportunities for vacuum electron devices producing radio-frequency radiation. Specifically, the capability to produce small circuit structures is allowing development of RF devices at frequencies impractical with traditional machining technology. This is generating increased interest in applications in the submillimeter and terahertz frequency range. High-power RF devices in this frequency range are needed for medical, communications, defence, and homeland security applications. Applications of THz radiation include measurement systems (network analysis, imaging), biological and medical applications (cell characterisation, thermal and spectral mapping), material characterisation (near-field probing, food industry quality control, pharmaceutical quality control)

The submillimeter and terahertz regions are areas where electron mobility in semiconductors cannot meet the specifications, but electrons travelling in vacuum can, assuming the electric can be shaped to modulate the beams and convert their energy to RF power.

Modern micro and nano-technologies can, however, overcome the typical severe limitations of vacuum tube devices, namely the difficult scalability of the device an the intrinsic low reliability and life-time.

Field emission array (FEA) cathodes offer significant advantages for high-frequency RF sources. FEAs may be produced lithographically (spindl cathodes) and have demonstrated emission current densities well in excess of 500 A/cm2 in laboratory environments for small arrays.

The spindl structure can be further improved by considering Carbon Nanotube as cold cathode emitters. Carbon nanotubes (CNTs) are perfectly graphetized, helical tubes that can be produced with diameters ranging from about 2 to 100 nm and lengths of several microns using different production methods. Threshold field, for aligned CNTs, is one order smaller with respect to the silicon one. Because carbon nanotubes are mechanically extremely strong and have good chemical stability, CNT cathodes are expected to have longer lifetimes and be less susceptible to ion damage than emitters made of conventional materials.

The first part of this talk presents a survey on the designs, realizations and characterizations of compact, inexpensive, low voltage novel vacuum electronic submillimeter and terahertz sources based on the integration of microtecnologies with nanometric objects such as Carbon Nanotubes. We then present the detailed description of the realization and characterization of field emitting devices obtained from the

selective ordered growth of SWCNTs on suitable substrates. We first realized reference samples by mean of lithographically defined pads on conductive Silicon substrate. Several characterization techniques have been used to check the SWCNT growth, namely scanning electron microscopy and Raman spectroscopy. On these reference samples, we also performed field emission measurements. Moreover, we investigate the realization of a prototypal nanotriode made with a layered structure in which every contact is separated through an insulating layer and obtained by means of a photolithographical procedure. Current characteristics of the nanotriode will be shown.