Chapter I

Introduction

Field emission electron sources require much less energy than thermionic sources since no heat is needed to emit electrons from a cathode surface. Arrays of carbon fibers with are 1-10 μm in diameter have proven to be very useful for electron emission. Micron sized fibers require less stringent vacuum conditions than thermionic emitters but applications have been limited due to poor reproducibility and rapid deterioration of the tip. An image of micron sized fiber are shown below[2]. Over the past decade, many research groups throughout the world

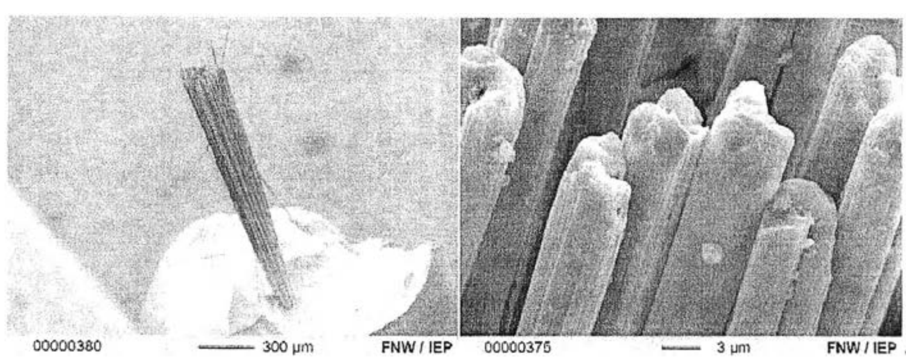

Figure 1.1: SEM image of a carbon fiber field emitter[2].

have shown that carbon nanotubes (CNTs) are excellent candidates for electron emission. CNTs are very practical for field emitters since they have high aspect ratios, small radius of curvature at their tips, high chemical stability, and high mechanical strength[3]. Furthermore, carbon nanotube emitters stably operate at moderate vacuum conditions. A cathode ray tube (CRT) lighting element is shown below where the conventional thermionic cathodes are replaced with CNT field emitters[4]. Field-emission carbon nanotube devices are among the first

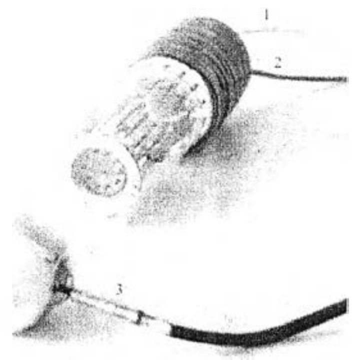

Figure 1.2: Field emission carbon nanotube device.

commercial applications of nanotechnology. The image below shows a selectively patterned carbon nanotube array for flat panal displays.

Carbon nanotubes can have diameters ranging from 1-100 nm and can have lengths of several microns. Although the emission of current through a nanotube is constrained because of its very small cross sectional area, the nanotubes can be arranged into an array allowing an unprecedented amount of current to pass through it. Carbon nanotube alignment is extremely important if high field emission currents are needed at low voltages. The nanotubes must be aligned in such a way that they are oriented perpendicular to the surface or substrate from which the voltage comes from. Since the geometry of carbon nanotubes can range greatly as shown below[3], the field emission characteristics can also have tremendous variation.

Field emission involves the extraction of electrons from a solid by tunneling through the surface potential barrier[5],[6]. The emission characteristics of CNTs can be determined by measuring the current collected on a phosphor screen positioned several millimeters away from the CNTs. A typical current versus voltage curve (shown below) can be compared with the Fowler-Nordheim equation for field emission that says $I = aE^2exp(-b/E)$ where a and b are constants that depend on

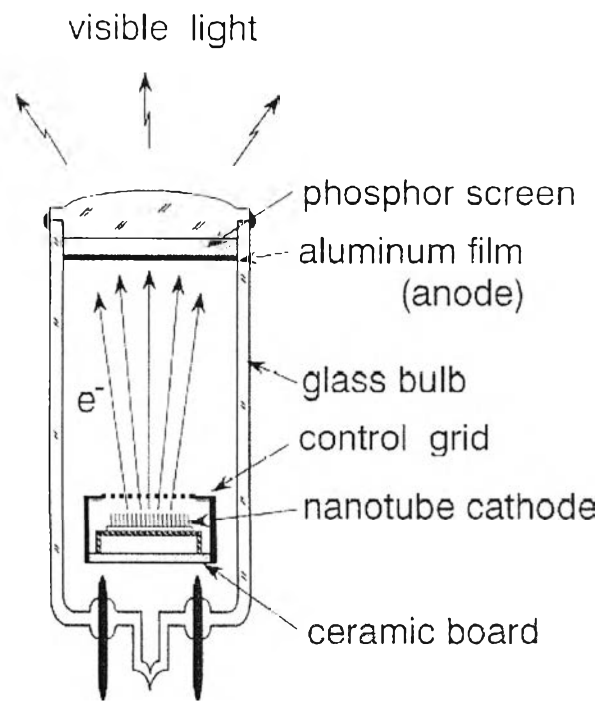

Figure 1.3: Schematic view of field emission carbon nanotube device.

the electronic work function of the surface and only slightly on the electric-field strength at the emitting surface[7]. E is the electric field defined as $E = \gamma E_o$, where $E_o = V/d$ is the average uniform field, V is the applied voltage d is the distance from the nanotube surface to the grid(see Fig. 1.3). The sharp tips and the geometry of the emitting surface cause the electric fields at the tips to be amplified by a factor γ compared with E_o.