Abstract

Traveling-wave Tube (TWT) has been widely used in satellite applications due to its high bandwidth, capabilities in high frequency operation, and high thermal tolerance. In the miniaturization of TWT, Planar Helix-Slow Wave Structure (PH-SWS) has been proposed, which can be fabricated using Silicon-based microfabrication techniques. To utilize this PH-SWS in TWT, a miniaturized, high current density field emitter is needed for its operation in TWT. Carbon Nanotubes (CNTs) has been proposed as a promising field emitting material. In this study, the main objective is to design fabricate a miniaturized, high current density field emitter which is capable of delivering signal gain of ~20 dB in PH-SWS TWT.

First, simulation study is carried out on the effect of electron beam current to the signal amplification performance of PH-SWS TWT. The simulation is carried out using CST STUDIO SUITE. From the simulation, it is found that the signal gain of TWT increases when the electron beam current increases from 2 to 25 mA. To achieve signal gain above 20 dB, electron beam current of > 6 mA, or current density of > 0.8 A/cm^2 rectangular emitting area is needed. from 1250x600 μm rectangular emitting area is needed.

After obtaining the required FE current density, it is important to select the most suitable technique to synthesize high FE current density CNTs. CNTs are grown using two approaches: plasma enhanced chemical vapor deposition (PECVD) and thermal chemical vapor deposition (TCVD). For TCVD technique, two types of catalyst sources are attempted, pre-deposited catalyst and floating catalyst sources. Among the investigated growth technique, it is found that floating catalyst TCVD technique yields higher FE current density due to the high field enhancement on CNT tips.

To reduce the inter-tube screening effect, CNTs can be grown separated islands by means of photolithography technique. However, CNTs growth using floating catalyst CVD technique is non-selective, which is challenging to grow CNTs in separated islands using such CVD technique. To grow CNTs in separated islands, CNTs are grown on Si and SiO_2 surfaces at growth temperatures from 760 to 880 °C. Selective growth of CNTs on Si is achieved at growth temperature of 790 °C.

By using the obtained selective growth condition, array of CNT bundles is grown on Si/SiO_2 structure, obtaining FE current density of ~ 90 mA/cm^2. However, it is found that CNTs possess random alignment at the obtained selective growth condition of 790 °C, reducing the field enhancement on CNT bundles. To improve the FE current density, CNT bundles are confined in pre-fabricated SiO_2 pits to retain its geometrical shape. From the FE measurement, CNT bundles confined in 2 μm and 0.5 μm diameters pits achieve FE current density of > 333.33 mA/cm^2 and > 1 A/cm^2, respectively. The obtained current density of > 1 A/cm2 can be speculated to achieve the research objective of > 20 dB signal gain in PH-SWS TWT, as simulated earlier.