Applied nanotechnology in space:

Proposal for DTU cube-sat Payload with Carbon Nanotube and Nanowire Based Devices.

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Introduction

An electron emitter can be used to maintain charge neutrality of a satellite and also actively control the satellite orbit if a tether is connected to the satellite. For tether experiments, the electron emitter actively charges up the satellite and the tether will attract and pick up charges from the ionosphere to generate a current in the tether and hence a force on the tether as it moves through the earth's magnetic field. This proposal aims at testing an effective nanotechnology-based electron emitter in space.

To date, electron emitters have normally been rather bulky and power consuming device of the hot-filament style used in TVs. But nanotechnology offers new and promising possibilities for making small chips with high efficiency electron emitters based on field emission from carbon nanotubes (CNT) and semiconducting nanowires (NW).

Field emission electron guns (FEG) devices consist of a nanoscale tip with a nearby anode. When a sufficiently high positive voltage is applied to the anode relative to the tip, electron can tunnel out from the tip and generate a well defined electron beam without the need for heated filaments or other large and power consuming elements.

The nanointegration group at MIC, DTU, has ongoing collaborations with the Nanotube group at Cambridge University, and the Nanometer Consortium at Lund university with the aim of integrating nanotubes and nanowires into standard silicon based microelectronic systems. Field emission devices is an obvious application of the developed technology – and the Nanotube group at Cambridge is pursuing this line of research intensively with several spectacular results [1,2]. Figure 1 shows a carbon nanotube FEG device from Cambridge.

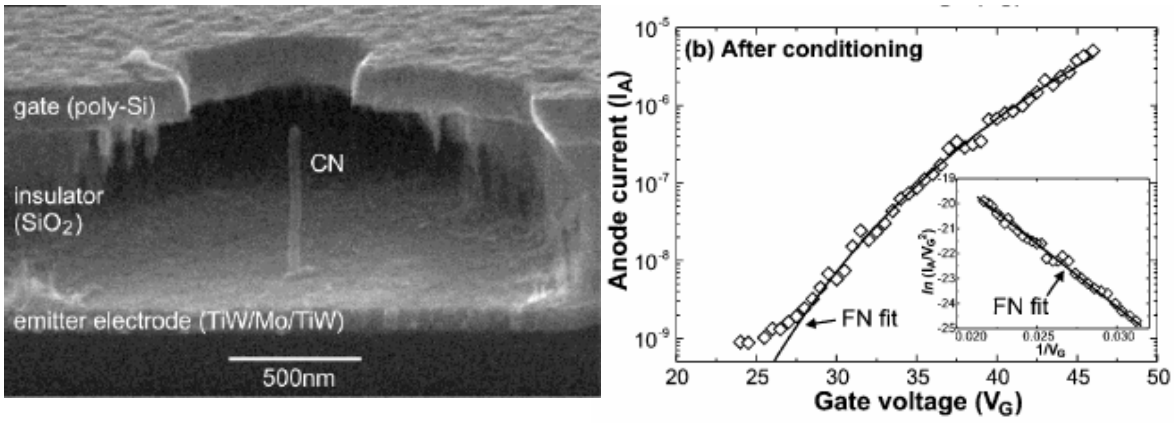

Fig. 1 CNT field emitter and its emission characteristics from [1]

These devices already could be interesting to test in a real space application. To do so, a voltage source capable of supplying up to 50 V seems to de ideal, but sources as low as 30V could provide emission.

The satellite power supply is about 3.3V and low current dc-dc up-conversion chips are available, such as the texas instruments TPS61040/41 with 1.8 V to 6 V input voltage range and adjustable output voltage range up to 28V.

Further search for DC-DC converters and the ongoing work on optimizing the CNT FEG should provide a very compact FEG unit for the cubesat, consisting of the emitter chip glued to the top of the tiny DC-DC converter, which is available as a surface mounted 5 pin chip. To measure the current from the device a voltage-current amplifier such as the Burr-Brown OPA129, another similarly small chip, could be added (would require two separate DC-DC converters for a +/- 10V supply), and the satellite would then be able to control the gate voltage and measure the emitted current from the cathode if it has a digital-analog and analog-digital converter (DAC and ADC), which is likely to be part of the mission anyway for controlling other units in the satellite.

Ideally the entire FEG unit will take up about a few square centimeters on a printed circuit board and require connection to the ~3.3V supply, DAC and ADC from the cubesat. The weight will be minimal - five surface mounted chips and a few discrete electronic components (a couple of resistors and small capacitances pr chip, and three sets of diodes+10µH inductors for the DC-DC converters). The FEG unit does not have to run continuously, but can be turned on and off at will. The power consumption during emission should be low, as the DC-DC converter has an efficiency of more than 75%.

In the coming months we are going to test other types of field emitters as well, made from both carbon nanotubes and nanowires. It is our hope that these will be even better than the existing devices.

Project plan

1. Make a student project about realizing the FEG.
2. Analyze the specific requirements for a satellite FEG – requirements on the emitted electron energy and current, stability etc.
3. Test preliminary CNT and NW devices in order to compare the performance of CNT and NW for the space environment.
4. Choose the best device and make FEG units for extensive testing of the system.
5. Write software interface and integrate the unit in the cube sat design.

- Beside the main FEG project goal, we will look into the possibility of integrating nanodevices into other parts of the satellite, such as the cold cathode microwave devices [2].

Outlook

This first simple application of devices with integrated nanotubes or nanowires, should attract some attention as one, if not the very first, flying application of nanotechnology in space. Apart from the FEG, we will also investigate the possibilities for using other devices made in our groups, such as the microwave diodes based on carbon nanotube emitters made by Ken Teo [2].

Conclusion

A simple and compact electron emitter unit based on already existing carbon nanotube devices seems to be a feasible experiment to carry on to the cubesat with very limited space, weight and power requirements.
Further development of the underlying nanotechnology-based devices is ongoing, and should help achieving an even better performance of the device before the expected launch.

References

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[2] "Microwave Devices: Carbon Nanotubes as Cold Cathodes"
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