EPSRC Centre for innovative manufacturing in ultra precision

www.ultraprecision.org
www.cdt-up.eng.cam.ac.uk

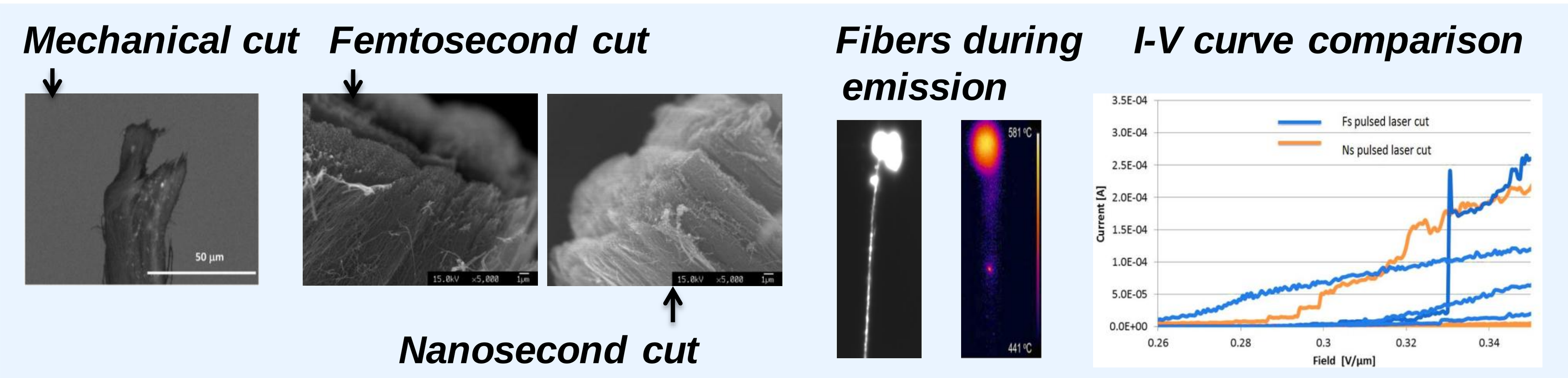
Laser Processing of Carbon Nanotube Fibres and Films

BACKGROUND

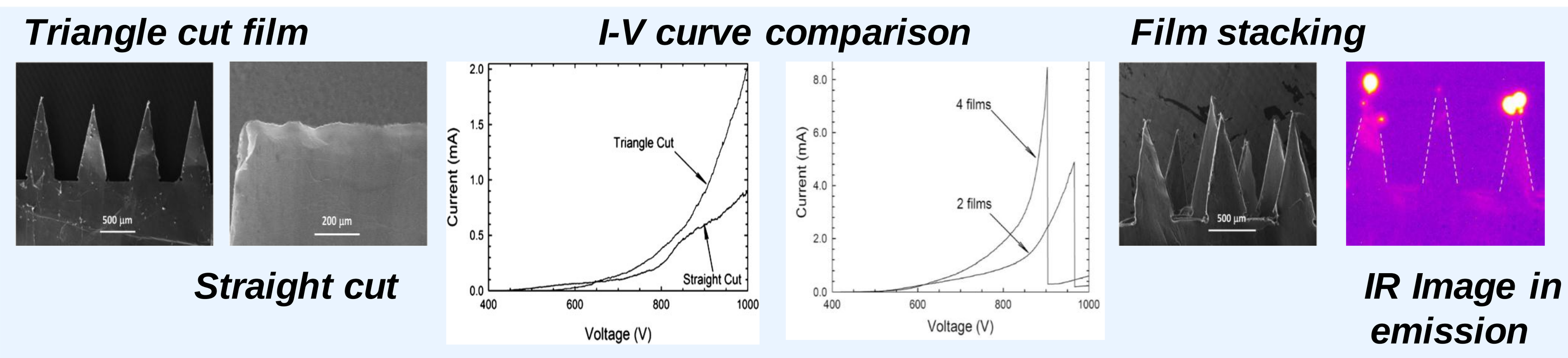
Thermionic cathodes operate at high temperatures often giving inefficient power utilisation, poor reliability and a reduced lifetime. The need for device thermal management adds to the complexity and weight of these devices. Field emission (FE) of electrons occurs when a high electric field is applied to a substrate by the quantum mechanical tunnelling effect. Efficient generation of FE requires sharp geometries as electric fields concentrate at these points. Carbon nanotubes (CNT) are rugged, chemically inert, have high geometric aspect and high current carrying capacities. These properties coupled with large scale fabrication capabilities offer a technology that has significant application potential for the creation of a new generation of field emission cathodes.

WORK TO DATE

Single emitters have been cut mechanically and using two laser sources. The lasers were used to reduce damage on the CNT and have control over the geometry of cut with the aim of improving emission. Lower turn on voltages have been observed using a femtosecond laser but it must be statistically validated. Temperature control has been identified of importance due to destructive failure seen in some samples at high temperatures.



Comparative emission trials between straight and triangular geometries on films has been carried out. Stacks of triangular films gave the highest emission, up to 7.6mA, with temperatures at the tip being below 840° C.



FUTURE WORK

Work proposed will investigate the use of laser processing as a potential manufacturing route for the production of arrays using CNT as base material. Previous work identified key areas required for the development of this technology.

1) Source material: fibres and film have substantial variation in geometry and thickness (typically 30 to 50 µm) making comparative trials challenging.

2) Handing challenges: position is affected by small environmental changes (e.g. wind, electrical charge) making repeatable construction of emitters for testing problematic.

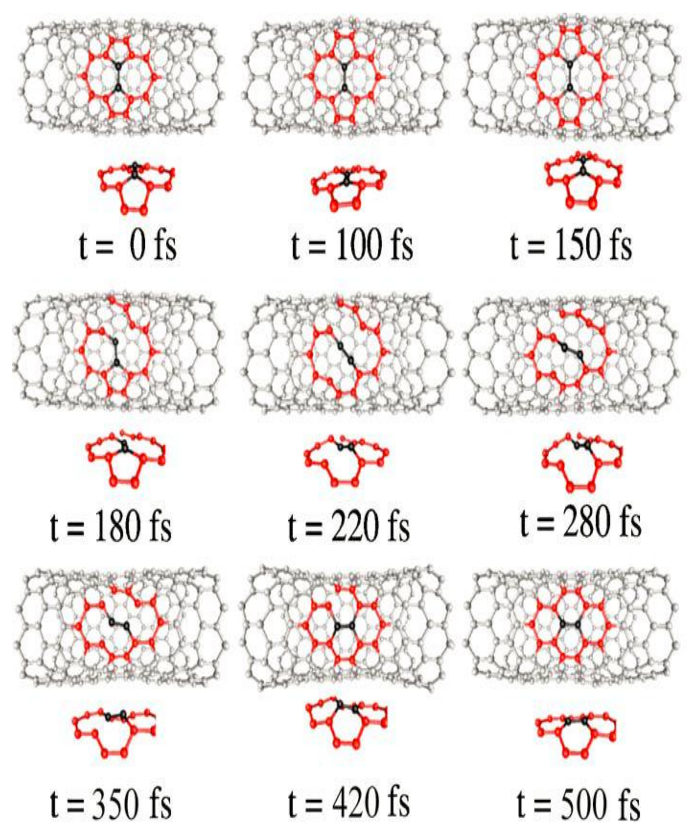
These two problems are driving the implementation of a statistical experimental design if meaningful results are to be obtained.

3) Laser-matter interaction: the hypothesis is that the interaction can be used to tailor material properties e.g. low turn-on voltage.

4) Geometric optimization: emission points are critical for FE. Literature states that a change of 4% in CNT height, length and spacing creates a dispersion in field enhancement factor which affects the emission. A design that gives distance optimization and accurate alignment between these points with thermal control will be required.

5) Manufacturability: it is essential that the final devices (single and large area) are designed in such a way that they can be mass produced as rugged reliable cathodes.

The understanding of laser-matter interaction is vital for this project. In work reported by Valencia et al. demonstrated defects can be removed using a laser. The image to the right shows the formation of a pentagon shape bond (top and bottom red structures) attached to a heptagon shape bond (left and right red structures). Reversible bond breaking is present and it enables a correction of defects. Further development of this technique and its application to FE has potential. The ability to change and tailor CNT properties could mean an improvement without adding other elements.



Rotated dimer (black) after interaction with a Gaussian shaped laser pulse (50fs). Taken from Valencia 2006

References:
Valencia, F., Romero, A. H., Jeschke, H. O., & Garcia, M. E. (2006). Large-amplitude coherent phonons and inverse Stone-Wales transitions in graphitic systems with defects interacting with ultrashort laser pulses. Physical Review B, 74(7), 075409. doi:10.1103/PhysRevB.74.075409

ACHIEVEMENTS

A paper has been published in the Journal of Materials Research in a Focus Issue called “Graphene and Beyond”, one of the images featured in this work was taken as cover for this edition.

Acknowledgement: I would like to thank the CONACY and EPSRC for funding my studies. Effort sponsored by the Air Force Office of Scientific Research, Air Force Material Command, USAF, under grant number FA9550-14-1-0070. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purpose notwithstanding any copyright notation thereon.

For additional information please contact:

Francisco Orozco
Centre for Industrial Photonics
University of Cambridge
pfo21@cam.ac.uk

info@ultraprecision.org
cip-admin@eng.cam.ac.uk

Cranfield UNIVERSITY
EPSRC Pioneering research and skills
UNIVERSITY OF CAMBRIDGE