Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA20129

Grantee name: Michael Gater

Details of the STSM

Title: Radiation optimised polymer memristor

Start and end date: 16/09/2024 to 05/10/2024

Description of the work carried out during the STSM

Initial electrical characterisation of polymer memristors fabricated at the University of Nottingham was carried out to access their reactance to irradiation. The devices were characterised for some core and application base metrics. A reference characterisation of all device structure's investigated (double barrier PMA PEO) was conducted within the first week. Due to the time constraint and multiple reference characterisation experiments, the study focused on three core thin film polymer structures shown below.

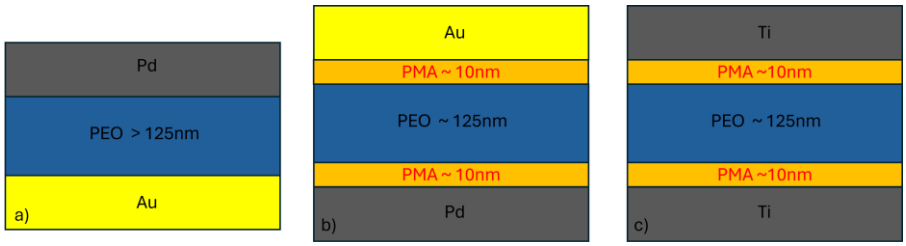

Fig. 1. Shows device structures investigated a) Inert electrode gold-palladium with Pure PEO active layer vertical device (Previous data already obtained for 125nm Pd-Au, layer thickness optimisation is being studied in tandem). b) Inert electrode double PMA barrier device c) Double barrier Ti electrode device.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

The devices we measured by an Agilent (Keysight) B1500A Semiconductor Device Parameter Analyzer, using different electrical characterisation tests (IV , Pulsed Retention , Continuous Pulse Delayed characterisation , Pulsed Endurance) . Standardised IV tests for all devices generally consisted of a voltage sweep from 0 to V_{max} to - V_{max} = { 1 , 1.5 , 2.0 , 2.5 } V . A pulsed retention time test consisted of a single pulse to V_{max} (50ms) and the change in conductance over time was measured. The conductance after any pulse was measured by applying a 50mV bias after the programming pulse for 30 seconds.

Irradiation was done at the facilities of the Son Espases Hospital, with 6 MeV X rays using a Varian linear accelerator, at room temperature and at constant dose rate of 10 rad/s, to a total dose up to 0.75krad measured by the embedded sensors in the Varian linear accelerator. Relative errors in total dose delivered to each sensor were below 1%. Irradiation of the devices will continue up too 1krad as part of the ongoing collaboration and verification of results from the previous stage.

Individual layers of device scale thin films were fabricated on blank glass slides containing no contact electrodes were also irradiated from 0 – 1 krad in order to do material characterisation when back in the UK. This will study will contain XRD , optical/ FT-IR absorption spectroscopy and raman spectroscopy to understand radiation effect on the thin film chemistry.

Description of the STSM main achievements and planned follow-up activities

Summary of STSM success:

The preliminary results of the work carried out point towards a successful STSM and the mission achieving it's expected outcomes, with the modulation of the electronic response as a product of irradiation. These results indicate two open routes as for development, the potential use of the device in personal dosimeters or introduction to the device fabrication process for improved memory applications. The results in the next section point towards a consistent repeatable result from the last STSM and further understanding of the device operation. This clearly fits within the remit of WG1, in the area of radiation sensing and nanofabrication technologies.

An industry collaboration has opened up with IC Malaga based around the devices above and creating of on chip crossbar arrays.

Preliminary Results :

The devices were measured three times: 1) Before irradiation ; 2) 12hrs after 0.25 krad irradiation 3) 12 hours after 0.5 krad irradiation. The measurement process as detail above contained IV sweeps and other characterisation pulse measurements. Results for a specific double barrier device is shown below in Fig. 1 a) (linear scale) and b) log scale, these depict the pre and post irradiation at varying levels. It is clear from the previous STSM that in the case of 1krad irradiation, exposure improved the desirable device characteristics. Notably the device exhibited greater operation current and separation between ON and OFF states; this is an improved hysteresis effect and higher current forces the device to operate in a bipolar manner, compared to a unipolar operation under 1 mA operation.

The 0.25krad device shows a shift in the output current and slight widening of the hysteresis. The device after this low dose continued to exhibit unipolar operation. The 0.5krad irradiation also showed an increase in output current and retained its unipolar operation with a similar ON/OFF ratio.

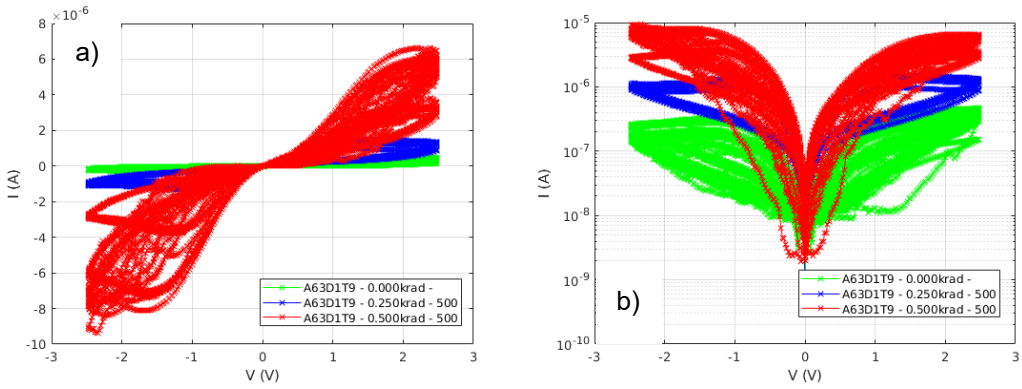

Fig 1. Shows the effects of irradiation on a Ti-TI electrode double barrier PMA physical barrier device. a) Voltage-Current sweep of the device between 2.5 V. b) Voltage-current sweep (log-scale) of same device for repetitive cycles. The conductivity of the device clearly increases with increasing radiation exposure while retaining its characteristic unipolar shape.

Agreed Future work & Publications

A paper based on the last STSM was presented in at the 1st Spanish Memristor Workshop, Barcelona, 1st of July 2024. A conference paper has been accepted for presentation later in the year - 2024 31st IEEE International Conference on Electronics, Circuits and Systems to be held in Nancy, France from November 18-20.

The work will continue so we can publish into high quality journals based on the work conducted in the second STSM.