**UNIVERSITY of the WESTERN CAPE**

# University of Missouri-University of the Western Cape Academic Exchange Program 2016 Report

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**University of the Western Cape**
**Host: Prof Suchi Guha**

**Host Institution: Department of Physics and Astronomy,**
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## Objective of visit

The objective of the research visit was to initiate collaborative research on hybrid organic-inorganic electronic devices. The overall thrust of our research group at the University of the Western Cape is to integrate nanostructures of inorganic materials such as silicon and metal oxides to produce photoactive material for its application into photovoltaic devices. In conjunction with this activity the integration of nanostructures of metal oxides into organic photoactive materials is pursued to exploit the advantages of the availability of nano-sized domains for effective charge transport in hybrid organic-inorganic photovoltaic devices. The overall aim is to contribute towards the realization of cost effective, flexible substrate devices with reasonable efficiencies for everyday use.

Specific objectives for the research visit were to:

(a) synthesize inorganic zinc-oxide (ZnO) and titanium dioxide ($TiO_2$) semiconductor nanoparticles for a comparative study
(b) investigate the structural properties of the metal oxide nanoparticles by means of high resolution electron microscopy and x-ray diffraction techniques
(c) investigate the optical properties of the metal oxide nanoparticles by means optical, vibrational, and photoluminescence spectroscopy
(d) investigate the optical absorption properties of different ratios of poly (3-hexylthiophene) (P3HT), (6,6)-phenyl C61 butyric acid methyl ester (PCBM), metal oxide nanoparticle hybrids for absorption matching purposes
(e) construct device samples, according to standard procedure but taking into account the necessary architecture for spectroscopic measurements, in order to investigate the sub bandgap absorption processes for enhanced understanding of the charge transfer mechanism of the hybrid material

## Objective successes

<u>Metal nanoparticle synthesis and characterization</u>

The first aspect of the exchange visit involved the synthesis and characterization, with electron microscopy, of the $TiO_2$ nanoparticles. This was performed at UWC, after which photoactive hybrids were prepared for the research visit. The photoactive layers were prepared by spin coating a mixture of donor material P3HT, acceptor material PCBM, and inorganic nanoparticles of titanium dioxide or zinc oxide in certain mass ratios. ZnO nanoparticles from a batch that were previously used during a research study by a UWC student was used for this objective as well. The metal oxide nanostructures were intended as additional electron acceptors to complement the PCBM, and thus enhance charge transfer in the hybrid material, ultimately to improve the efficiency of devices prepared from such materials. The efficacy of the addition of ZnO vs $TiO_2$ with regards to pristine blends of P3HT: PCBM only, would thus be investigated via spectroscopic means. UV-vis absorbance measurements were performed at the Physics Department of the University of Missouri, which showed that the incorporation of metal oxide nanoparticles, viz $TiO_2$

and ZnO respectively, did not alter the spectral range over which the photoactive layers absorb light. This is in comparison with pristine P3HT: PCBM. In addition, by measuring the absorbance of the layers that were annealed at normal processing temperatures of devices, no evidence was found of degradation of the optical properties of the material, which negated the need to investigate degradation of the material with other spectroscopic techniques. This concluded the investigation of samples prepared at UWC, which gave valuable insight on the type of hybrid material that was used in some UWC projects, and how the processing conditions may alter the material properties.

<u>Construction and characterization of hybrid devices</u>

The second phase of the research visit involved the construction of hybrid electronic devices, with emphasis on the application of metal oxide nanostructures in solar-cells and photodetectors, which is one of the focus areas in the laboratory of Prof Guha. It is of importance to note that the same types of materials and device structures are used for both hybrid solar cells and photodetectors. During this time device type architecture in the 'inverted' configuration was investigated, where the hole transfer layer is located underneath the metal contact. It has the advantage of being stable to environmental influence, and should theoretically outperform the 'normal' device configuration devices, in which an electron transfer layer is situated underneath the metal contact of the device. Research into this device architecture is still under-represented in literature. Activities in Prof Guha's lab with the aid of Mr Alec Pickett, a PhD candidate, that were investigated during this phase of the visit involved

(a) identification of suitable work function metals for contacts on top of active materials for suitable energy level alignments of transparent conducting oxide, active layer and metal
(b) adoption of P3HT as active material for use as a standard to compare other polymers with
(c) device manufacture, with the express aim of comparing the contribution of nanostructured ZnO thin films on top of the transparent conducting oxide contact, to the device efficiency; here pulsed laser deposited ZnO layers, ZnO nanoridge films for enhanced absorption in the active layer, and ZnO nanoparticles as optical spacer on top of the pulsed laser deposited films were compared
(d) current density-voltage measurements for device efficiency calculations
(e) responsivity measurements for photo detecting plausibility
(f) synthesis of molybdenum trioxide as hole transfer layer, its incorporation in the inverted device structure, and measurements as in (c) and (d) above

Although all devices during these activities did not yield the desired responses, from the exposure in my host's laboratory the need to optimize buffer layers (metal oxide layers for electron or hole transfer) by solution processing for our group's hybrid organic devices has become evident. At the moment we do not possess the relevant vacuum deposition equipment for the deposition of metal oxide thin films, and until we do the solution processing is very much a feasible option to attain devices with some level of electrical response. Two new research projects were identified soon after my return. These involve the use of $TiO_2$ nanostructured thin films as electron transfer layer, and the synthesis of ZnO nanoparticles down to the correct dimensions, and its implementation as optical spacers for enhanced absorption by the active layer. These BSc Honours projects are aimed at continuation into MSc studies in 2017. Successful synthesis of especially the desired dimension ZnO nanoparticles at UWC, and its implementation in devices in Prof Guha's laboratory, is seen as the first step in a continuing collaboration in future. An additional invaluable experience was the opportunity to be participating in experiments that yield information such as the responsivity of the device, which gives insight into the factors influencing the quantum efficiency of the device. These new insights steer current projects on organic-inorganic active materials I am involved in at UWC to a significant extent. Overall, my positive experience in the laboratory of Prof Guha can be attributed to her welcoming me as a contributing team member, with access to all the relevant research equipment in her well-resourced lab.

An academic visit by Prof Guha to our Department at UWC is envisaged in 2017, whereby she will participate in the teaching of the Nanophysics MSc course at UWC, and participate in our research activities as per our research collaboration.

**Value of the UM/UWC Exchange program**

The exchange program has allowed me the opportunity to personally benefit from interaction with staff and students based in a department with state-of-the-art facilities, who perform world-renowned research. I have embarked on research in the organic electronic device field relatively recently, and this exchange offered me the opportunity to learn more about experimental design in this field, which opens up more avenues for potential research, and thus my intellectual development. This will also have significant impact on the research projects of current and prospective research students. If given the opportunity to participate in the exchange again, I would definitely do so and hope that the program can continue well into the future to serve the needs of both UM and UWC.

**Exchange Experience and Acknowledgements**

From the beginning of the application process to the return journey I have experienced nothing but the most courteous and helpful assistance from Prof Uphoff and the Office of the President of UM (Ms Brenda Dennis), and the International Relations Office at UWC, in terms of the planning and the arrangements made. This ensured that I could adapt quickly to the day to day university activities. I therefore did not experience any notable difficulties during the exchange. I gratefully acknowledge the financial support of the UM/UWC Exchange Program. My sincere gratitude to Prof Suchi Guha for hosting me, her husband Prof Carsten Ullrich, Prof Paul Miceli and his wife Martha, for the welcome and hospitality I enjoyed. I also wish to thank the Department of Physics and Astronomy at the Colombia campus for the use of their facilities.