Solar Energy Research in the Engineering Design Research Group

Rami Ghannam

James Watt School of Engineering, University of Glasgow, Glasgow G12 8QQ, UK.
Email Address: rami.ghannam@glasgow.ac.uk

Harnessing the Sun's vast energy into electricity or heat can profoundly transform the economies of countries with transitional economies and enable a more sustainable future. At Glasgow University's Engineering Design (END) Research Group, our research on solar energy systems ranges from large scale energy generation systems to microscale energy harvesters for implantable and wearable electronic applications. The aim of this document is to summarise some of our research activities in this exciting area.

In terms of small scale energy generation, our focus has been on wearable, implantable and portable devices. In fact, implantable and wearable electronic devices can improve the quality of life as well as the life expectancy of many chronically ill patients, provided that certain biological signs can be accurately monitored. To ensure that these devices can truly improve a patient's quality of life, non-obstructive and novel energy harvesting solutions are necessary.

First, we embarked on developing experimentally verified mathematical models to help designers predict the performance of novel solar cell architectures and materials. A selection of our work in this area is available here: [Abdellatif, Ghannam and Khalil 2014; S. Abdellatif et al. 2015; S. O. Abdellatif et al. 2016; Abdellatif, Josten et al. 2018; Abdellatif, Sharifi et al. 2018; Zhao et al. 2018]. Moreover, we proposed a framework for simulating the performance of PV cells in the literature [Zhao et al. 2021].

Next, we began developing improved and optimised energy harvesters for IoT and healthcare devices. An examples of our work in this area is available here: [Zhao et al. 2019; Zhao et al. 2020; Hatem, Elmahgary et al. 2021; Hatem, Ismail et al. 2021]. Furthermore, we investigated how these energy harvesters can form part of an overall power management circuit, as demonstrated here: [Htet et al. 2018].

For large scale energy generation, our work has focused on concentrated photovoltaic systems (CPV). Here, expensive photovoltaic material was replaced with cheap optical concentrated that focus light onto a small PV cell area, resulting in the co-generation of heat and electricity. These systems can also be used to drive membrane desalination systems, as demonstrated here [ElSherbiny et al. 2015; Escher et al. 2010; Müller et al. 2011; Escher et al. 2016]. We have also investigated how this energy can be effectively managed: [Munir et al. 2019].

References

Abdellatif, S, R Ghannam and ASG Khalil. 2014. Simulating the dispersive behavior of semiconductors using the Lorentzian–Drude model for photovoltaic devices. *Applied optics* 53 (15): 3294–3300.

Abdellatif, S, S Josten, P Sharifi, K Kirah, R Ghannam, ASG Khalil, D Erni and F Marlow. 2018. Optical investigation of porous TiO2 in mesostructured solar cells. Paper presented at the Physics and Simulation of Optoelectronic Devices XXVI, vol. 10526, 105260A. International Society for Optics and Photonics.

Abdellatif, S, K Kirah, R Ghannam, ASG Khalil and W Anis. 2015. Enhancing the absorption capabilities of thin-film solar cells using sandwiched light trapping structures. *Applied optics* 54 (17): 5534–5541.

Abdellatif, S, P Sharifi, K Kirah, R Ghannam, ASG Khalil, D Erni and F Marlow. 2018. Refractive index and scattering of porous TiO2 films. *Microporous and Mesoporous Materials* 264:84–91.

Abdellatif, Sameh Osama, Khaled Kirah, Rami Ghannam, Ahmed Khalil and Wagdy Anis. 2016. Modelling various solar cells materials using lorentzian-drude coefficients. *International Journal of Recent Contributions from Engineering, Science and IT* 4 (4): 63–67.

ElSherbiny, Ibrahim MA, Rami Ghannam, Ahmed SG Khalil and Mathias Ulbricht. 2015. Isotropic macroporous polyethersulfone membranes as competitive supports for high performance polyamide desalination membranes. *Journal of Membrane Science* 493:782–793.

Escher, Werner, Rami Ghannam, Ahmed Khalil, Stephan Paredes and Bruno Michel. 2010. Advanced liquid cooling for concentrated photovoltaic electro-thermal co-generation. Paper presented at the 2010 3rd International Conference on Thermal Issues in Emerging Technologies Theory and Applications, 9–17. IEEE.

Escher, Werner, Bruno Michel, Stephan Paredes and Rami Ghannam. 2016. Photovoltaic thermal hybrid systems and method of operation thereof. US Patent 9,437,766.

Hatem, Toka, Maryam G Elmahgary, Rami Ghannam, Mohamed A Ahmed and Sameh O Abdellatif. 2021. Boosting dye-sensitized solar cell efficiency using AgVO3-doped TiO2 active layer. *Journal of Materials Science: Materials in Electronics,* 1–9.

Hatem, Toka, Zahraa Ismail, Maryam G Elmahgary, Rami Ghannam, Mohamed A Ahmed and Sameh O Abdellatif. 2021. Optimization of Organic Meso-Superstructured Solar Cells for Underwater IoT^2 Self-Powered Sensors. *IEEE Transactions on Electron Devices.*

Htet, Kaung Oo, Rami Ghannam, Qammer H Abbasi and Hadi Heidari. 2018. Power management using photovoltaic cells for implantable devices. *IEEE Access* 6:42156–42164.

Müller, M, W Escher, R Ghannam, J Goicochea, B Michel, CL Ong and S Paredes. 2011. Ultra-High-Concentration Photovoltaic-Thermal Systems Based on Microfluidic Chip-Coolers. Paper presented at the AIP Conference Proceedings, 1407:231–234. 1. American Institute of Physics.

Munir, Hafiz Mudassir, Rami Ghannam, Hong Li, Talha Younas, Noorbakhsh Amiri Golilarz, Mannan Hassan and Abubakar Siddique. 2019. Control of distributed generators and direct harmonic voltage controlled active power filters for accurate current sharing and power quality improvement in islanded microgrids. *Inventions* 4 (2): 27.

Zhao, Jinwei, Rami Ghannam, Qammer H Abbasi, Muhammad Imran and Hadi Heidari. 2018. Simulation of photovoltaic cells for implantable sensory applications. Paper presented at the 2018 IEEE SENSORS, 1–4. IEEE.

Zhao, Jinwei, Rami Ghannam, Kaung Oo Htet, Yuchi Liu, Man-kay Law, Vellaisamy AL Roy, Bruno Michel, Muhammad Ali Imran and Hadi Heidari. 2020. Self-Powered Implantable Medical Devices: Photovoltaic Energy Harvesting Review. *Advanced healthcare materials* 9 (17): 2000779.

Zhao, Jinwei, Rami Ghannam, Man-Kay Law, Muhammad Ali Imran and Hadi Heidari. 2019. Photovoltaic power harvesting technologies in biomedical implantable devices considering the optimal location. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology* 4 (2): 148–155.

Zhao, Jinwei, Zengyi Xu, Man-Kay Law, Hadi Heidari, Sameh O Abdellatif, Muhammad Ali Imran and Rami Ghannam. 2021. Simulation of Crystalline Silicon Photovoltaic Cells for Wearable Applications. *IEEE Access* 9:20868–20877.

Rami Ghannam is a Senior lecturer (Associate Professor) in Engineering System Design at the University of Glasgow. He is the director of the Engineering Education Research Group at Glasgow University. He obtained his BEng degree in Electronic Engineering from King's College and was awarded the Siemens Prize. He subsequently received his DIC and MSc degrees from Imperial College London, as well as his PhD from the University of Cambridge in 2007. He held previous industrial positions at Nortel Networks and IBM Research GmbH. He is a Senior Member of the IEEE, a Senior Fellow of Glasgow's RET scheme and serves as Scotland's Regional Chair of the IEEE Education Society.