Attachment Content:

Solar Energy

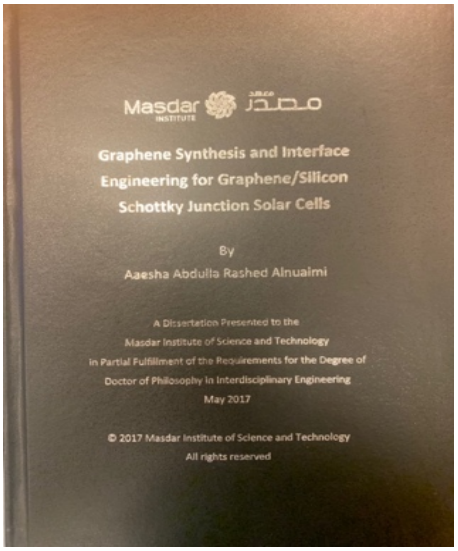
Advanced research works are carried out at Khalifa University by Prof. Ammar Nayfeh and his research team to improve the efficiency of the solar cells efficiency using novel materials as follows:

1. ***Metal and Semiconductor Nanoparticles to Improve Solar Cells***

In this work, the research team studied both metal and semiconductor nanoparticles. They did both semiconductor and metal nano particles. First, plasmonic solar cells were fabricated and the effect of Au nanoparticles on the performance of a-Si:H solar cells was investigated experimentally. In addition, the performance of thin-film amorphous silicon-based n+-i-p+ solar cells in the presence of an exterior top thin film of mono-dispersed ultra-small 2.85 nm diameter silicon nanoparticles has been examined.

2. ***2D materials: Investigation of interfacial layers for graphene/silicon schottky junction solar cells***

Dr. Aaesha Alnuaimi finished her PhD in 2017. Her thesis was on the graphene-Si junction and interface which should behave like a metal/Si junction. To study Gr/Si junction experimentally, graphene was synthesized by chemical vapor deposition (CVD) method and PN junction solar cells fabricated. The effect of metal oxide interfacial layers has also been studied using ALD. The first study has been performed with chemically doped graphene and Al_2O_3 interfacial layer. Engineering the interface with Al_2O_3 resulted in improving the efficiency of Gr/Si solar cell from 3.77% to 8.75%. Subsequent experiments using HfO_2 and ZnO have been carried out with chemical-doping-free graphene layer. The efficiency of the cells improved from 1.77% to 6.91% with HfO_2 and to 6.28% with ZnO interfacial layers. *This work was seminal in Graphene/Si junctions.*


Masdar مصدر
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Graphene Synthesis and Interface Engineering for Graphene/Silicon Schottky Junction Solar Cells

By
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A Dissertation Presented to the
Masdar Institute of Science and Technology
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Interdisciplinary Engineering
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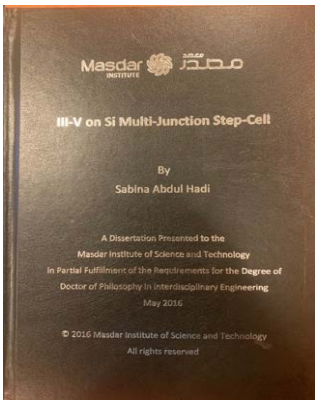
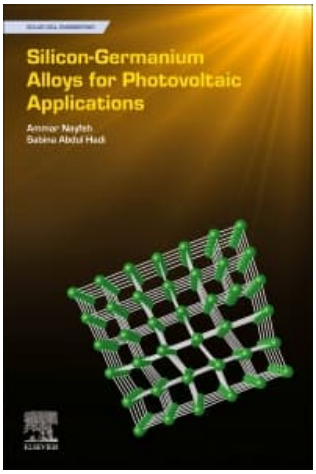
III-V on Si Multi-Junction Step-Cell





Dr. Sabina Abdul Hadi during her PhD worked on the development of III-V on Si multi-junction solar cells. Multi-junction (MJ) solar cells have the highest reported efficiency to date as they utilize solar spectrum more efficiently compared to single junction cells by having vertical stack of solar cells absorbing wider range of optical wavelengths. However, one drawback of MJ solar cells is their high costs, since the materials used in their fabrication involve expensive Ge and/or III-V group materials, most commonly GaAs. In her research, Dr. Abdul Hadi explored 2-terminal III-V / Si MJ solar cells, where top cell is made of $GaAs_{1-x}P_x$ layers grown on inexpensive Si substrates. In such 2-terminal setup, sub-cells are connected in series where the sub-cell with lowest current limits overall MJ cell performance. Thus, optimization problem focuses on achieving maximum matching sub-cells currents. Another challenge is use od III-V on Si materials is their lattice mismatch, which can cause significant material defects in III-V layers if they are grown/deposited directly on Si substrate. One way to grow $GaAs_{1-x}P_x$ layers on Si with minimum defects, is via graded SiGe buffer layers (~ 6-7 μm thick), allowing for fabrication of high quality III-V top cell. In her work, Dr. Abdul Hadi in our collaboration with MIT Professor Eugene Fitzgerald and his team of researchers have shown by experiment and simulations that monolithic III-V/SiGe/Si dual-junction cell performance would be limited by Si sub-cell due to undesired optical absorption in SiGe layers due to their low bandgap and high absorption. In order to reduce the optical losses in SiGe layer, a MJ step-cell design was proposed, where bottom cell is partially exposed to direct sunlight in order to boost photo-generated current in it.

Step-cell design was analyzed numerically and by using detailed balance method. Theoretical efficiency limit analysis of step-cell, ignoring buffer layer optical losses, showed that step-cell provides added degree of freedom in MJ cell optimization, allowing use of conventionally non-optimum and potentially low-cost materials without significant efficiency losses. Furthermore, numerical modeling of $GaAs_{1-x}P_x$/Si bonded and GaAsP/SiGe/Si monolithic step-cells was carried out using TCAD Synopsys simulation tools, showing benefits of step-cell. Moreover, Dr. Abdul Hadi has demonstrated proof-of-concept step-cell device experimentally, where $GaAs_{0.75}P_{0.25}$ cell grown on SiGe/Si substrates served as the top cell. Finally, in her PhD work, Dr. Abdul Hadi showed that cost estimates indicate that III-V/Si MJ step-cell has potential to be low-cost high efficiency source of PV energy.

Patent: “Method and device for low cost, high efficiency step photovoltaic cells”, Application PCT/US2017/056335 **https://patents.google.com/patent/US20200052141A1/en?oq=US20200052141A1**

Book: Ammar Nayfeh and Sabina Abdul Hadi “Silicon-Germanium Alloys for Photovoltaic Applications” Elsevier, 2023. https://shop.elsevier.com/books/silicon-germanium-alloys-for-photovoltaic-applications/nayfeh/978-0-323-85630-0