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Discovering Challenges in Fabrication of Nanostructured c-Si Solar Cells with Metal Oxides Carrier Selective Contacts

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A photovoltaic cell provides direct conversion of solar in to electrical energy. Most modern solar cells are based on silicon due to well-developed technology, high efficiency, and high reliability and relatively low cost. In this research, our approach is based on nano-texturing of the crystalline silicon (black c-Si) with reactive ion etching (RIE)[1] and KOH techniques, ALD deposition of titanium oxide (TiO_2)[2] and RF magnetron sputtering of nickel oxide (NiO) films as carrier selective contacts[3,4]. Black c-Si technology allows reaching reflectivity below 1%. TiO_2 is a wide band gap semiconductor, transparent to photons with energy below 3.2 eV, it is a n-type electron selective layer. NiO is also wide bandgap (3.4 eV) p-type semiconductor, complementary to TiO_2, allowing only hole transport. Further fabrication process included RCA cleaning of nanostructured surfaces and deposition of Al_2O_3 passivating film with atomic layer deposition (ALD)[5]. In order to create local area carrier selective contacts, standard photolithography was used to make opening in Al_2O_3 film. 5 nm of TiO_2 film was deposited with ALD at 80°C. The second photolithography was applied form back contacts openings priory RF sputtering of Ni in O_2 and Ar plasma and NiO film deposition. Front contact grid was formed with the third photolithography and liftoff process. Both, front and back contacts were deposited with electron beam method with a thickness of 600 nm of Al.

In summary, characterization results of the fabricated cell helped to define a number of challenges:

- High surface damage during RIE process and therefore high recombination losses
- ALD Al_2O_3 process shows low passivation quality due possible low quality of TMA precursor.
- ALD TiO_2 films were deposited with $TiCl_4$ precursor, which is also lacking good passivation quality, TiO_2-Si form leaky diode due to interface defects and some Ti metal traces at the interface.
- NiO RF sputtering damages Si due to the nature of sputtering process. The stoichiometry of NiO film sputtered from Ni in O_2 and Ar plasma is not predictable and can be modified with a small parameters shift.
- Al electron beam deposition possibly damaging TiO_2 5nm film, which leads to diode leakage

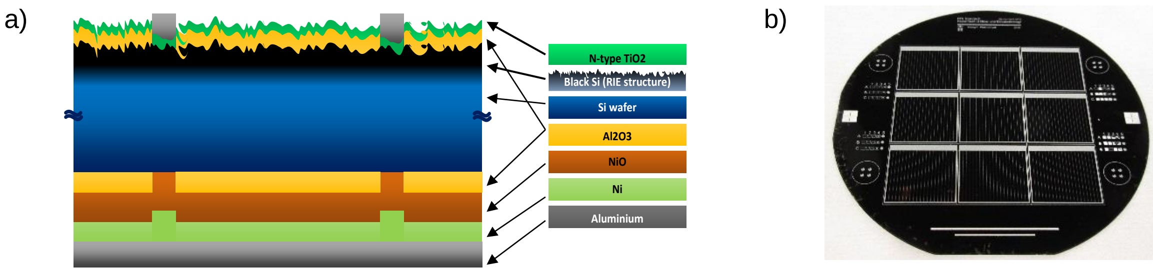

Figure 1. Nanostructured c-Si solar cells with metal oxide carrier selective contacts: a) cross-section schematics of the solar cell architecture, b) photo image of fabricated black silicon solar cells with carrier selective contacts

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