Area 1 Crystalline Silicon and thin film PV

SILICON-HYBRID MULTI-JUNCTION DEVICES FOR PHOTOVOLTAIC AND (PHOTO-) ELECTROCHEMICAL APPICATIONS.

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Photovoltaic (PV) device configurations based on multi-junctions have the advantage of improved utilization of both photons in the solar spectrum and the energy of the photons. PV bottom junctions based on low-bandgap semiconductors allow to utilize the low energetic photons, whereas high-bandgap semiconductors in the top PV junctions allow to efficiently utilize the photon energy for high voltage generation. As a consequence multi-junctions PV devices are a straightforward approach to achieve higher solar-to-electricity conversion efficiencies (η). In addition, multi-junctions are interesting building blocks for new solar-to-fuel approaches based on PV/photo-electrochemical(PEC) or PV/electrochemical(EC) configurations. Multi-junctions PV devices offer high flexibility in delivering the high voltages of 1.6-3.2 V required to split water or reduce carbon-dioxide.

In this contribution we report on the optimization of a large variety of hybrid multi-junction PV devices. The devices are based on 1) a large portfolio of photovoltaic materials and 2) various types of PV device architectures, like: amorphous silicon (a-Si:H), amorphous silicon-germanium (a-SiGe:H), and nano-crystalline silicon (nc-Si:H) p-i-n junctions; CIGS/CdS hetero-junctions; organic photovoltaic (OPV) devices; and monocrystalline silicon wafer/a-Si:H based hetero-junction solar cells (c-Si HJ). Every type of multi-junction device configurations exhibits its own advantage, like high conversion efficiencies, cost-effective module topologies, limited usage of materials, easy up-scalable processing methods for large areas, high water resistant PV materials to allow flexible and cheaply encapsulated modules and high voltage (and current) material devices for monolithically integrated PEC-PV concepts.

The results of various types of devices will be presented: a-Si:H/CIGS 2-junctions, a-Si:H/OPV 2-junctions, and a-Si:H/a-Si:H/OPV 3-junctions, nc-Si:H/c-Si 2-junction and a-Si:H/nc-Si:H/c-Si 3-junction and a-Si:H/a-SiGe:H/c-Si 3-junctions.

The general design rules of these hybrid PV devices to accomplish high conversion efficiencies are discussed, like tackling the crucial electrical and optical loss mechanism. First, a detailed study on a wide variety of tunnel-recombination junctions for hybrid devices will be presented. Secondly, to realize conditions close to current matching a wide variety of light management concepts are discussed, like: modulated surface textured substrates and interfaces to establish a compromise between ideal light trapping and processing of high quality PV materials; bi-functional intermediate layers that act as reflector layers and tunnel recombination junctions; and minimalizing the parasitic absorption losses of supporting layers. The current state-of-the-art hybrid PV devices will be presented.

Finally, examples of the application of these multi-junction devices in solar-to-fuel and water purification applications will be presented.