THE CHALLENGE OF IMPROVING ENERGY CONVERSION EFFICIENCY IN SOLAR CELLS

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INTRODUCTION

The total worldwide production of solar cells was 37 GW in 2013. For bulk Si solar cells, the conversion efficiency of their large-area modules has now reached 20 %. In terms of price, Si solar cells produced in China and CdTe solar cells are taking the lead in cost reduction. A marked improvement of energy conversion efficiency is essential to reduce further the electricity cost. A conversion efficiency of 25% is targeted for practical Si PV modules by 2025. On the other hand, thin-film solar cells are expected to achieve a conversion efficiency of 20% by exploiting new materials developed in the future and by applying a multi-junction structure. Now is the time to bring together the experience and know-how of researchers in Photovoltaics to speed up the development of materials and devices.

Currently, I am acting as a group leader of two collaborative university–industry research consortiums that focus on innovative solar cells. One is the "Thin-Film Full Spectrum Solar Cells" project of METI/NEDO and the other is the "Si Nano-Wire Solar Cells" project of MEXT/JST. The themes of both projects are challenging and we require a significant change in mindset to achieve our goals, but the fruit of our success will be sweet. Here, I discuss the organizations and functions of the two collaborative university–industry research consortiums and also recent achievements.

THIN-FILM FULL SPECTRUM SOLAR CELL

To increase the performance of solar cells, solar spectrum splitting technique has been considered and studied. It was found from the simulation that the total efficiency of nearly 25% can be obtained at the splitting wavelength of 600 nm for thin-film type solar cell using a-Si and CIGS as the top and bottom cells, respectively. The experiment has been carried out to verify the simulation results. By optimization of device and optical splitter, up to now the total efficiency of about 23 % has been obtained at the splitting wavelength of 614 nm. Further work has been done using InGaP as the top cell instead of a-Si. Up to now a high efficiency of 26% has been measured for InGaP/CIGS configuration using developed spectrum splitting technique. Higher performance can be expected with c-Si bottom cell or under concentration application.

DEVELOPMENT OF Si NANO-WIRE SOLAR CELLS

Si is a semiconductor with 1.1 eV band gap, way different from 1.5 eV band gap which is logically the most suitable band gap for converting solar energy. The energy conversion efficiency of silicon solar cells is about 25% and getting closer to 28% to 29%, which is considered the theoretical limitation. This research is aiming to realize a unique technology of "Bandgap control of Si using nano-wire" to break the physical limitation of band gap and drastically improve the performance of silicon solar cells. At the same time, this research tackles an extremely difficult challenge of realizing ultra-high efficiency with a tandem system of nano-wire silicon solar cell and heterojunction silicon solar cell. Based on these technologies, we aim to develop silicon solar cells with 30% energy conversion efficiency that breaks the conventional wisdom.