Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp686-687

Recent Results for Concentrator Photovoltaics in Japan

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Abstract

This paper summarizes the Europe-Japan Collaborative Research Project on Concentrator Photovoltaics (CPV); NGCPV Project (a New Generation of Concentrator PhotoVoltaic cells, modules and systems. The following results have been obtained: 1) CPV cell with 3J world-record efficiency of 44.4 % by Sharp Co., 2) 50 kW CPV plant operation with average DC efficiency of 27.8% in Spain (since mid-2012), 3) New "Intrepid" CPV module with 31.3% have been developed by Daido Steel Co., 4) Fundamental researches on novel materials for CPV were also conduced.

1. Introduction

The Europe-Japan Collaborative Research Project on CPV has been initiated under support by the EC (European Commission) and NEDO (New Energy and Industrial Technology Development Organization) since June 2011. Because high concentration PV has great potential of higher efficiency and lower cost compared to conventional crystalline Si PV and thin-film PV.

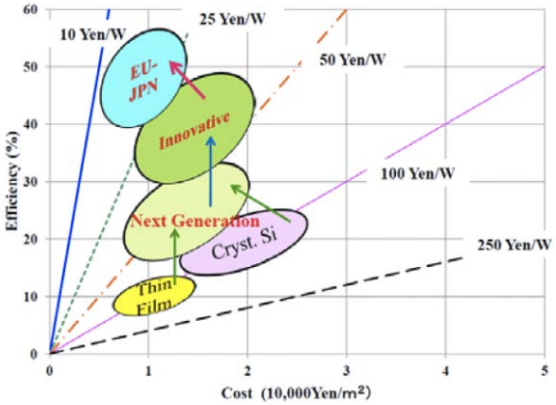

Fig. 1. High efficiency and low-cost targets of NEDO PV R&D Projects.

The aim of this project was to accelerate the move to very high efficiency and lower cost CPV technologies and to enhance widespread deployment of CPV systems as shown in Fig. 1. 7 organizations such as UPM, FhG-ISE Imperial College, BSQ, CEA-INES, ENEA, and PSE in Europe and 9 organizations such as Toyota Tech. Inst., Univ. Tokyo, AIST, Sharp Co. Daido Steel Co., Kobe Univ., Miyazaki Univ., Asahi Kasei Co., and Takano Co. participate in this project. The targets of this project are 1) to develop world-record efficiency CPV cells of more than 45%, 2) to develop world-record efficiency CPV modules of 35%, 3) to establish standard measurements of CPV cells and modules, 4) to install 50kW CPV system in Spain, to carry out field test of CPV system and to manage power generation of CPV systems, and 5) to develop high-efficiency and low-cost new materials and structure cells such as III-V-N, III-V-on-Si tandem, quantum dots and wells. This paper presents outline of this project and most recent results such as world record efficiency (37.9% under 1-sun) cell and high-efficiency (44.4% under 250-300 suns) concentrator cell with inverted epitaxial grown InGaP/GaAs/InGaAs 3-junction solar cells.

2. Main Activities of NGCPV Project

2.1 New materials and device characterization

Atomic scale characterizations of new III-V-N and quantum & nanostructures were developed by using FT-IR, TEM, X-ray reciprocal space mapping and PPT as shown in Fig. 2. CBE-grown GaAsN cells with 13.7% have been demonstrated based on understanding defect behavior by using various characterization tools and fundamental process of epitaxial growth of III-V-N materials. New Sb-added buffer layers and defect reduction for GaAs film on Si have also been developed.

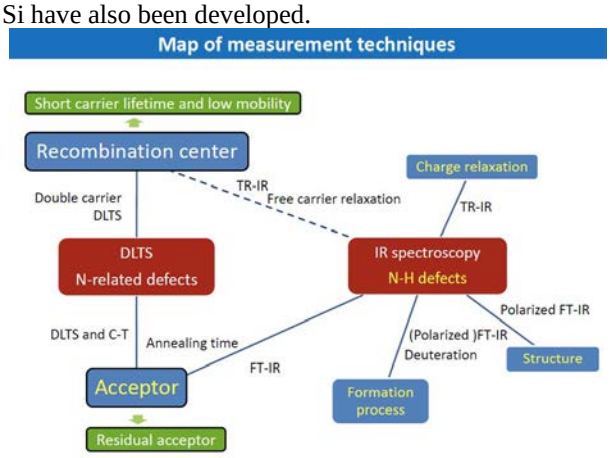

Fig. 2. Measurement tools for clarifying defect behavior III-V-N behavior.

2.2 Development of advanced CPV cells

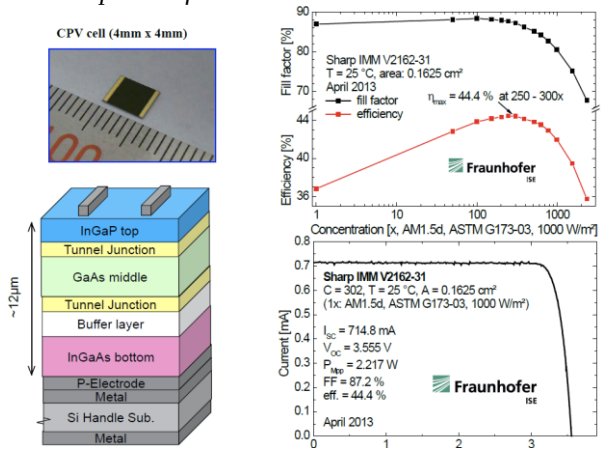

Fig. 3. A structure, I-V curve and concentration ration dependence and I-V curve of inverted epitaxially grown InGaP/GaAs/InGaAs 3-junction solar cells.

World-record for inverted epitaxialy grown lattice-matched InGaP/GaAs/InGaAs triple-junction solar cells with efficiencies of 44.4 % @300 suns and 37.9% under 1-sun have been achieved by Sharp as shown Fig. 3. 4-junction solar cells on Ge fabricated using wafer-bonding technology by FhG-ISE have shown 36.3 % under 1-sun and 38% under concentration, respectively.

Upright and inverted metamorphic triple-junction solar cells have shown lifetime of more than 30 years.

2.3 Development of CPV modules and systems

Dome-shaped Fresnel Koeler optics have been developed and optical efficiency of about 85% and large acceptance angle have been realized in cooperation with Daido Steel. CPV modules with mini-module efficiency of 34.6 % (302.8 cm^2) and those with 1m^2 module efficiency (maximum efficiency of 32.0% and average efficiency of 31.4%) have been fabricated by Daiso Steel in cooperation with European partners as shown in Fig. 4.

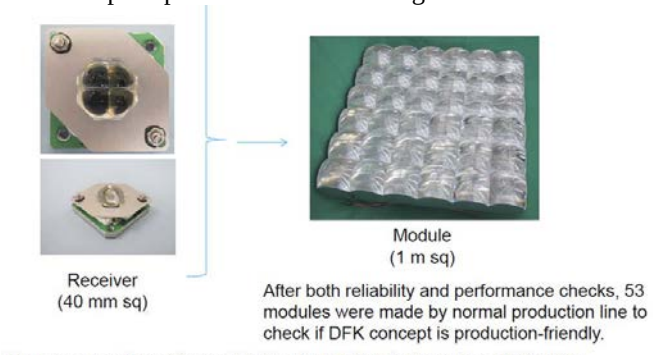

Fig. 4. Development of large area CPV module with average efficiency of 31.4%.

Data analysis tools have been established and modeling of power and energy predicts performance of CPV systems are very well. As shown in Fig. 5, average DC efficiency 27.8% has been demonstrated with 50kW CPV system installed near Toledo, Spain..

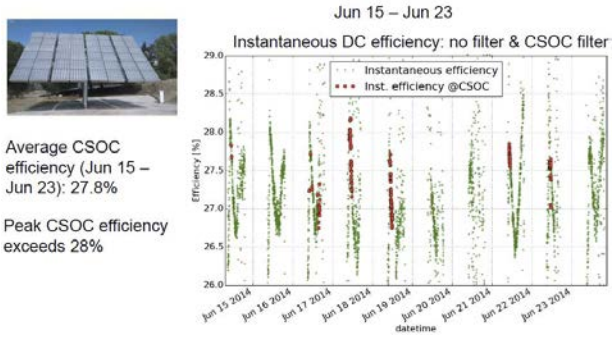

Fig. 5. DC efficiency results of the CPV system installed in Spain.

3. Summary and Future Direction

Under this project, world-record efficiency CPV solar cells with an efficiency of 44.4% with inverted epitaxially grown InGaP/GaAs/InGaAs 3-junction solar cells by Sharp Co. and 46.0% with direct bonded AlInGaP/GaAs/InGaAsP/InGaAs 4-junction solar cells have been developed and 34.6% CPV mini-module has also been demonstrated. Therefore, high performance concentrator PV is very promising. However, there are some problems to be solved in order to realize automobile, agriculture, large-scale PV applications and so forth.

Figure 6 shows future efficiency prediction of various types of solar cells. III-V compound CPV solar cells have great potential of more than 50%. InGaP/InGaAs/Ge, InGaP/GaAs/InGaAs 3-junction solar cells, and InGaP/AlGaAs/InGaAsN/Ge, InGaP/AlGaAs/InGaAs/Ge, InGaP/AlGaAs/InGaAsP/InGaAs have great potential of over 45% under concentration. Concentrator PV is expected to contribute to major PV as well as the first crystalline Si PV and the second thin-film PV

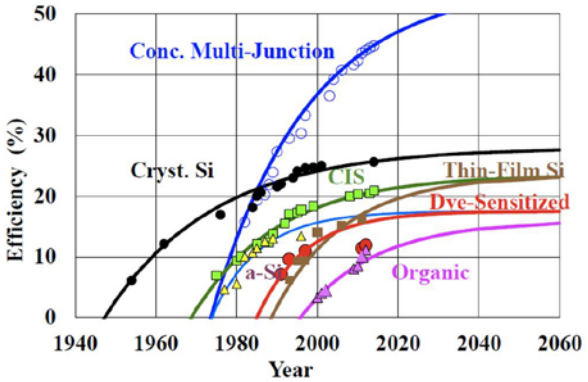

Fig. 6. Future efficiency prediction of various types of solar cells.

Acknowledgment

The authors wish to express sincere thanks to NEDO and EC for their kind support and to Prof. A. Luque, Dr. A. Bett, Prof. Y. Okada, Prof. A. Marti, Prof. Sugiyama, Prof. Y. Nakano, Dr. Hishikawa, Dr. G. Siefer, Prof. G. Sala, Prof. Y. Ohshita and other Japanese and European partners for their fruitful collaboration.