Impact of Photovoltaic-powered Vehicles

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Development of high-efficiency solar cell modules and expanding their application fields are significant for the further development of photovoltaics (PV) and the creation of new clean energy infrastructure based on PV. Notably, the development of PV-powered electric vehicle (EV) applications is desirable and very important for this end. According to the NEDO's Interim Report "PV-Powered Vehicle Strategy Committee" [1], new larger PV market with more than 10GW and 50GW in 2030 and 2040, respectively are expected to be established when PV-powered vehicles are developed as shown in Fig. 1. Cumulative PV capacity for PV-powered vehicles will be 50GW and 0.4TW in 2030 and 2040, respectively.

This paper presents impacts of solar cell module efficiency CO_2 emission reduction, battery storage cost resuction and driving distance increase of vehicles [2,3]. Effects of introduction of high-efficiency solar cell modules into EVs upon reduction in CO_2 emission were analysed. Figure 2 shows calculated results for CO_2 emission of PV-EV installed with solar cell modules with different efficiencies as a function of electric mileage in comparison with those of EV and PV production. It is clear in Figure 2 that the PV-EV installed with the higher efficiency solar cell modules has great potential of reduction in CO_2 emission. 55% - 73% CO2 reduction will be realized by using the PV-powered vehicles with electric mileage of 10kW/kWh. Electricity cost saving for EV charging by usage of PV was also analysed in this study. Figure 2 shows calculated results for charging electricity cost of EV and PV-EV as a function of electric millage by assuming 30 km/day as average daily driving distance. The results show effectiveness of high-efficiency solar cell modules for charging electricity cost saving of electric vehicles. For example, electricity cost saving is \$254.1/year for 40% module and \$149.1/year for 20% module in the case of electric mileage of 4 kW/kWh, \$167.2/year for 40% module and \$117.8/year for 20% module in the case of electric mileage of 10 kW/kWh.

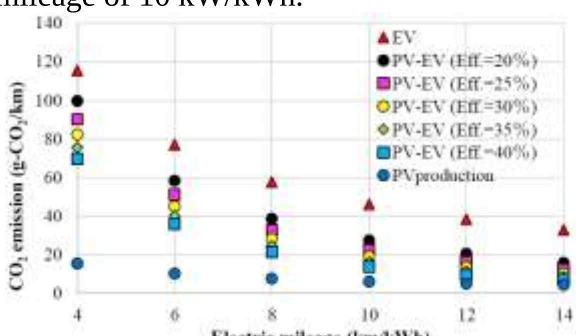

Fig. 1. Calculated results for CO_2 emission of PV-powered electric vehicles (PV-EV) installed with solar cell modules with different efficiencies as a function of electric mileage in comparison with those of electric vehicles (EV) and PV production.

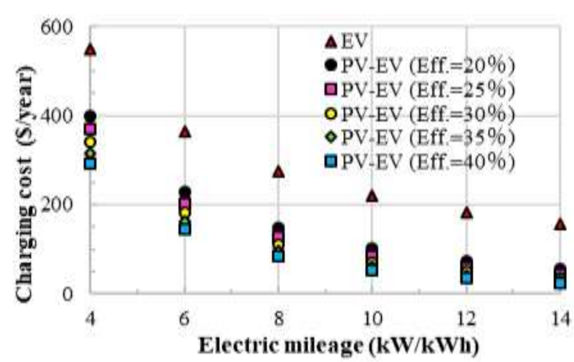

Fig. 2. Calculated results for charging electricity cost of EV and PV-EV as a function of electric mileage by assuming 30 km/day as average daily driving distance.

As shown in Figs. 2 and 3, high-efficiency solar cell modules have great potential of CO2 emission reduction and charging electricity cost saving of vehicles. Figure 3 shows analutical results for efficiency potential and best efficiencies of III-V compound MJ (multi-junction) solar cells [4]. The 2, 3, 4, 5 and 6-junction solar cells have potential efficiencies of 36.6%, 44.0%, 48.8%, 50.4% and 51.4%, respectively, as shown in Fig. 3. Cost reduction of solar cell modules is also very important for VIPV (vehicle integrated photovoltaics). The Si-based tandem cells that combine Si with other materials such as III-V compound, II-VI compound, perovskite chalcopyrite, and so forth are desirable for realizing super high-efficiency and low cost. The Si tandem solar cells [5] have been receiving considerable attention because of their potentials.

Figure 4 shows calculated results for driving distance of vehicles powered by perovskite/Si 2-junction, III-V/Si 2-junction and III-V/Si 3-juncttion tandem solar cells and III-V 3-junction tandem solar cells and module as a function of module efficiency and temperature coefficient (TC) in comparison with estimated values of vehicles powered by perovskite/Si 2-junction, II-V/Si 2-junction and III-V/Si 3-juncttion tandem solar cells and III-V 3-junction tandem solar cells and module and actual driving distance calibrated of the Prius 2019 [2] powered by III-V 3-junction solar cell module and the Sono Motors Sion [6] powered by back-contact Si solar cell module. The III-V/Si 3-junction solar cell modules have potential of driving distance of 30 km/day average and more than 50 km/day on a clear day.

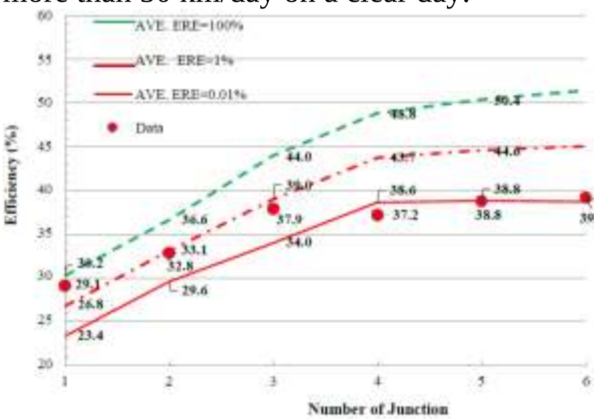

Fig. 3. Calculated efficiencies of III-V compound MJ solar cells under 1-sun conditions as a function of number of junctions and external radiative efficiency (ERE) in comparison with efficiency data (best laboratory efficiencies) reported in references.

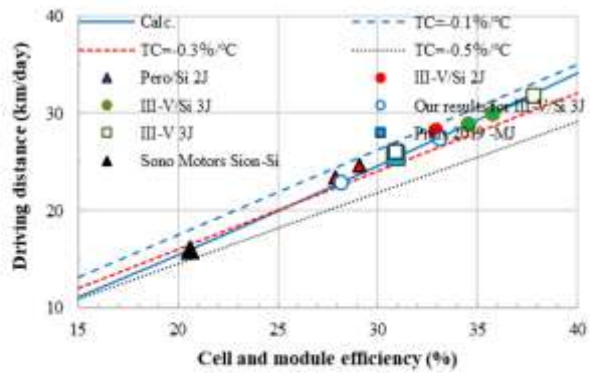

Fig. 4. Calculated results for driving distance of vehicles powered by perovskite/Si 2-junction, III-V/Si 2-junction and III-V/Si 3-juncttion tandem solar cells and III-V 3-junction tandem solar cells and module as a function of cell and module efficiency and temperature coefficient (TC) in comparison with estimated values of vehicles powered by perovskite/Si 2-junction, III-V/Si 2-junction and III-V/Si 3-juncttion tandem solar cells and III-V 3-junction tandem solar cells and module and actual driving distance calibrated of the Prius 2019 [2] powered by 3-junction solar cell module

In this paper, our recent approaches such as demonstration car (Toyota Prius PHV) by using Sharp's high-efficiency III-V 3-junction solar cell modules (output power of 860W), static low concentrator InGaP/GaAs/InGaAs 3-junction solar cell module and so forth are presented. The III-V/Si tandem solar cells are expected to have a high potential for various applications because of its high conversion efficiency of larger than 36% for dual-junction and 42 % for triple-junction solar cells under 1-sun AM1.5 G illumination, lightweight and low-cost potentials. In addition, static low concentrator InGaP/GaAs/InGaAs 3-junction solar cell module with efficiency of 32.84% and so forth are demonstrated.

References

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Biography

Masafumi Yamaguchi has received his Ph.D. degree from Hokkaido Univeristy, Japan (1978). He is now Professor Emeritus and Invited Research Fellow at the Toyota Technological Institute, Japan, Visiting Professor, Kyushu University, Chairman of the PV-Powered Vehicle Strategy Committee under the NEDO, former Project Leader of the PV R&D Project under the NEDO, former Research Supervisor of the Creative Clean Energy Generation using Solar Energy under the JST. He has received numerous awards such as the Becquerel Prize from the Eurpean Commission in 2004, the William Cherry Award from the IEEE in 2008, the PVSEC Award in 2011, the WCPEC Award in 2014 for his outstanding contribution to the development of science and technology of photovoltaic solar energy, and to the International collaboration and cooperation.