Special Lecture in Green Nanotechnology

Nov. 27, 13:00-15:00
Place:機械知能系講義室3

「Research on ultra-high energy conversion efficiency solar cells by using the superlattice semiconductor structures」

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Abstract

At present, approximately 90% of the primary energy is supplied by fossil fuels such as oil, coal, and natural gas, and their usage have been rapidly increasing year by year [1]. However, they have various risks in term of sustainability. For example, fossil fuels are unable to be used for eternity due to their limited resources, as are indicated by the reserve-to-production ratios of 53 for oil, 55 for natural gas, and 113 years for coals, respectively. Therefore, renewable energy, such as solar, wind, and biomass is paid much attentions to solve the energy problem. Among them, solar photovoltaics (PV) is a most promising technology for sustainable energy.

In the current status, crystalline silicon solar module has widely accepted for household PV system and gigawatt PV station. The IEA (International Energy Agency) reported that 75 gigawatts of PV were installed globally in 2016, bringing the installed global PV capacity to at least 303 gigawatts [2]. However, its conversion efficiency is too low to replace the fossil fuels from the viewpoint of power generation cost.

III-V compound semiconductors multi-junction solar cells under concentrated sunlight is a promising concept for realizing high-efficiency and low-cost solar PV power generation. The most widely used lattice-matched triple-junction structure, InGaP (1.85 eV)/InGaAs (1.42 eV)/Ge (0.67 eV), has a limitation in performance due to the current-mismatch with the wide bandgap of the middle cell, and further enhancement in cell efficiency is expected by lowering the bandgap to approximately 1.2 eV.

The insertion of a quantum structure such as multiple quantum wells (MQWs) into

the absorbing *i*-layer of solar cells could be a potential solution to the current-matching issue in multiple-junction solar cells [3]. This is because the MQW structure can expand the sunlight absorption region toward longer wavelengths and enhance the short-circuit current (I_{SC}). However, an MQW itself functions as recombination centers for photogenerated carriers, leading to degradation in both the open-circuit voltage (V_{OC}) and the fill factor (*FF*), thus lowering the conversion efficiency of solar cells. To address this problem, an MQW with a very thin barrier structure, hereafter called a superlattice (SL) structure, has been proposed [4, 5]. In the SL, it is well known that the coupling of the wave functions between adjacent quantum wells causes a mini-Brillouin zone along the growth direction, which results in the formation of minibands of electrons and holes [6]. For solar cells, it is expected that photoexcited carriers can move across the absorbing *i*-layer without recombination through these minibands, thus improving the photovoltaic performance.

In this special lecture, the application of nano-order semiconductor structures for the solar cell is lectured in addition to overview of energy problem and fundamental semiconductor physics.

(Reference)

[1] http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

[2] https://www.iea.org/renewables2018/

[3] K. W. J. Barnham *et al.*, J. Appl. Phys. 67, 3490 (1990).

[4] Y. P. Wang *et al.*, Appl. Phys. Express 5, 052301 (2012).

[5] H. Fujii *et al.*, J. Appl. Phys. 116, 203101 (2014).

[6] J. H. Davis, *The Physics of Low-Dimensional Semiconductors* (Cambridge University Press, New York, 1998) Chaps. 5 and 6.