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## Hybrid Photovoltaics and Semiconductors

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Solar energy is believed to play a key role in global energy system in the near future, because of its clean and renewable nature. Solar photovoltaics (PV), which convert solar energy to electricity, is currently a highly competitive technology that ready to contribute to the greenhouse gas emission mitigation. By the end of 2020, global installed solar PV capacity has reached  $\sim 707$  GW [1], and the average PV module price has been reduced to 0.21 US\$/Wp [2], competitive to the conventional fossil energy. PV module price exhibits an impressive learning rate of  $\sim 40\%$  from 2006 to 2020, indicating its cost reduces by 40% every time the cumulative capacity doubles. One of the most important driver for the module price reduction is the PV technology improvement, especially the device structure evolution and power conversion efficiency increase.

Currently, the PV market is dominated by the crystalline silicon (c-Si) PV technology ( $\sim 95\%$  market share in 2020), and thin film PV technology (mainly CdTe and CIGS solar cells) occupies another 5% market [1]. Last few years have seen the c-Si PV technology switch from aluminum back surface field (Al-BSF) cell and passivated emitter and rear cell (PERC), which has occupied  $\sim 80\%$  of the PV production in 2020. However, the PERC cell features a PCE limit of  $\sim 24\%$  on industrial production line with technologies principally available [3]. The carrier recombination losses at the metal-silicon contact regions as well as the heavily doping induced issues (e.g. Auger recombination, bandgap narrowing and free carrier absorption) were identified as the key factors that limit the PCE of PERC cells. As predicted in Figure 1b, c-Si heterojunction solar cells with passivating contacts will be the next generation

high-efficiency PV production ( $\geq 25\%$ ) after PERC [3]. In the meantime, emerging PV technologies, such as the perovskite and organic solar cells, are also attracted considerable attention thanks to their potential low-cost and flexibility. To overcome the theoretical PCE limit of single-junction solar cells, tandem device is of particular appeal. The most successful example is the perovskite/c-Si tandem solar cells, already achieving a high PCE of 29.5%.

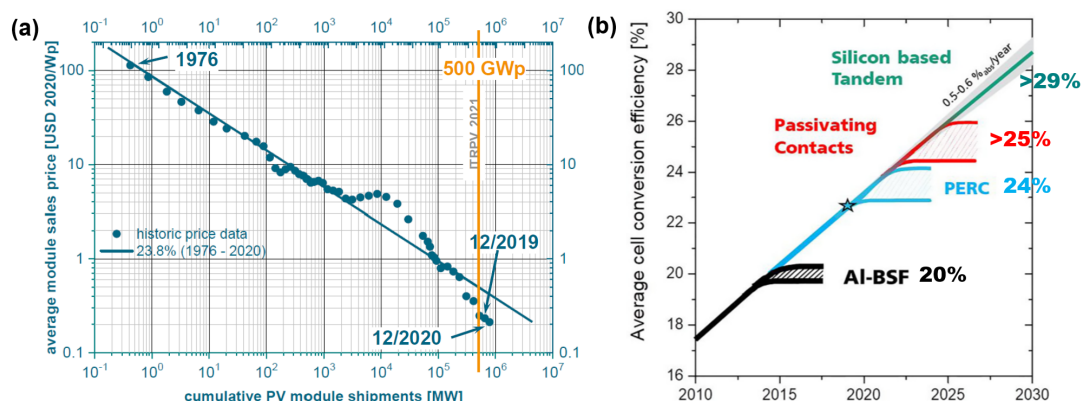


Figure 1 (a) Learning curve for module prize as a function of cumulative shipments; (b) Research and development roadmap of c-Si PV productions.

The current focus issue on Hybrid Photovoltaics and Semiconductors is dedicated to this endeavor. Cutting-edge works on photovoltaics technologies, including c-Si solar cells, perovskite solar cells, organic solar cells, tandem solar cells and semiconductor defects, are presented. Yu et al. achieved an impressive mass production PCE of 23.24% on industrial PERC cell with a high bifacial rate of 78% [4]. Two smart methods, prolonged annealing and CO<sub>2</sub> plasma interface treatment, were developed to increase the PCE of silicon heterojunction solar cells, resulting in a high PCE of up to 23.3% on industrial six-inch substrate [5,6]. Wang et al. presented a novel dopant-free electron-selective CsF<sub>3</sub> contact, achieving a high PCE of 21.27% at a low cost [7].

[1] PV report, Fraunhofer ISE, June 2021.

[2] International technology roadmap for photovoltaic (ITRPV), 12<sup>th</sup> Edition, April, 2021.

[3] M. Hermle, F. Feldmann, M. Bivour, J. C. Goldschmidt, S. W. Glunz, Appl. Phys. Rev. 7, 021305 (2020).



Baoquan Sun is a professor of Soochow University, China. He received his Ph.D. at Tsinghua University. After postdoc. research in the Cavendish Laboratory at Cambridge University and Los Alamos National Laboratory, he joined Institute of Functional and Soft Materials of Soochow University in 2008. His main research fields are nanostructured semiconductor materials, conducting inks, charge separation and transport, interface engineering for flexible electronics, light-emitting diodes, and silicon solar cells.



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