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A Review on recent developments on solar technology

Nisha Sharma[1], Khushbeen[2]

Asst. Prof Printing Dept (Electrical Engg), GJUS&T Hisar[1]

Asst. Prof Printing Dept, GJUS&T Hisar[2]

Abstract: The photovoltaic market is booming with over 30% per annum compounded growth over the last 5 years. Most of the solar cells being supplied to this market are "first generation" devices based on crystalline or multicrystalline silicon wafers. "Second generation" thin-film solar cells based on amorphous silicon/hydrogen alloys or polycrystalline compound semiconductors are starting to appear on the market in increasing volume. PV remains the most rapidly growing energy technology by a wide margin. Different methods have been adopted to increase cell efficiency and various research done on solar cell have been discussed in this paper.

Keywords: PV cell

I INTRODUCTION

Solar technologies have evolved a lot since they first made their debut in the 1960s. While previously solar photovoltaics (PV) were seen as a thing of the future, today, technological breakthroughs have positioned the industry for huge growth. A series of new developments in solar PV technology also promise to contribute to the industry's success. Enormous progress has been made in recent years on a number of photovoltaic (PV) materials and devices in terms of conversion efficiencies. Ultrahigh-efficiency (>30%) PV cells have been fabricated from gallium arsenide (GaAs) and its ternary alloys such as gallium indium phosphide (GaInP2)[2]. The primary objective of the worldwide photovoltaic (PV) solar cell research and development is to reduce the cost of PV cells and modules to a level that will be competitive with conventional ways of generating power. One way to achieve this is to significantly increase the conversion efficiency of PV materials and devices. Major advances have been made in recent years in improving the efficiency of almost all of the leading PV materials and devices. Basically, there are two approaches to increasing the efficiency of solar cells: (1) selecting the semiconductor materials with appropriate energy gaps to match the solar spectrum and the optimizing their optical, electrical, and structural properties; and (2) innovative device engineering, which enables more effective charge collection as well as better utilization of the solar spectrum through single and multijunction approaches. Although, there is no accepted definition of what constitutes a high efficiency device it is very much a function of a given technology and how it impacts the overall cost structure[3].

II ADVANCES IN SOLAR CELL TECHNOLOGY

Researchers have longed looked for ways to improve the efficiency and cost-effectiveness of solar cells - the life blood of solar PV systems. A solar PV array is comprised of hundreds, sometimes thousands of solar cells, that individually convert radiant sun light into electrical currents. The average solar cell is approximately 15% efficient, which means nearly 85% of the sunlight that hits them does not get converted into electricity. As such, scientists have constantly been experimenting with new technologies to boost this light capture and conversion. Light-Sensitive Nanoparticles. Recently, a group of scientists at the University of Toronto unveiled a new type of light-sensitive nanoparticle called colloidal quantum dots, that many believe will offer a less expensive and more flexible material for solar cells. Specifically, the new materials use n-type and p-type semiconductors - but ones that can actually function outdoors. This is a unique discovery since previous designs weren't capable of functioning outdoors and therefore not practical applications for the solar market. University of Toronto researchers discovered that n-type materials bind to oxygen - the new colloidal quantum dots don't bind to air and therefore can maintain their stability outside. This helps increase radiant light absorption. Panels using this new technology were found to be up to eight percent more efficient at converting sunlight.

Gallium Arsenide. Researchers at Imperial College University in London believe they have discovered a new material - gallium arsenide - that could make solar PV systems nearly three times more efficient than existing products on the market. The solar cells are called "triple junction cells" and they're much more efficient, because they can be chemically altered in a manner that optimizes sunlight capture. The model uses a sensor-driven window blind that can track sun light along with "light-pipes" that guide the light into the system.

III TOTAL SOLAR INSTALLED

The global installed capacity of solar electricity has increased by six times between 2010 and 2013. At the end

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of 2009, the total installed capacity was 23 GW. In the next four years, an average of about 28 GW was added every year, taking it to 135 GW by the end of 2013.

Table 1

TOTAL SOLAR INSTALLED CAPACITY

	2009	2010	2011	2012	2013
Germany	6.578	11.68	19.34	28	31.3
Italy	0.676	1.906	10.8	18.86	20.46
Spain	5.961	6.425	7.386	10.13	9.315
France	0.331	0.62	2.05	4.056	4.756
Rest of Europe	3.131	9.327	12.5	7.351	12.97
Japan	2.627	3.618	4.914	6.914	13.91
United States	1.698	3.055	5.26	12.8	17.55
China	0.3	0.8	3.49	7	18.3
Rest of World	1.697	2.567	3.268	3.886	6.429
Global	22.999	40.001	69	99	135

All figures in gigawatt; information from International Energy Agency

According to figures published by the International Energy Agency (IEA) a few months ago, more than 36 GW of new solar capacity was added in 2013, or about 100 MW per day (see table 1). Solar cells consist of semiconductor materials—typically crystalline silicon—that convert sunlight directly into electricity. Made up of many cells, solar panels can be linked together into any number of system sizes, from multi-kilowatt residential rooftop systems to massive ground-mounted arrays measured in hundreds or thousands of megawatts. China—the leading manufacturer of PV—had until recently installed very little solar power at home. Those days are over. Between 2010 and 2012, China's PV capacity grew nearly ninefold to 7,000 megawatts. Then in 2013, China added at least 11,300 megawatts, the largest PV addition by any country in a single year. With 18,300 megawatts, China now trails only Germany (at 36,000 megawatts) in overall capacity. (See data.) More than half of China's new PV in 2013 was installed in the western provinces of Gansu, Xinjiang, and Qinghai, far from population centers. A 320-megawatt PV project—the world's largest—was completed in late 2013 alongside the Longyangxia hydropower dam in Qinghai. As large project development in remote areas continues, China is also looking to increase the number of small systems that do not require long-distance electricity transmission, aiming for more than 8,000 megawatts of rooftop PV in 2014. It appears that China will soon lead the world in solar power as it does in wind: in May 2014, the government announced a PV target of 70,000 megawatts by 2017.

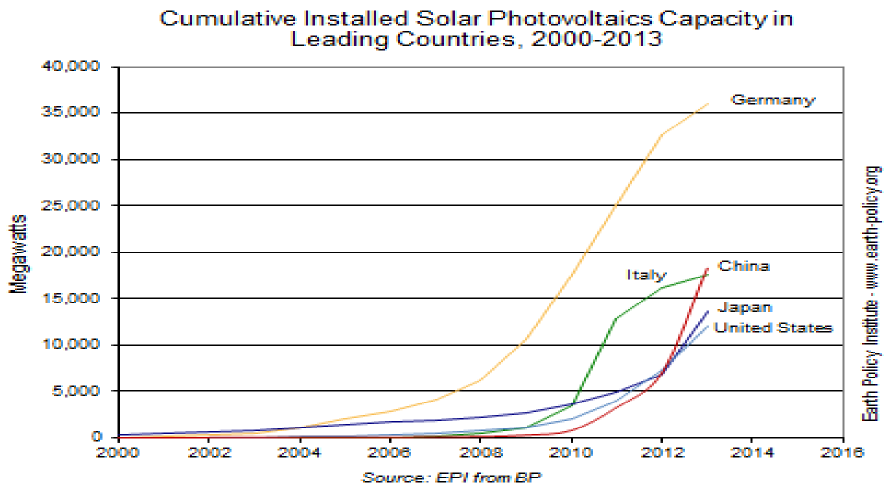

Figure 1

To the east, Japan installed the second-most PV in 2013, adding 6,900 megawatts to reach 13,600 megawatts of solar power in operation. The main driver of this doubling was a generous feed-in tariff (FIT) introduced a year after the 2011 Fukushima nuclear disaster to promote renewable energy development. (In general, a FIT guarantees generators a certain price over a fixed term for the electricity they send to the grid. Most of the world's PV development to date has been catalyzed by FITs.) Small rooftop systems still dominate Japan's PV landscape, but 2013 marked the first year when most new capacity came from larger projects. In early 2014, an 82-megawatt park—Japan's largest—opened in Oita Prefecture. And in June 2014, Kyocera and four other companies agreed on plans for a 430-megawatt project on farmland in the Goto Islands off Nagasaki Prefecture in Kyushu, Japan's third-

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largest island. Solar panels will be mounted on stilts, allowing enough sunlight to pass through to crops. The electricity produced, capable of powering 140,000 homes, will be delivered by undersea cable to Kyushu. As PV development accelerates, Japan is fast approaching its 2020 target of 28,000 megawatts. India nearly doubled its PV capacity in 2013. The western desert states of Gujarat and Rajasthan contain more than half of the country's 2,300 megawatts of PV. In June 2014, shortly after his election as prime minister, Narendra Modi's administration announced an expansion of the National Solar Mission goals for 2022—from 22,000 to 34,000 megawatts—in order to generate 3 percent of the country's electricity from solar power. The solar consultancy Bridge to India notes that PV sited on just 6,200 square miles, about 0.5 percent of India's land area, could generate 50 percent more electricity than India currently uses. of course, 300 million Indians still lack access to electricity, while hundreds of millions more experience frequent shortages due to an unreliable grid. The good news is that installing rooftop PV in rural areas is cheaper than building a central power plant and grid, and electricity from PV is now cheaper than that from diesel generators. In addition, in a country where irrigation pumps running on diesel or grid electricity chronically overdraw underground aquifers, solar power offers a solution. A new government program will help farmers buy solar-powered pumps if they switch to water-saving drip irrigation. This is a triple-win: water use drops without affecting yields, fossil fuel use declines, and the government saves up to $6 billion per year in diesel and electricity subsidies. Elsewhere in Asia, South Korea grew its PV capacity 40 percent to nearly 1,500 megawatts in 2013. And Thailand expanded its Lopburi Solar Farm to 84 megawatts, part of an 80 percent boost in national solar installations to 700 megawatts. With its 2013 PV boom, Asia unseated Europe to become the leading region in annual installations. Downward adjustments to renewable energy incentives in Europe slashed new PV installations there by more than one third. Germany reduced its FIT rates for new projects faster than planned in an attempt to save on payments, and that cut installation rates in half. Reining in solar incentives has also slowed PV installations in Italy, now the third-ranked country in overall capacity with 17,600 megawatts. FIT rates for new PV plants were reduced beginning in mid-2011 and eventually eliminated in mid-2013. But PV system costs in Italy have fallen by 56–70 percent over the last five years, depending on size, a positive sign for PV competitiveness after the FIT. A recently-finished 700-kilowatt rooftop system on an Ikea store in Pisa, one of the first unsubsidized projects, will generate electricity at a price that rivals or bests the grid average. Across the Atlantic, solar power is starting to take off in the United States. The country added some 4,800 megawatts in 2013, increasing its total PV capacity by 65 percent to 12,000 megawatts. Factors contributing to this growth include continually falling system costs (2013 saw an average 15 percent drop), utilities meeting state-mandated obligations to sell electricity from renewables, and home solar leasing arrangements gaining in popularity. More than half of the new U.S. PV capacity in 2013 came online in California, long the leading solar state. In addition to small residential systems, many large solar parks are operating or under construction in California, including the two Solar Star projects slated for completion in late 2015. With a combined 580 megawatts, these two plants are expected to generate enough electricity for 250,000 homes. Arizona, which added 420 megawatts of PV in 2013, boasts the 290-megawatt Agua Caliente project outside Phoenix. Rounding out the top five states in 2013 were North Carolina (340 megawatts), New Jersey, and Massachusetts (240 megawatts each). PV is gaining steam in other countries in the Americas as well. Canada added 440 megawatts to reach 1,200 megawatts in 2013. Mexico nearly doubled its PV capacity to 100 megawatts and is expected to reach 240 megawatts by the end of 2014. In Chile, the U.S. firm SunEdison announced in June 2014 the completion of the largest PV plant in Latin America, its 100-megawatt project in the Atacama Desert. And Brazil looks likely to nearly double its PV capacity to more than 70 megawatts in 2014. Another sunbaked country building its PV capacity is Australia, now with 3,300 megawatts. One in seven homes there generates electricity with rooftop PV. In South Australia, the figure is one in four homes. In the Middle East, Israel has installed the most solar PV to date. Its installed PV base grew 75 percent in 2013 to 420 megawatts. Dubai in the United Arab Emirates switched on a 13-megawatt project in October 2013 that is planned to expand to at least 100 megawatts and perhaps 10 times that size. By 2032, Saudi Arabia aims to have 16,000 megawatts of PV. In Africa, where small off-grid PV systems have been the norm, South Africa dominates in PV capacity. At least three large projects with a combined 175 megawatts have been inaugurated in that country's Northern Cape province since late 2013. The Chinese solar firm Hanergy plans to build a 400-megawatt park in Ghana. And Skypower FAS Energy, a Canadian-Saudi joint venture, signed agreements with Nigerian federal and state governments in May 2014 to install 3,000 megawatts of utility-scale PV there by 2019. PV remains the most rapidly growing energy technology by a wide margin. Indeed, global PV installations for 2014 should reach at least 40,000 megawatts, expanding world PV capacity by another 30 percent. As concerns about climate change grow, solar PV has firmly established itself as an integral player in the transition from fossil fuels.

IV SOLAR ENERGY NEW TRENDS

Flower Power for Better Solar Cells

With a surface resembling that of plants, solar cells improve light-harvesting and thus generate more power. Scientists reproduced the epidermal cells of rose petals that have particularly good antireflection properties and integrated the transparent replicas into an organic solar cell. This resulted in a relative efficiency gain of twelve percent. With a surface resembling that of plants, solar cells improve light-harvesting and thus generate more

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power. Scientists of KIT (Karlsruhe Institute of Technology) reproduced the epidermal cells of rose petals that have particularly good antireflection properties and integrated the transparent replicas into an organic solar cell. This resulted in a relative efficiency gain of twelve percent [5]. Photovoltaics works in a similar way as the photosynthesis of plants. Light energy is absorbed and converted into a different form of energy.

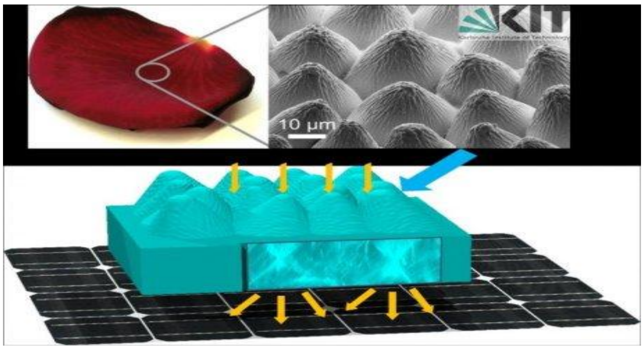

Figure 2

In this process, it is important to use a possibly large portion of the sun's light spectrum and to trap the light from various incidence angles as the angle changes with the sun's position. Plants have this capability as a result of a long evolution process -- reason enough for photovoltaics researchers to look closely at nature when developing solar cells with a broad absorption spectrum and a high incidence angle tolerance. Ultra-thin solar cells can easily bend around a pencil New flexible photovoltaics could power wearable electronics. The flexible photovoltaics, made by researchers in South Korea, could power wearable electronics. Scientists in South Korea have made ultra-thin photovoltaics flexible enough to wrap around the average pencil. The bendy solar cells could power wearable electronics like fitness trackers and smart glasses. The researchers report the results in the journal Applied Physics Letters, from AIP Publishing.

Thin materials flex more easily than thick ones -- think a piece of paper versus a cardboard shipping box. The reason for the difference: The stress in a material while it's being bent increases farther out from the central plane. Because thick sheets have more material farther out they are harder to bend.

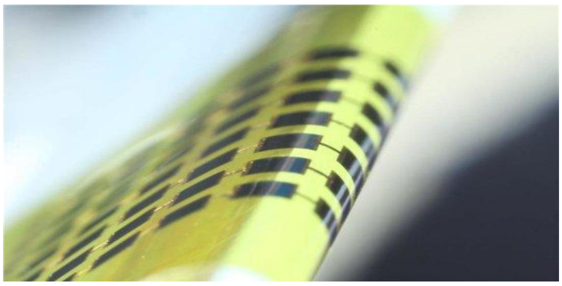
Figure 3

Perovskite solar cells surpass 20 percent efficiency

Researchers are pushing the limits of perovskite solar cell performance by exploring the best way to grow these crystals Researchers are pushing the limits of perovskite solar cell performance by exploring the best way to grow these crystals. EPFL researchers are pushing the limits of perovskite solar cell performance by exploring the best way to grow these crystals. Michael Graetzel and his team found that, by briefly reducing the pressure while fabricating perovskite crystals, they were able to achieve the highest performance ever measured for larger-size perovskite solar cells, reaching over 20% efficiency and matching the performance of conventional thin-film solar cells of similar sizes.

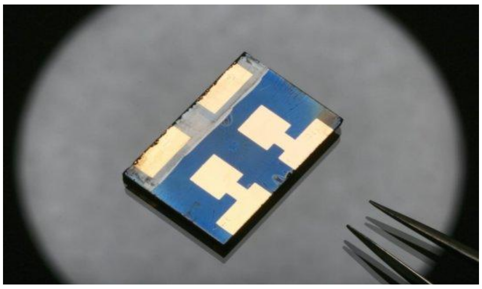
Figure 4

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Bionic leaf turns sunlight into liquid fuel
New system surpasses efficiency of photosynthesis. A new "bionic leaf" system uses solar energy to produce liquid fuel. Scientists have created a system that uses solar energy to split water molecules and hydrogen-eating bacteria to produce liquid fuels. The system can convert solar energy to biomass with 10 percent efficiency, far above the 1 percent seen in the fastest-growing plants.

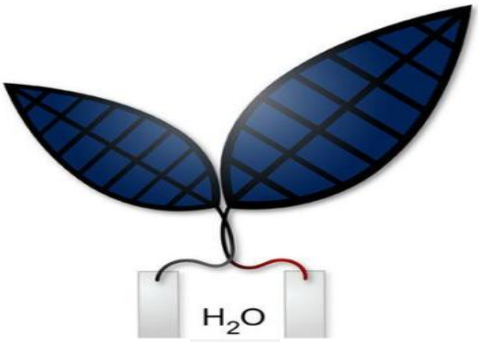

Figure 5

The days of drilling into the ground in the search for fuel may be numbered, because if Daniel Nocera has his way, it'll just be a matter of looking for sunny skies. Nocera, the Patterson Rockwood Professor of Energy at Harvard University, and Pamela Silver, the Elliott T. and Onie H. Adams Professor of Biochemistry and Systems Biology at Harvard Medical School, have co-created a system that uses solar energy to split water molecules and hydrogen-eating bacteria to produce liquid fuels.[4] "This is a true artificial photosynthesis system," Nocera said. "Before, people were using artificial photosynthesis for water-splitting, but this is a true A-to-Z system, and we've gone well over the efficiency of photosynthesis in nature." While the study shows the system can be used to generate usable fuels, its potential doesn't end there, said Silver, who is also a Founding Core Member of the Wyss Institute at Harvard University. "The beauty of biology is it's the world's greatest chemist -- biology can do chemistry we can't do easily," she said. "In principle, we have a platform that can make any downstream carbon-based molecule. So this has the potential to be incredibly versatile."

V CONCLUSION

Remarkable progress has been made in recent years in improving the conversion efficiencies of a number of PV devices. Photovoltaic technology has entered a new era where the urban residential generation of electricity is becoming the dominant application area. Australia is in a good position to maintain a strong presence in this industry as it grows to become a multi-billion dollar industry over the coming decade. A sympathetic environment for the introduction of grid connected residential photovoltaic systems, considered important for this continued local growth, is important. Future PV installations may use electricity produced by solar energy to split water [18] and produce hydrogen (e.g. for hydrogen fuel cells in cars), or to recharge electrically-powered vehicles. Many more possibilities for PV use exist, and they may even power manufacturing facilities for PV panels, which would reduce carbon dioxide emissions from PV manufacturing itself. The numerous potential applications of PV installations and their use as a non-polluting, renewable source of energy are important advantages of PV technology. Improvements in their design and manufacturing will increase their attractiveness for use in energy production for all consumers.

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