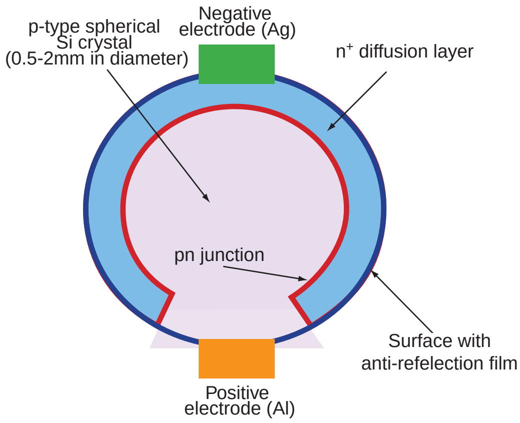
Technology Focus

Spherical Solar Cells Solve Issue of 3-D Sunlight Reception

Solar cells have come to be increasingly utilized. The cumulative capacity of solar cell power generation systems installed in 2000 reached 711MW worldwide and 317MW in Japan. And in the future, the installation of solar power systems is expected to grow rapidly.

Favorable conditions are speeding up the installation of these systems. The improvement in manufacturing technology has made it possible to lower production costs, and the governments of various countries are taking measures for the introduction of solar cell systems. The public on the other hand, is getting more and more aware of the issue of the global environment and the problems of future energy resources.



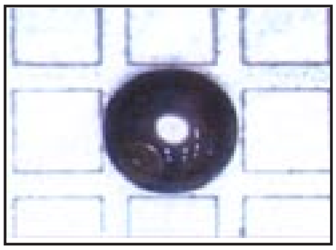


Fig. 2: Cross sectional structure of spherical Si micro solar cell device

Working With the Source

Needless to say, sunlight is the energy source of solar cells, which are designed to capture sunlight and convert it to electricity. As such, a solar cell power generation system is very simple. Unlike fossil energy resources, which are distributed unfairly on the earth, a solar cell power generation system can produce electricity directly anywhere there is light, so that there is no need to worry about the depletion of resources or an adverse effect of waste on the environment. Because of these advantages, the gradual spread of its utilization is a natural course of things.

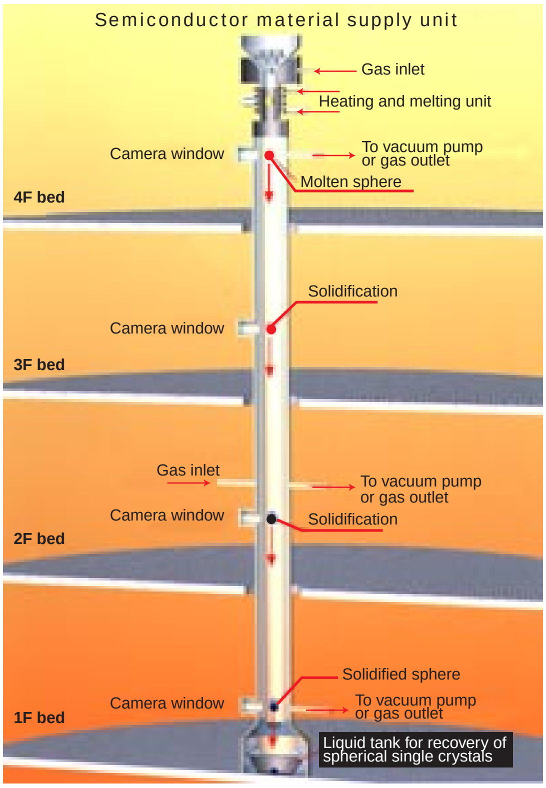


Fig. 1: Equipment and method for manufacturing spherical micro solar cells (model)

However, there are not a few problems to be addressed for a further spread of this power generation system. Basically, it cannot produce electricity when and where there is no light, thus it must be supplemented by other energy sources. Therefore, it must be developed in combination with other energy storage and power generation systems such as batteries and fuel cells.

Overcoming Obstacles

As for the problems with the solar cell itself as a power generation device, a further reduction in the production cost of solar cell systems is needed. As the matter stands at present, the power generation cost by solar cells is about two or three times higher than that of utility power supplied to ordinary households. Furthermore, since a solar cell system is exposed to sunlight, it is important that it should be improved in weatherability and durability so that it may be sufficiently reliable.

Coming Up With Solution

It is more than half a century since the solar cell power system was invented. It has been a product rather in the shade compared with semiconductor ICs and other semiconductor products whose progress has been spectacular.

So far, various materials and manufacturing methods, together with a variety of solar cell types, have been developed and introduced to the market. However, they have been developed based on the types that are designed to capture sunlight with a flat surface. Kyoto Semiconductor Corp. however has developed a spherical micro solar cell that captures sunlight three-dimensionally (3-D) to improve its power generation capacity.

Basic Concept of Spherical Micro Cell

Sunlight is captured by a solar cell not only as direct sunlight but also as light diffused by clouds and as light reflected

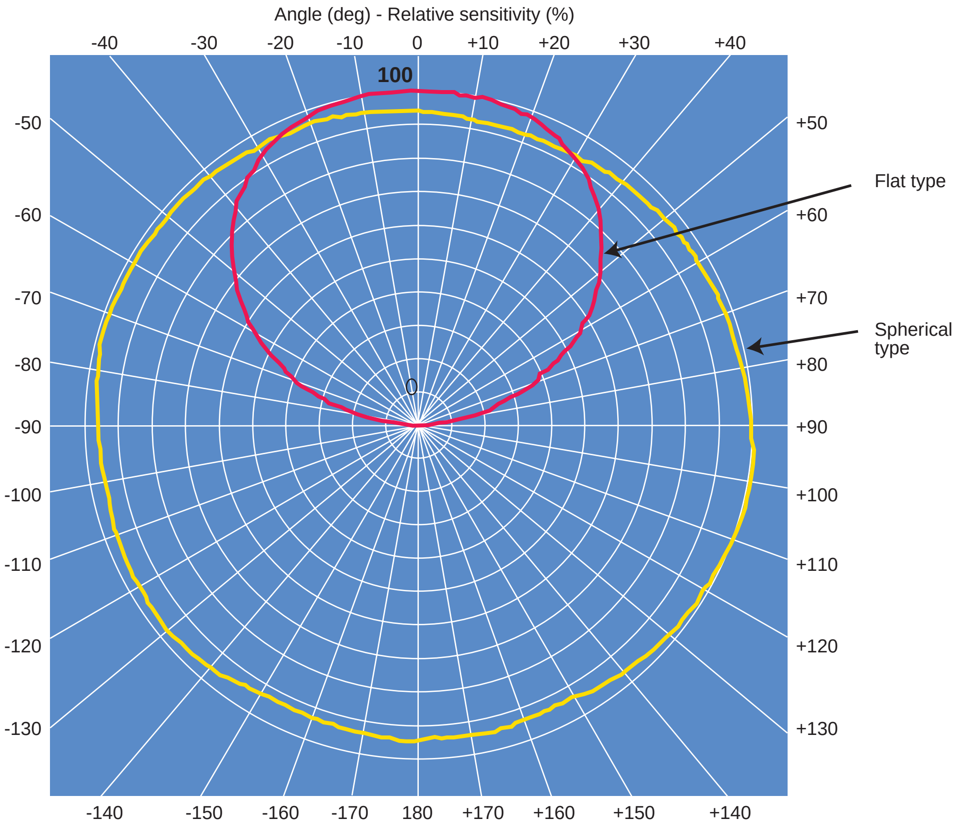


Fig. 3: Directivity characteristics of spherical type compared with flat types

from buildings. The quantity and energy of sunlight as incident light to a solar cell vary according to the positions of the sun, weather conditions and the conditions of the objects around that reflect sunlight. Therefore, the main point of a solar cell is to capture as much sunlight as possible under these conditions to convert it to electricity. Viewed from this standpoint, it cannot be said that solar cells with a flat light reception surface, which are now in practical use, can sufficiently meet these diverse conditions.

In contrast, the basic concept of a spherical solar cell is that a spherical sunlight reception surface can capture light in all directions and increase its power generation capacity and that it can minimize output fluctuations even under direct sunlight and even when the angle of reflected incident light changes. Furthermore, the diameter of a spherical solar cell should be reduced in order to increase the proportion of the light reception surface area of a semiconductor crystal to its volume so as to raise the efficiency of the material.

Manufacture of Spherical Silicon Single Crystals

Since silicon exists in abundance as a natural material and can be obtained at a relatively low cost, almost all solar cells use this material. Compared with amorphous and polycrystalline silicon, single crystal silicon has higher conversion efficiency of light to electricity. It also exhibits higher reliability as it suffers deterioration and other problems less than other materials.

The spherical micro solar cell is made by using a sphere (with a diameter of 0.5 to 2mm) of single crystal silicon. The sphere is obtained in the following manner: A certain amount of material silicon is fed to the upper part of a drop tube, 14m high, and is melted and made to fall in a free state through the tube. The molten material silicon becomes spherical and solidifies in the course of the fall.

Impurities contained in the material silicon are also removed in this process by evaporation and segregation. This process -- the manufacture of spherical single crystals close in size to finished cells in the course of crystal manufacture -- eliminates conventional production processes such as the pulling of single crystal ingots and their slicing, thus reducing production costs by saving power. (Fig. 1)

Cell Structure and Its Characteristics

Diffused on the surface of a p-type spherical silicon single crystal without excepting for a part of its surface are n-type impurities, and a thin n-type layer is provided to form a spherical pn junction parallel to the surface of the sphere. After that, a positive and a negative electrode, opposed to each other, are formed in the centers of the p-type and the n-type surface, respectively. Covering the other parts of the surface with anti-reflection film completes a solar cell (Fig. 2). This electrode arrangement makes the cell non-directive and can realize an even

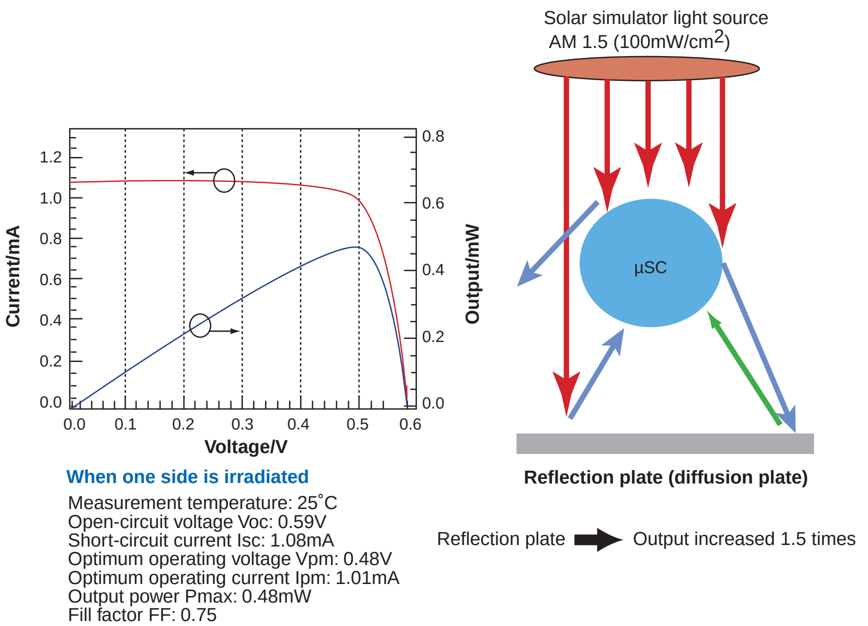
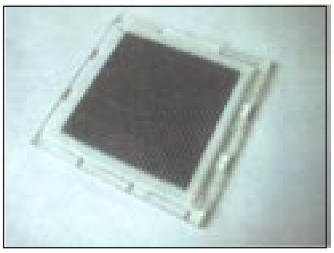
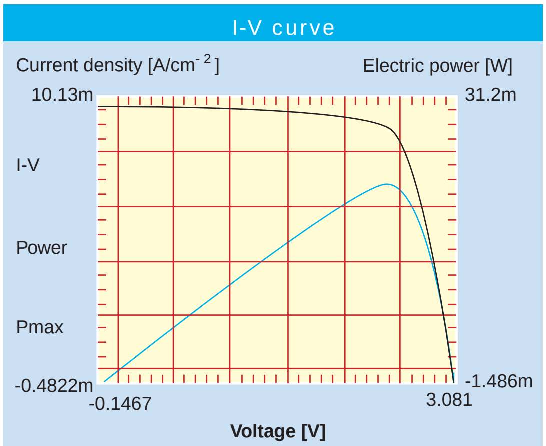


Fig. 4: IV characteristics of spherical micro solar cells



No. of cells: 1760

Aperture: 60 percent
(projected cell area - 40 percent)

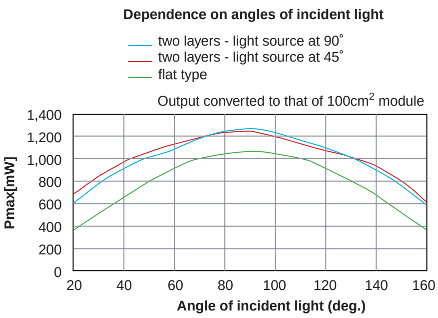


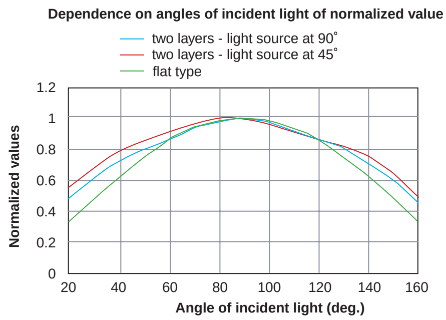
(Reference: IV characteristic curve)

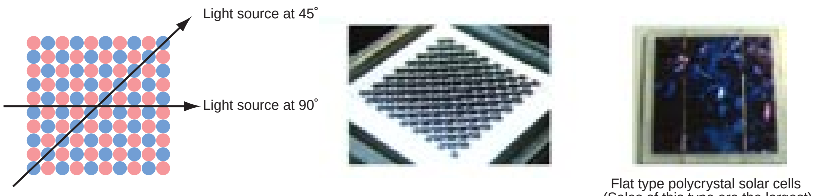
AM1.5 (100mW/cm^2) Temperature=25.2˚C

Voc = 2.984V Isc = 0.4822A
Vpm = 2.338 V Ipm = 0.4504A
Pmax = 1053mW FF = 0.744

Fig. 5: Test-manufactured module (example) -- flat type module for collection of diffused solar radiation







Spherical micro solar cell mini-module

Flat type polycrystal solar cells
(Sales of this type are the largest)

Fig. 6: Spherical type compared with conventional type

distribution of generated current, facilitating a series and parallel connection of the cell to other cells.

Conventional solar cells invariably have a flat light reception surface and pn junctions parallel to the light reception surface, irrespective of the kinds of semiconductors employed, and no matter whether they are bulk, thin film or amorphous crystals. Therefore, their output power is the highest when incident light is vertical relative to it and the reflection increases and the output declines, as the angle of incident light becomes larger. Furthermore, since the light reception surface is generally on one side, no electricity is produced on the other side even if light is shed on it.

In the case of a spherical micro solar cell sphere, a larger part of its surface can receive light excepting for its positive and negative electrodes. It has an extremely low degree of directivity and can capture light in almost all directions to produce electricity (Fig. 3).

Neither the output power of a spherical micro cell can be correctly measured by a conventional method, nor has a method yet been decided for its measurement. Basically, a solar cell should capture direct, reflected and diffused light for power generation, thus it cannot be called an insufficient method to measure the output power of a solar cell by showering light on it vertically from a single light source as is done for the output measurement of flat-type light reception solar cells.

A current-voltage (IV) measurement system using a solar simulator (artificial sunlight source) is employed to measure the IV characteristics of a spherical micro cell, a method adopted for conventional flat-type single junction solar cells (Fig. 4). The output of a solar cell increases 50 percent if a reflection plate is provided on the opposite side of a light source compared with its output measured without a reflection plate. This means that there is ample room for a spherical micro solar cell to improve its output by devising effective ways of collecting reflected light.

The light-electricity conversion efficiency of a test-manufactured spherical micro solar cell was calculated by using the conventional method of output measurement. In case the light of a solar simulator was radiated at AM 1.5 condition in a vertical direction relative to the axis of the electrodes of a solar cell, its light-electricity conversion efficiency -- a proportion of its output power to the radiated intensity of illumination per projected area -- was 18.9 percent without a reflection plate. There is no doubt that this value will be raised through the improvement of design and production technology in the future.

Structure, Characteristics of Spherical Micro Solar Cell Modules

The spherical micro solar cell has a single spherical pn junction. The cell is very small, but its maximum open voltage is the same as that of a larger flat junction type cell.

If spherical micro solar cells are combined, they respond to the need for a large capacity power source as well as for a small capacity power source. The cells are spherical and excellent in mechanical strength, and a necessary number of these cells can be connected for series or parallel connection. A small current and high voltage module of spherical micro solar cells is economical, as it is small as a whole because of its low current, though the number of cells connected in series is large.

The test-manufactured module of spherical silicon micro solar cells is simple in structure (Fig. 5). The module is connected in series and parallel with fine copper wire, and is mounted on a white resin reflection plate, with its surface covered with transparent resin. Measuring 130 × 130 × 10mm, it has 57 cells connected in series and 30 cells connected in parallel. Under direct daylight in the daytime on a clear day, it develops a voltage of about 25V and a power of 1W (max.).

An illustration (Fig. 6) shows the data on the dependence on the angles of incident light of the output of a module of spherical micro solar cells arranged in two layers (upper and lower layer) and that of a flat-type silicon polycrystal solar cell module with the same light reception surface, together with the outside views of these modules.

The micro solar cell module used for the measurement has its cells arranged so that the gaps between adjacent cells are filled with other cells, with a white reflection place underneath.

In case a solar cell is used outdoor for power generation, the angle of incident light changes as time passes. Thus it is not proper to compare the efficiencies of solar cells in terms of light-electricity conversion efficiencies measured only when a solar simulator is in a vertical direction relative to the module. Rather, comparison should be based on the quantity of electricity generated by a day's sunlight. A spherical micro solar module is lower in output decline and produces more electricity than the flat-type solar module even when the angle of incident light is small.

A new spherical solar cell module which is flexible and can utilize light in all directions

The photo above shows a test-manufactured flexible module with spherical solar cells arranged on a flat surface and connected inside a thin transparent resin sheet. This is thin and transparent and can be used in various forms as a solar power generation cell sheet, which partially receives light or partially shields light. The photo shows the module as its four diodes emit light under sunlight.

Featuring Spherical Micro Solar Cells

Compared with conventional solar cells, spherical micro solar cells have simple structure and require a simple production process. Spherical micro solar cells can be manufactured easily into standard modules, and with mass production, manufacturing costs will be further reduced.

Spherical micro solar cell modules respond to a variety of power source needs ranging from an extremely small to a large power source through free connection of cells. Spherical micro solar cell modules can respond in size and shape to diverse design and other application needs. Practically non-directive, they can increase their output power through improvement of the efficiency of light utilization.

With a broad-ranging directivity, there are few restrictions on their mounting, and as they can be shaped freely, they will be used on structures and cars in which importance is attached to design.

About This Article

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