Fraunhofer Institut
Solare Energiesysteme

Press Release

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World Record: 41.1% efficiency reached for multi-junction solar cells at Fraunhofer ISE

Researchers at the Fraunhofer Institute for Solar Energy Systems ISE have achieved a record efficiency of 41.1% for the conversion of sunlight into electricity. Sunlight is concentrated by a factor of 454 and focused onto a small 5mm² multi-junction solar cell made out of GaInP/GaInAs/Ge (gallium indium phosphide, gallium indium arsenide on a germanium substrate).

"We are elated by this breakthrough," says Frank Dimroth, head of the group III-V – Epitaxy and Solar Cells at Fraunhofer ISE. "At all times the entire team believed in our concept of the metamorphic triple-junction solar cells and our success today is made possible only through their committed work over the past years."

Since 1999, Fraunhofer ISE has been developing metamorphic multi-junction solar cells, which are a special type of solar cells using III-V semiconductor compounds. These cells are made out of thin $Ga_{0.35}In_{0.65}P$ and $Ga_{0.83}In_{0.17}As$ layers on GaAs or Ge substrates. These materials are especially suitable for converting sunlight into electricity. They can be combined together, however, only by applying a trick called metamorphic growth. In contrast to conventional solar cells, the semiconductors in these cells do not have the same lattice constant (distance between the atoms in a crystalline structure). This makes it difficult to grow the III-V semiconductor layers with a high crystal quality, since at the interface of materials with different lattice constants strain is present that results in the creation of dislocations and other crystal defects. The researchers at Fraunhofer ISE have succeeded in overcoming this obstacle. They have managed to localize the defects in a region of the solar cell that is not electrically active. As a result, the active

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regions of the solar cell remain relatively free of defects – a prerequisite for achieving the highest efficiencies. Prof. Eicke R. Weber, Director of Fraunhofer ISE emphasizes, "This is an especially good example of how the control of crystal defects in semiconductors can lead to a breakthrough in technology."

This metamorphic crystal growth now enables the researchers to use a much larger range of III-V compound semiconductors for growing their multi-junction solar cells. For these highly efficient structures, it is decisive that the solar spectrum is divided into three equally large spectral regions by a suitable choice of light absorbing materials. In this way all of the three subcells generate the same amount of current. This is an important argument in favor of a serial connected solar cell, where the device current is limited ultimately by the smallest current generated by one of the subcells. By choosing the metamorphic $Ga_{0.35}In_{0.65}P$/ $Ga_{0.83}In_{0.17}As$/Ge material combination, a solar cell structure could be chosen for the first time that is completely current matched under the terrestrial solar spectrum. This is what makes the structure so efficient for solar energy conversion and is an important reason for the achievement of the high efficiencies. At a sunlight concentration factor of 454, the researchers in Freiburg set a world record of 41.1%. Even at a higher sunlight concentration of 880, an efficiency of 40.4% was measured.

The high efficiency multi-junction solar cells are used in concentrating photovoltaic systems for solar power stations in countries with a large fraction of direct solar radiation. Fraunhofer ISE is working together with the company Azur Space in Heilbronn as well as Concentrix Solar GmbH in Freiburg to make this technology competitive as soon as possible. "The high efficiencies of our solar cells are the most effective way to reduce the electricity generation costs for concentrating PV systems," says Dr. Andreas Bett, Department Head at Fraunhofer ISE. "We want that photovoltaics becomes competitive with conventional

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methods of electricity production as soon as possible. With our new efficiency results, we have moved a big step further towards achieving this goal!"

The research on III-V multi-junction solar cells for concentrating photovoltaics at Fraunhofer ISE in the last 15 years has been initially supported by the German Federal Ministry of Education and Research BMBF and later as well by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety BMU. Also the Deutsche Bundesstiftung Umwelt DBU contributed financially by providing several grants for doctoral students.

Text of the PI and photos can be downloaded from our web page: www.ise.fraunhofer.de

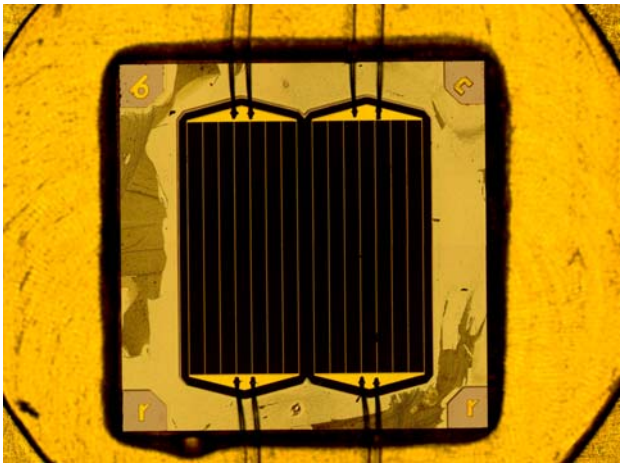

Figure 1: Photo of the new world record solar cell made of $Ga_{0.35}In_{0.65}P/Ga_{0.83}In_{0.17}As/Ge$ with a cell area of 5.09 mm².

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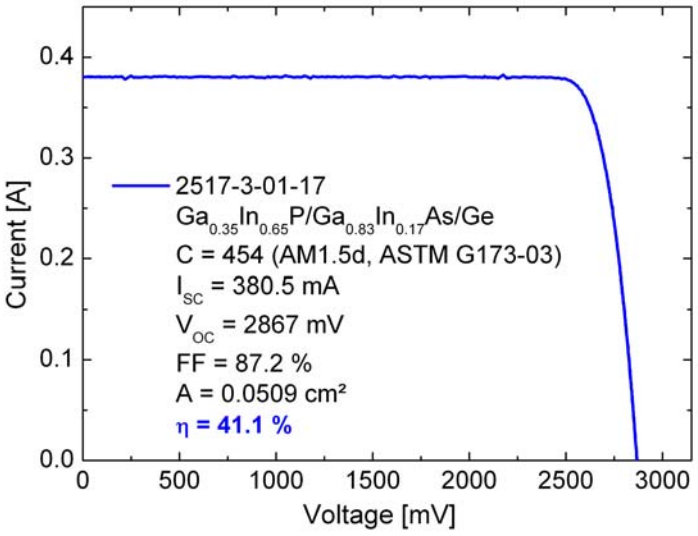

Figure 2: IV characteristics of the GaInP/GaInAs/Ge triple junction solar cell at a solar concentration of 454 suns. The measurements were carried out by the CalLab at Fraunhofer ISE.

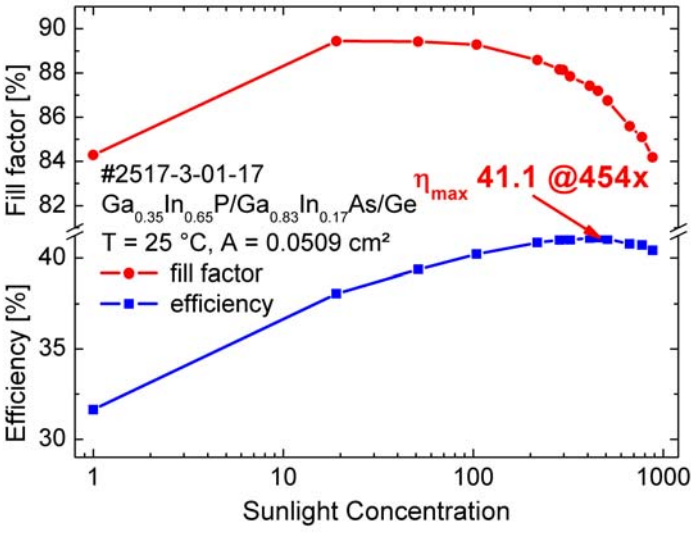

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Figure 3: Dependence of the efficiency on the concentration factor of sunlight. The measurements were carried out by the CalLab at Fraunhofer ISE.

Figure 4: The research team at Fraunhofer ISE celebrates their success in reaching a new world record efficiency with the Institute Director Prof. Eicke Weber (center), Dept. Head Dr. Andreas Bett (left) and the Group Leader Dr. Frank Dimroth (right).

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