Self-organized indium arsenide quantum dots for solar cells

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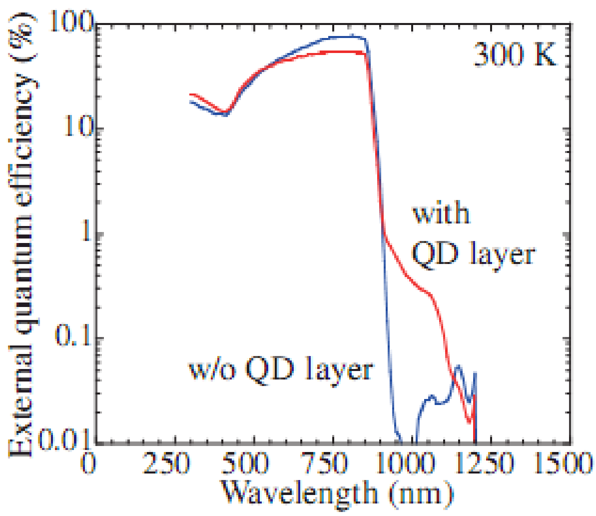


External quantum efficiency of solar cell with only one InAs-QD layer

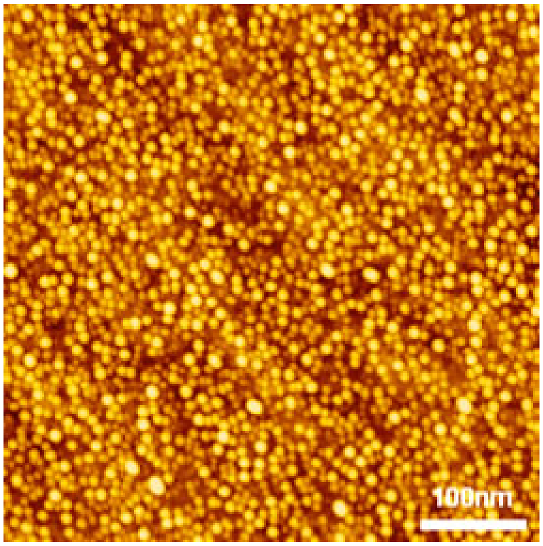
Kouichi Yamaguchi is internationally recognized for his pioneering research on the fabrication and applications of 'semiconducting quantum dots' (QDs). "We exploit the 'self-organization' of semiconducting nanocrystals by the 'Stranski-Krasnov (SK) mode of crystal growth for producing ordered, highly dense, and highly uniform quantum dots," explains Yamaguchi. "Our 'bottom-up' approach yields much better results than the conventional photolithographic or 'top-down' methods widely used for the fabrication of nano-structures."

Notably, electrons in quantum dot structures are confined inside nanometer sized three dimension boxes. Novel applications of 'quantum dots'—including lasers, biological markers, qubits for quantum computing, and photovoltaic devices—arise from the unique opto-electronic properties of the QDs when irradiated with light or under external electromagnetic fields.

"Our main interest in QDs is for the fabrication of high efficiency solar cells," says Yamaguchi. "Step by step we have pushed the limits of 'self-organization' based growth of QDs and succeeded in producing highly ordered, ultra-high densities of QDs."

The realization of an unprecedented QDs density of 5 x 10^{11} cm^{-2} in 2011 was one of the major milestones in the development of 'self-organization' based semiconducting QDs for solar cells by Yamaguchi and his colleagues at the University of Electro-Communications (UEC). "This density was one of the critical advances for achieving high efficiency quantum dot based photo-voltaic devices," says Yamaguchi.

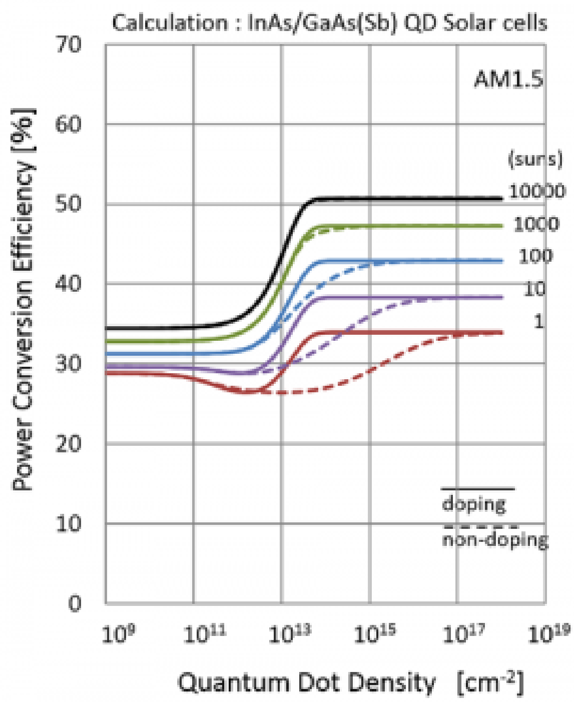
Specifically, Yamaguchi and his group used molecular beam epitaxy (MBE) to grow a layer of InAs QDs with a density of 5 x 10^{11} cm^{-2} on GaAsSb/GaAs (100) substrates. Importantly, the breakthrough that yielded this high density of highly ordered QDs was the discovery that InAs growth at a relatively low substrate temperature of 470 degrees Celsius on Sb-irradiated GaAs layers suppressed coalescence or 'ripening' of InAs QDs that was observed at higher temperatures. Thus the combination of the Sb surfactant effect and lower growth temperature yielded InAs QDs with an average height of 2.02.5 nm.



InAs QD density: 1.0×10^{12} cm^{-2}

The potential for photovoltaic device applications was examined by sandwiching a single layer of InAs QDs in a pin-GaAs cell structure. The resulting external quantum efficiency of these solar cell structures in the 900 to 1150 nm wavelength range was higher than devices with the QD layer.

"Theoretical studies suggest QDs solar cells could yield conversion efficiencies over 50%," explains Yamaguchi. "This is a very challenging target but we hope that our innovative approach will be an effective means of producing such QD based high performance solar cells. We have recently achieved InAs QDs with a density of 1 x 10^{12} cm^{-2}."



Variation of power conversion efficiency with quantum dot density (calculated results).

More information: Edes Saputra, Jun Ohta, Naoki Kakuda, and Koichi Yamaguchi, "Self-Formation of In-Plane Ultrahigh-Density InAs Quantum Dots on GaAsSb/GaAs(001)", *Appl. Phys. Express* 5, 125502, (2012). DOI: dx.doi.org/10.1143/APEX.5.125502

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Provided by University of Electro Communications