Microdome p-GaN surface boosts nitride PV

Taiwan team develops simple, mechanically robust process to create surface texturing.

Taiwan-based researchers have boosted the energy conversion efficiency of nitride semiconductor solar cells (SCs) by 102% by texturing the p-type gallium nitride (p-GaN) contact layer with ‘microdomes’ [Cheng-Han Ho et al, Appl. Phys. Lett., vol101, p023902, 2012]. The collaborators were variously based at National Taiwan University, National Central University, and Ubilux Optoelectronics Corp.

One effect of the microdomes is to reduce the amount of reflection at the surface of nitride semiconductor solar cells due to the large difference in refractive index (~2.4) with that of air (1). Such structures have previously been used by researchers at Lehigh University in the USA to improve extraction efficiency in light-emitting diodes.

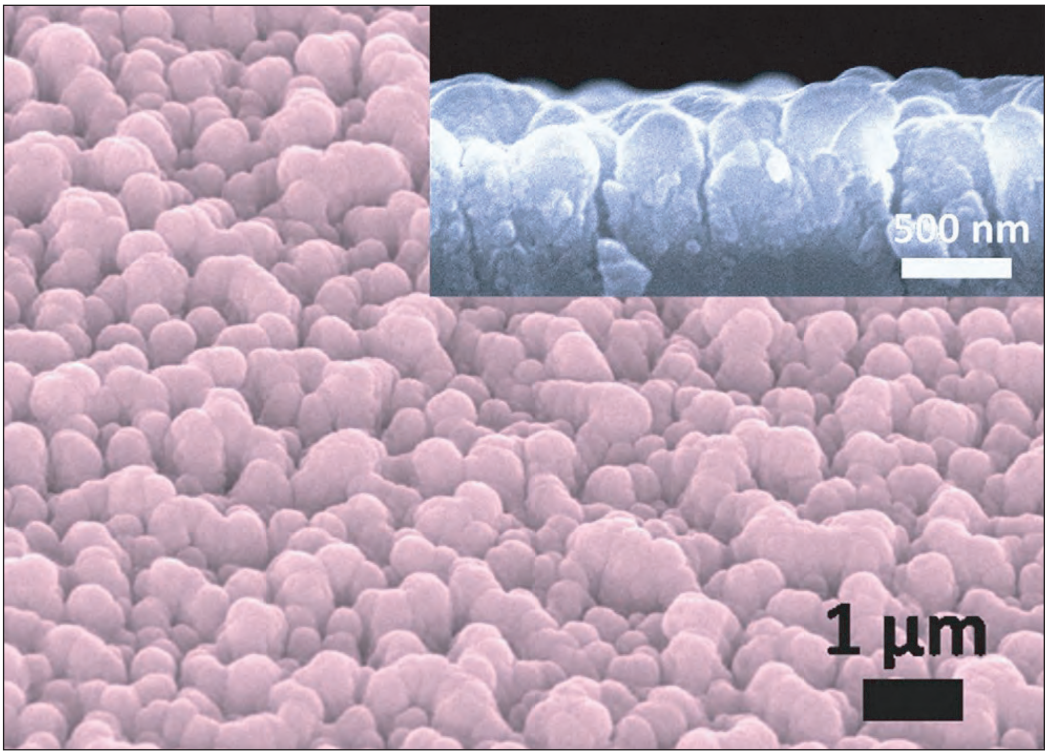

Figure 1. 45°-tilted SEM image of MQW solar cells with p-GaN microdomes. Inset shows cross-sectional SEM image.

The Taiwan researchers used a simple, mechanically robust process that textured of the top surface of p-GaN on indium gallium nitride (InGaN) multi-quantum well (MQW) structures that convert light to electrons and holes.

The surface texture was controlled through the tri-methyl-gallium flow rate and substrate temperature during epitaxial growth. A flat surface is achieved by a flow rate of 40–50μmol/min and temperature of 950–1100°C. Micro-roughened p-GaN (Figure 1) results from higher flow rates (more than 55μmol/min) and lower temperature (less than 920°C).

The p-GaN microdomes were 530nm (±250nm) in height and 600nm (±370nm) in diameter. Specular reflection experiments on flat and microdome p-GaN showed a reduction in reflection of at least half in the 340–600nm wavelength range.

The surface texturing improves both short-circuit current (J_{sc}) and fill-factor (FF, ratio of maximum obtainable power to product of short-circuit current and open-circuit voltage, V_{oc}). These improvements (Table 1) give a conversion efficiency of 0.87%, which is a 102% increase compared with a conversion efficiency of 0.43% for a flat-surface device.

The low conversion efficiency is due to the cut-off wavelength for these devices (~450nm) being shorter than the peak of the incident solar spectrum (~500nm). The devices therefore miss out on the bulk of the energy contained in solar radiation. It is hoped that further development will lengthen the cut-off

Table 1. PV characteristics of InGaN MQW solar cells with two kinds of surface structure.

Surface structure	J_{sc} (mA/cm^2)	V_{oc} (V)	FF (%)	η (%)
Flat	0.43	2.28	44.1	0.43
Microdomes	0.54	2.23	72.4	0.87

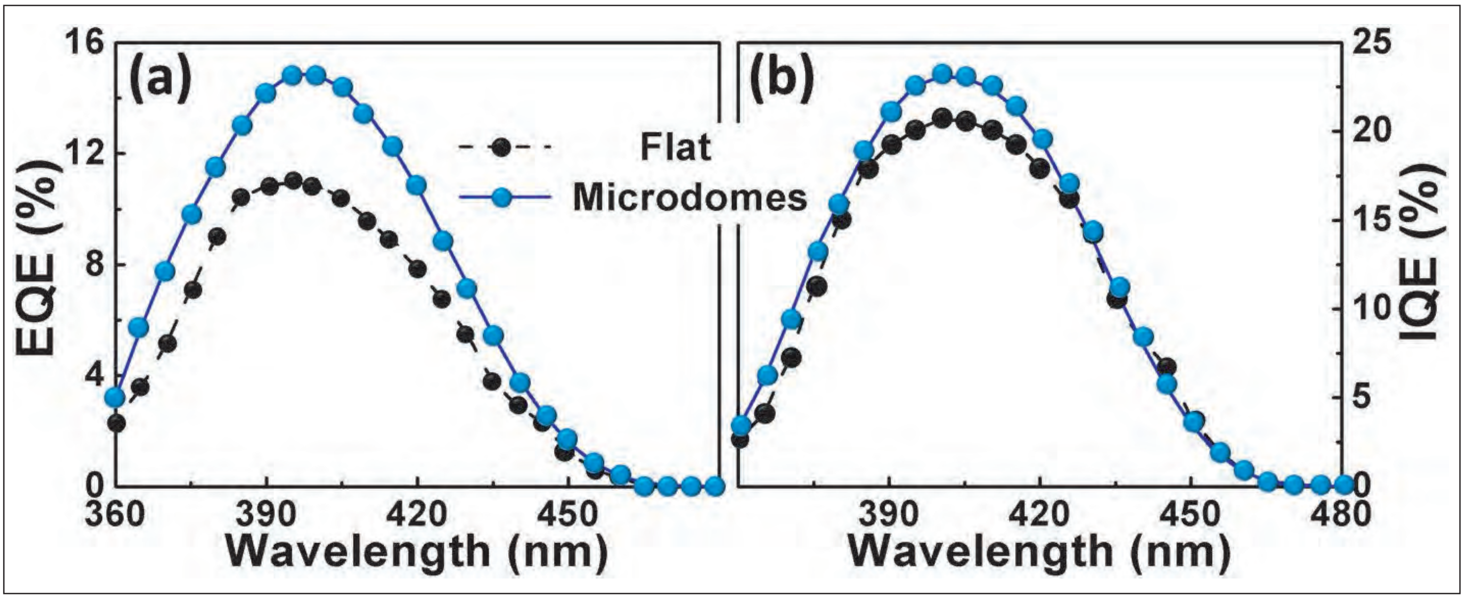

Figure 2. (a) EQE curves and (b) IQE curves for solar cells with two kinds of surface structure.

energy, enabling the use of such devices as part of multi-junction cells.

The fill-factor boost is thought to partly originate from strain reduction of the microdome layer leading to reduced piezoelectric fields in the device, alongside the suppressed reflection at the air/p-GaN interface. Reduced piezoelectric fields can improve photo-carrier separation/collection.

Spectral measurements of external (EQE) and internal (IQE) quantum efficiencies showed improvement from a microdome p-GaN layer falling in the range 360–450nm (Figure 2). The IQE improvement could originate in the lower piezoelectric field, but more detailed experiments are needed to correctly determine IQE, it is said. ■

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