The buffer had a TDD of ~1×107 cm-2 from defect counting of several ECCI images, a sufficiently low value to achieve high-performance GaAsP 1J cells and on par with devices in the literature; the average TDD on top of the DBRs was similar to the buffer alone. For the GaAsP/AlxGa1-xAsP DBRs, the experimental reflectance spectra (measured in air) had peak values of 80 and 94% for x = 0.4 and x = 0.8, respectively, with the higher index contrast of Al0.8Ga0.2AsP providing a significant improvement in both peak reflectance and reflectance bandwidth. The experimental spectra also matched our simulations closely, with the experimental reflectance slightly higher due to over-estimation of parasitic absorption in the simulated GaAsP layers. Lastly, early cell simulations show enhanced QE with the added DBRs, enabling a tandem cell efficiency improvement of as much as 1.1%. In summary, we grew (Al)GaAsP DBRs on thinned buffers with reasonable TDD values for high-efficiency GaAsP solar cells and reflectance profiles closely matching simulated values, and also showed simulated improvements in QE. At the conference, we plan to present Al0.2Ga0.8AsP/Al0.8Ga0.2AsP DBRs without the parasitic absorption of GaAsP and further refinements to our simulations of the effects of DBRs on solar cell performance.

1 Richter, A. et al. IEEE J. Photovoltaics 3, 1184–1191 (2013) 2 Lepkowski, D. L. et al. Sol. Energy Mater. Sol. Cells 230, 1–9 (2021) 3 Fan, S. et al. Cell Reports Phys. Sci. 1, 100208 (2020)

09:30 AM

Translucent Solar Cells Fabricated with Nanosecond Pulsed Laser Beams

Mr. Ashif Chowdhury[1], Prof. Heayoung Yoon[1]
[1]University of Utah

Translucent solar cells offer a promising option for building-integrated photovoltaic technologies (BiPV), capable of generating substantial electrical power while allowing some sunlight to pass through to the building. Among various designs, architectures using perforated microstructures enable adjustable transparency. However, conventional lithography and etching processes are limited in the scalability of these cells to PV module levels.
This work explores a rapid patterning technique utilizing a nanosecond laser beam (λ = 355 nm) to create microhole arrays on commercial Si solar cells. In our prototype cells, this method produces a hexagonally arranged array of microholes (≈ 22 µm in diameter), with a microhole spacing of 10's of µm to 100's µm. The array, measuring 20 mm × 7 mm, is created in under 7 seconds. Photovoltaic analysis of cells with 120 µm spacing (transparency ≈ 1 %) shows retention of over 93 % of the initial short-circuit current density (Jsc), with the open-circuit voltage (Voc) and fill factor (FF) maintaining 85 % and 80 % of their initial values, respectively. This suggests that most damage is localized near the junction region. Electron microscopy reveals a SiOx layer beneath the Si surface, likely formed by reactions with ambient oxygen. We will address optimizing the process to reduce laser-induced damage at the junction and remove surface debris to boost device performance.

9:45 AM
Coffee Break
ESJ Building

10:15 AM
Growth of Group III-Nitrides
Session Chairs: Russell Dupuis (Georgia Institute of Technology), Theeradetch Detchprohm (Georgia Institute of Technology)
ESJ 0202

10:15 AM

Epitaxial Growth of Multichannel AlScN/GaN Heterostructures by Molecular Beam Epitaxy (Student)

Mr. Thai-Son Nguyen[1], Mr. Chandrashekhar Savant[1], Prof. Huili (Grace) Xing[1], Prof. Debdeep Jena[1]
[1]Cornell University

AlScN is a promising ultrawide bandgap semiconductor material with lattice-matching and high-k capabilities strongly desired for GaN electronics. Molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD) have been employed to create single-channel AlScN/GaN HEMT heterostructures [1, 2, 3] with two-dimensional electron gases (2DEGs) of electron densities surpassing 2 ×
1013/cm2, electron mobilities exceeding 1500 cm2/V.s, and sheet resistances below 250 Ω/□ [2]. HEMTs fabricated using these heterostructures exhibit remarkable performance characteristics, such as a current density greater than 3
A/mm [4] and an output power exceeding 8 W/mm at 30 GHz [3]. Ferroelectric AlScN barrier layers enable ferroelectric gating effects, enabling FerroHEMTs [4] with the potential for high-speed, high-power reconfigurable single-channel transistors. But multichannel AlScN/GaN heterostructures have not been reported. Compared to AlN, AlGaN, or AlInN barriers, AlScN is lattice matched to GaN at approximately 9-11% Sc, thereby allowing for enhanced conduction band offset and superior 2DEG confinement without suffering from strain-induced structural degradation. Additionally, AlScN possesses a stronger spontaneous polarization than AlGaN and AlInN, suggesting the potential for thinner stacks and higher total sheet charge densities in AlScN/GaN multichannel structures.
We report the MBE growth and transport properties of multichannel AlScN/GaN multichannel heterostructures in this work. Near lattice-matched (11-12% Sc) composition was targeted for AlScN barriers. Samples of five-channel AlScN/GaN and AlScN/AlN/GaN were grown on GaN-on-sapphire templates with AlScN barrier thickness of 10 nm and various GaN channel thicknesses between 20 nm and 50 nm. 2 x 2 µm area atomic force micrographs showed smooth surfaces with root-mean-square (RMS) roughness measuring below 1 nm. Both AlScN/GaN and AlScN/AlN/GaN heterostructures were pseudomorphically grown onto the GaN substrate as verified by reciprocal space mapping (RSM). Sharp interfaces were achieved by MBE and the barrier thicknesses were precisely controlled, as confirmed by X-ray diffraction (XRD) analysis. These five-channel heterostructures consistently exhibited total sheet charge densities of approximately 1 × 1014/cm2, among the highest carrier densities ever reported for multichannel GaN