Department of Electrical and Computer Engineering
Materials Engineering Program
Texas Center for Superconductivity at Univ. of Houston
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New possibilities in nitride photonics exploiting porosity

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Abstract:

Porous semiconducting nitrides are effectively a new class of semiconducting material, with properties distinct from the monolithic nitride layers from which devices from light emitting diodes (LEDs) to high electron mobility transistors are increasingly made. The introduction of porosity provides new opportunities to engineer a range of properties including refractive index, thermal and electrical conductivity, stiffness and piezoelectricity. Quantum structures may be created within porous architectures and novel composites may be created via the infiltration of other materials into porous nitride frameworks. A key example of the application of porous nitrides in photonics is the fabrication of high reflectivity distributed Bragg reflectors (DBRs) from alternating layers of porous and non-porous GaN. These reflectors are fabricated from epitaxial structures consisting of alternating doped and undoped layers, in which only the conductive, doped layers are electrochemically etched. Conventionally, trenches are formed using a dry-etching process, penetrating through the multilayer, and the electrochemical etch then proceeds laterally from the trench sidewalls. The need for these trenches then limits the device designs and manufacturing processes within which the resulting reflectors can be used. We have developed a novel alternative etching process, which removes the requirement for the dry-etched trenches, with etching proceeding vertically from the top surface through channels formed at naturally-occurring defects in the crystal structure of GaN. This etch process leaves an undoped top surface layer almost unaltered and suitable for further epitaxy. This new defect-based etching process provides great flexibility for the creation of a variety of sub-surface porous architectures on top of which a range of devices may be grown. Whilst DBR structures enable improved light extraction from LEDs and the formation of resonant cavities for lasers and single photon sources, recent development also suggest that thick, subs-surface porous layers may enable strain relaxation to help improve the efficiency of red microLEDs for augmented reality displays. Meanwhile, the option of filling pores in nitride layers with other materials provides new opportunities for the integration of nitrides with emerging photonic materials, such as the hybrid-perovskite semiconductors, with perovskites encapsulated in porous nitride layers demonstrating greatly improved robustness against environmental degradation.

Short Bio:
Rachel Oliver received her MEng (2000) and PhD (2003) degrees from the University of Oxford, UK. She then moved to Cambridge as a Research Fellow at Peterhouse College, and later won a prestigious Royal Society University Research Fellowship. In 2011, she took up her permanent academic position at the University of Cambridge and she is currently Professor of Materials Science and Director of the Cambridge Centre for Gallium Nitride. She held a Leverhulme Senior Research Fellowship in 2015-2016 and delivered the Rank Prize Lecture in Photonics in 2018. She was one of the Women in Engineering Society's Top 50 Women in Engineering in 2020.

Rachel's research focusses on understanding how the small scale structure of nitride materials effects the performance and properties of devices. She uses expertise in microscopy and materials growth to develop new nanoscale nitride structures which will provide new functionality to the devices of the future. She was the first to apply atom probe tomography to nitride materials, developed the first InGaN-based single photon source, and most recently has patented novel methods compatible with large scale manufacturing for the porosification of nitride materials. She is a founder and Chief Scientific Officer of Poro Technologies Ltd, a University spinout company exploiting her group's research on porous nitrides, and hence developing novel red microLEDs.

Rachel is also a passionate advocate for increased equality, diversity and inclusion in science and engineering and a leader and founder member of The Inclusion Group for Equity in Research in STEMM (TIGERS). She is an Equality and Diversity Champion for the University of Cambridge School of Physical Sciences and has addressed the Parliamentary and Scientific Committee on equity issues.