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InGaN Quantum Dot Fabrication using Quantum Size Controlled Photoelectrochemical Etching.

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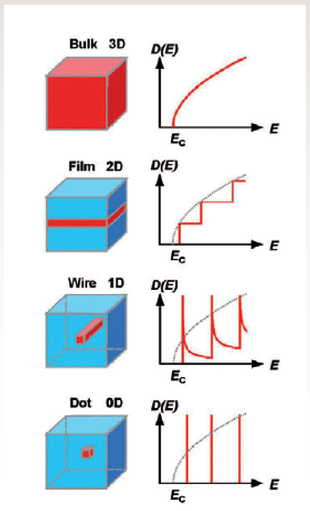
Problem:

Quantum dots (QDs) demonstrated using colloidal or Stranski-Krastanov growth methods result in ensembles of dots with large size distributions at random locations on a surface. Improved device performance and enhanced functionality could be achieved if we could realize improved size distributions and deterministic positioning of QDs on a surface.

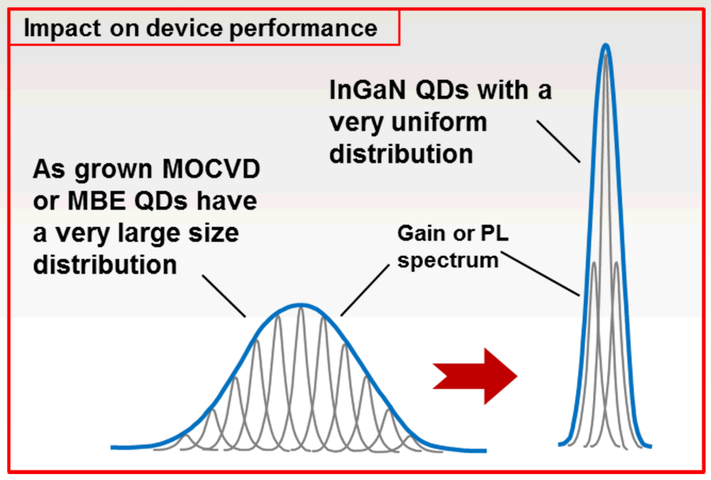
Approach:

We have developed a new method of quantum QD fabrication using band gap selective photoelectrochemical (PEC) etching. During etching, as a nanoscale sized piece InGaN enters the quantum size regime, the QD energy levels increase, absorption stops, and etching stops. We call this quantum size control. Particle size and emission wavelength are determined by the PEC etch wavelength.



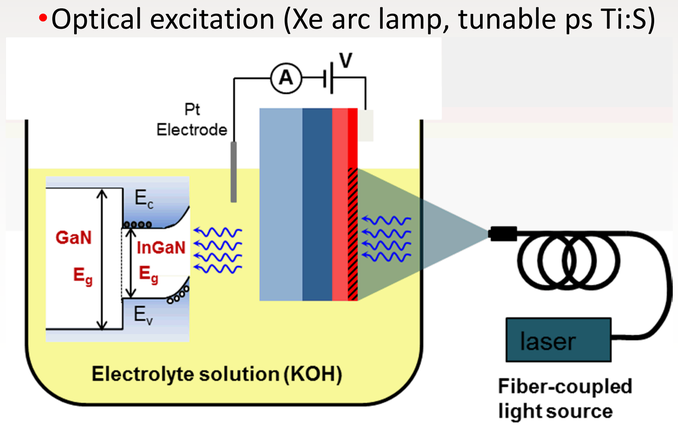
Monodisperse QD Distributions

Impact on device performance

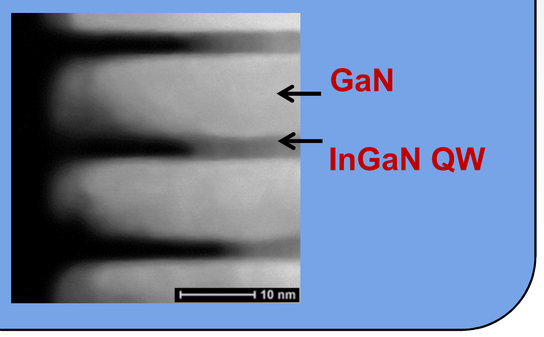


Photoelectrochemical (PEC) Etching:

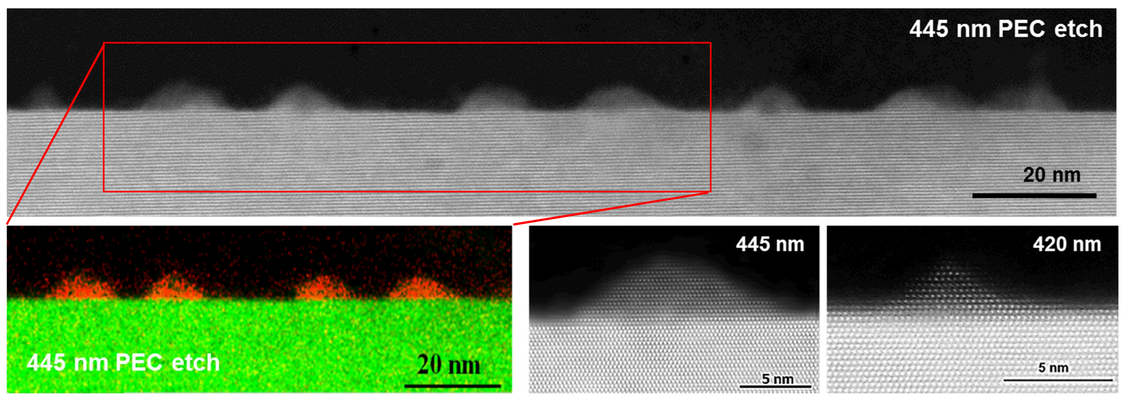
- Very few wet etches work for III-nitrides
- **Band gap selective (Etch InGaN over GaN)**
- Optical excitation (Xe arc lamp, tunable ps Ti:S)

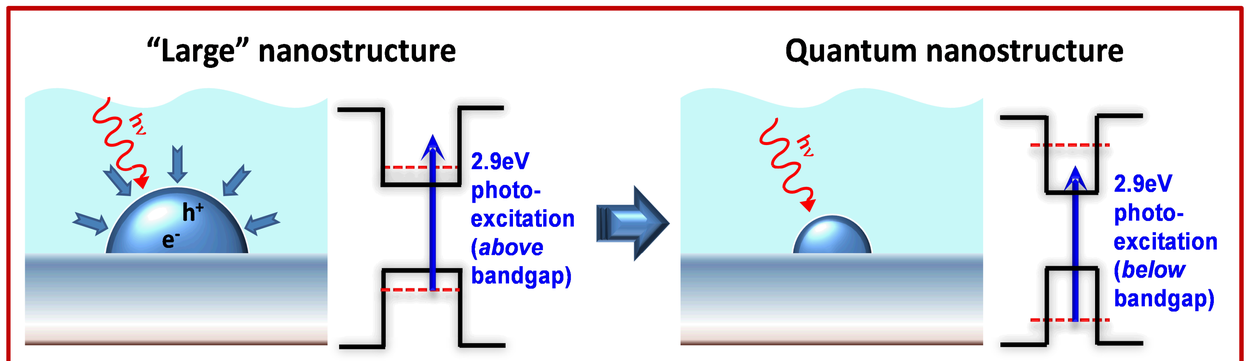


Band gap selective nature of PEC etching - InGaN is etched, but GaN is not.



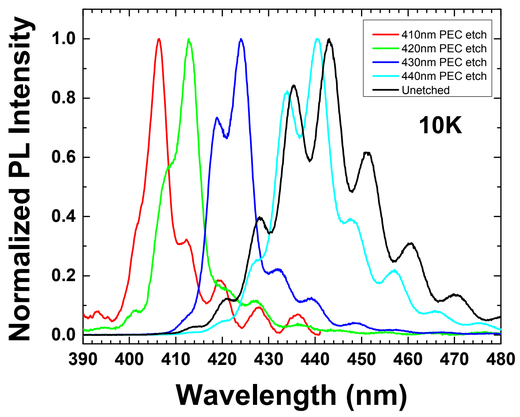
TEM images of PEC-etched InGaN QDs:



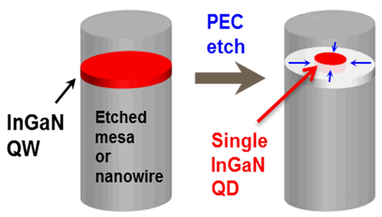


Photoluminescence from PEC-etched InGaN QDs:

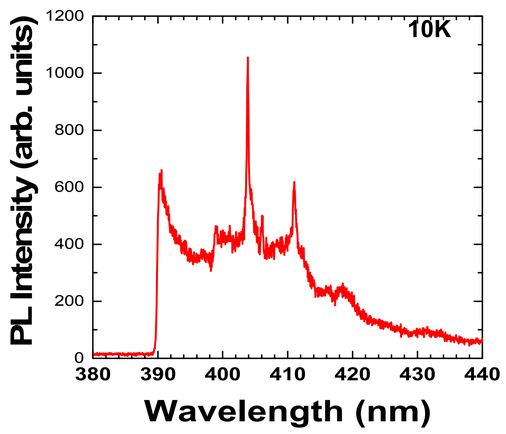
Emission from ensembles of QDs
- FWHM narrows to ~ 6nm



Fabrication of single QDs:



Emission from single QDs:



Conclusions:

- Demonstrated PEC-etched InGaN QDs
- Potential for very narrow size distributions
- Potential for deterministic placement of single QDs
- Details of PEC etch are not well understood
- Fundamental limits are not well understood
- Could be extended to other material systems
  - e.g. GaAs, InP, Si

Impact:

- Ties to the SEQIS research challenge
- This technology would impact QD lasers
  - Improved gain, efficiency, temperature performance
- Deterministic placement at the nanoscale
  - Single photon sources, emitters in cavities
  - Etch nanowires down to quantum wires

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National Nuclear Security Administration

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