Nitride Single Photon Sources

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Single photon sources are a key enabling technology for quantum communications, and in the future more advanced quantum light sources may underpin other quantum information processing paradigms such as linear optical quantum computation. In considering possible practical implementations of future quantum technologies, the nitride materials system is attractive since nitride quantum dots (QDs) achieve single photon emission at easily accessible temperatures [1], potentially enabling the implementation of quantum key distribution paradigms in contexts where cryogenic cooling is impracticable.

However, nitride heterostructures grown along the polar c-axis typically exhibit large internal electric fields due to the polarisation mismatch between different alloys and to piezoelectric effects. Electrons and holes captured by a QD are separated by the field, reducing their probability of recombination and limiting the single photon source emission rate. Whilst a number of approaches are being explored to overcome this issue, utilisation of nitride QDs grown on non-polar surfaces is particularly attractive since not only are the internal fields expected to be greatly reduced, but also the emission should be polarised along a specific crystal direction due to changes in the valence band structure induced by the asymmetric strain state of the material.

We have developed three methods for the growth of non-polar InGaN QDs utilising variously: modified forms of droplet epitaxy [2] and Stranski-Krastanov growth [3] on planar non-polar surfaces and exploitation of a self-assembled nanomask on the non-polar sidewalls of nanorod structures [4] (Figure 1). In all cases, we observe highly polarised emission with a short radiative lifetime, and the properties of the QDs correlate well with the predictions of a model based on k.p theory. The most successful QDs exhibit polarised optically-pumped single photon emission up to 220 K, a temperature accessible by on-chip cooling [5] (Figure 2), and we have demonstrated highly polarised electroluminescence from a single photon light emitting diode [6] (Figure 3).

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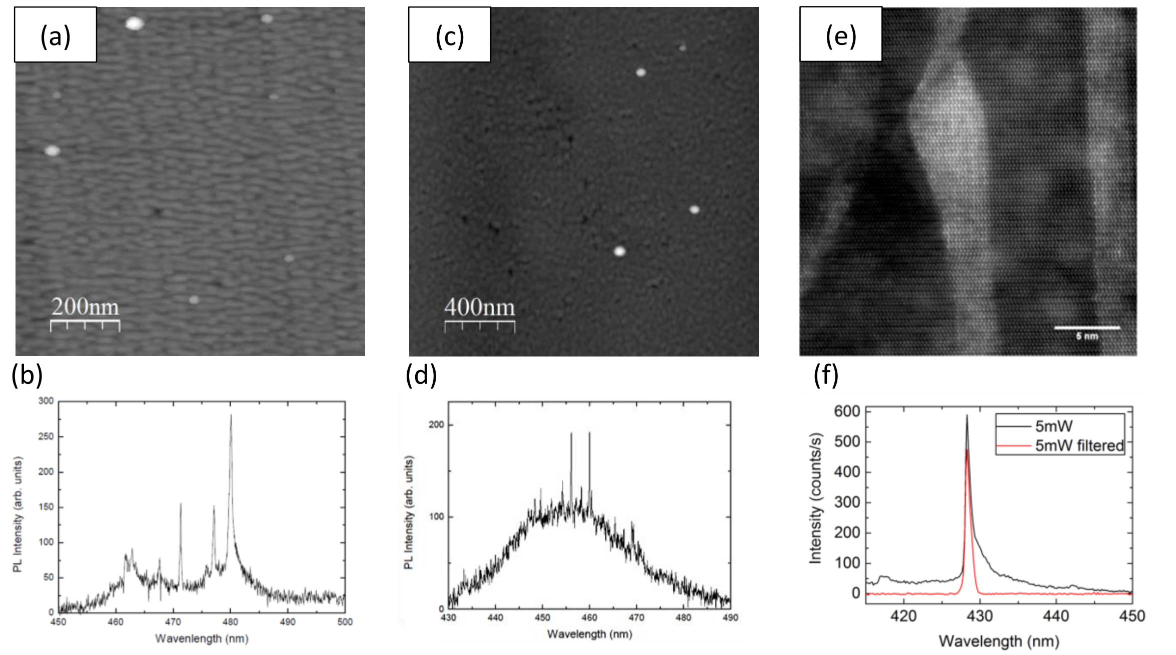

Figure 1: Microstructural and optical characterisation of non-polar nitride quantum dots grown by different methods: (a) Atomic force microscopy of nanostructures used to form quantum dots in midwifed droplet epitaxy, micro-photoluminescence from which is shown in (b). (c) Atomic force microscopy of nanostructures formed using an alternative self-assembly approach related to Starnski-Krastanov growth, micro-photoluminescence from which is shown in (d). (e) Transmission electron microscopy of quantum dots on a nanowire sidewall, micro-photoluminescence from which is shown in (f).

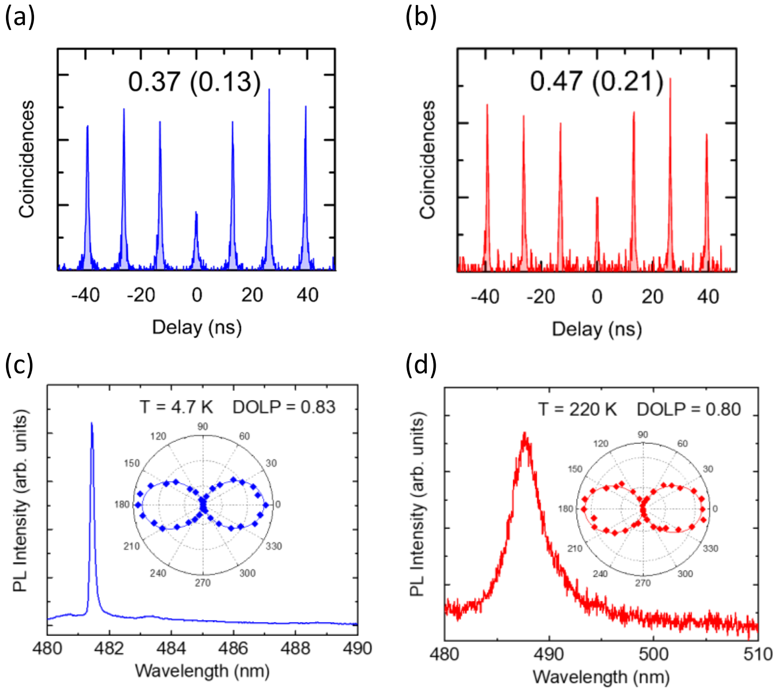

Figure 2: For quantum dots grown by the modified droplet epitaxy approach, single photon emission is observed at 4 K (a) and persists up to 220 K (b). (Raw $g^2(0)$ values are given on each plot, followed (in brackets) by background corrected values.) For the quantum dot shown in (a) and (b) a degree of linear polarisation of ≥0.8 is seen at both 4 K (c) and 220 K (d).

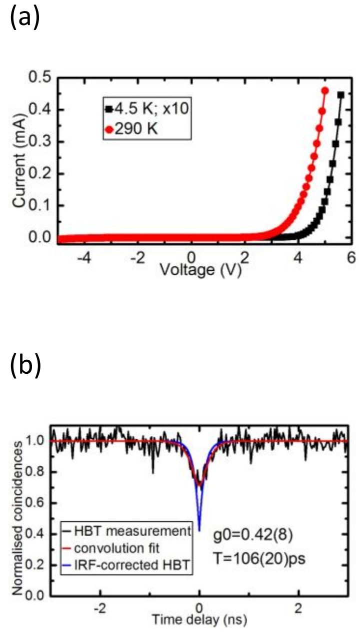

Figure 3.: Using an approach based on Stranski-Krastanov growth, a single photon LED has been fabricated: (a) Current-voltage characteristics, (b) $g^2(\tau)$ data.