Single-photon emitters and bandgap tailoring in dilute nitride nanowires

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Abstract: We develop a new route to create single-photon emitters monolithically integrated on Si substrates; we employ dilute nitrides GaAs nanowires, providing pure quantum emitters in the 900-1100 nm range at cryogenic temperatures.

Quantum light sources based on single and entangled photons are ideal building blocks for quantum communication and powerful information processing. While conventional self-assembled III-V quantum dots have demonstrated very high single-photon purity and brightness, it is quite challenging to grow them on the cost-effective silicon substrates with high quality. Growth on silicon is instead possible for III-V nanowires (NWs), which are filamentary crystals that can be grown in a scalable and flexible way by a bottom-up approach. However, single-photon sources in NWs have yet to reach the maturity of conventional quantum dots.

Here, we discuss two new methods to achieve the desired quantum light emitter properties in NWs. In both cases, we will focus on dilute nitride NWs, where the incorporation of a dilute (<3%) amount of N atoms leads to notable bandgap reduction due to the band-anticrossing interaction between GaAs bands and N levels.

The first approach is similar to the conventional approach of creating quantum emitters *during NW growth*, but we explore novel heterostructure combinations, such as GaAs/GaAsN/GaAs core/shell/shell radial heterostructures. As shown in Fig. 1 a), we exploited the peculiar localizing role of N in the electronic potential of thin dilute nitrides GaAsN NWs, combined with a thin GaAsN shell and high zincblende crystalline quality, to realize highly pure single photon emitters grown on Si substrates [1,2].

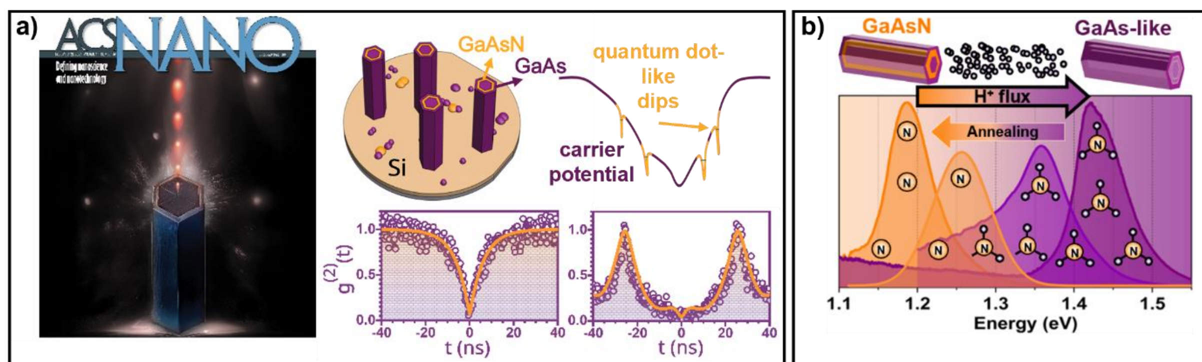

Fig. 1 (a) Quantum light emission properties of thin GaAs/GaAsN/GaAs NWs monolithically grown on Si [1]. (b) Wide-range bandgap engineering through post-growth hydrogenation followed by annealing in thick single GaAs/GaAsN/GaAs NWs [3].

The second approach –more challenging but also very attractive as it can potentially allow for a finer energy tunability– is based on the creation of light emitters *after NW growth*. We have realized controlled hydrogen irradiation, and we will discuss how the formation of N-H bonds can be exploited to achieve on-demand bandgap engineering in thick dilute nitride NWs [3]. As shown in Figure 1 b), thermal annealing of hydrogenated NWs allows for a fine energy tunability over a 300 meV energy range, without any device, external fields, or any new growth process. Additionally, local bandgap engineering to create quantum confined structures can be realized by using partial hydrogenation of the NWs [4], or by employing nanoscale masks and scanning near field optical microscopy to selectively incorporate hydrogen in nanosized regions.

References

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