Large Scale Deterministic Creation of Single Photon Emitters in Silicon Nitride Nanopillars

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Abstract: We demonstrated large scale deterministic creation of single photon emitters in annealed silicon nitride on silicon oxide pillars. The estimated single photon emitter yield is approximately 50% with a lateral accuracy of ±85nm.

1. **Introduction**

As quantum optical technology matures and becomes a viable platform for quantum information technology applications there will be a strong need for quantum optical platforms that are not only high performance but also scalable. In this work we build upon our prior discovery of bright and stable single photon emitters in silicon nitride [1]. Silicon nitride, is already an industry standard platform for visible photonic circuitry [2]. As a result it is one of the most promising platforms for integration with solid state color centers. However, other approaches suffer from the typical issues faced by all hybrid integration schemes: difficulty of fabrication and efficient light coupling [3]. The SiN native emitter promises to circumvent many of these difficulties by allow for homogeneous integration of SiN SPE's with SiN photonic circuitry. This work provides another key step in realizing this vision by demonstrating a method whereby SiN-SiO2 emitters may be fabricated with high yield and relatively good location accuracy allowing for following aligned fabrication steps at scale.

2. Results

To create large scale emitters for this project first high density plasma enhanced chemical vapor deposition (HDPCVD) SiN was grown on SiO2 coated silicon wafers. The SiN was grown to a thickness of approximately 50nm and the oxide is nominally 3um grown commercially on Si via industry standard low pressure chemical vapor deposition (LPCVD). A chrome hardmask was then patterned using electron beam lithography and liftoff. This mask was used during the reactive ion etching (RIE) of the pillars. The etch depth was approximately 90nm, leading to an intentional overetch of ~40nm into the SiO2. This was done to avoid the creation of single photon emitters between pillars. Once the pillars were etched the chrome hardmask was chemically removed and the sampled cleaned with Pure Strip to remove any possible organic contamination. Rapid thermal annealing (RTA) was performed for 60 seconds at 1100C to activate the SiN emitters [1]. Figure 1(a) shows the scanning electron microscope image of the resulting pillar array. The inset shows a cross sectional diagram of the pillar after etching and chrome strip. The pillars have a diameter of 170nm and are spaced 1um apart from each other.

After fabrication and thermal processing photoluminescence (PL) mapping was performed using a homebuilt confocal microscope setup. Results of the spatial mapping of the array can be seen in figure 1(b). The cross in the center of the image is an alignment mark to aid in finding the arrays. Pillars can be seen all around the cross. One thing to note is that the emitter diameter appears much larger in the PL map compared to the SEM due to the convolutional effect of the confocal spot size.

In order to assess the single photon emitter per pillar yield and performance of this method a row of emitters was selected and the emitters were scanned sequentially. This was done to avoid any bias in selection of the emitters based on brightness which might artificially increase the fabrication yield. To assess if a single photon emitter is present second order autocorrelation measurements was taken on 17 different pillars. The result of these autocorrelation measurements can be seen in figure 1(d). The measured autocorrelations were fitted with a standard 3-level model to estimate the $g^{(2)}(0)$ value for each pillar. A summary of these results can be seen in figure 1 (c). Of the 17 emitters measured 9 have fitted $g^{(2)}(0)$ values below 0.5 indicating ~50% of all pillars measured have single photon emitters embedded in them.

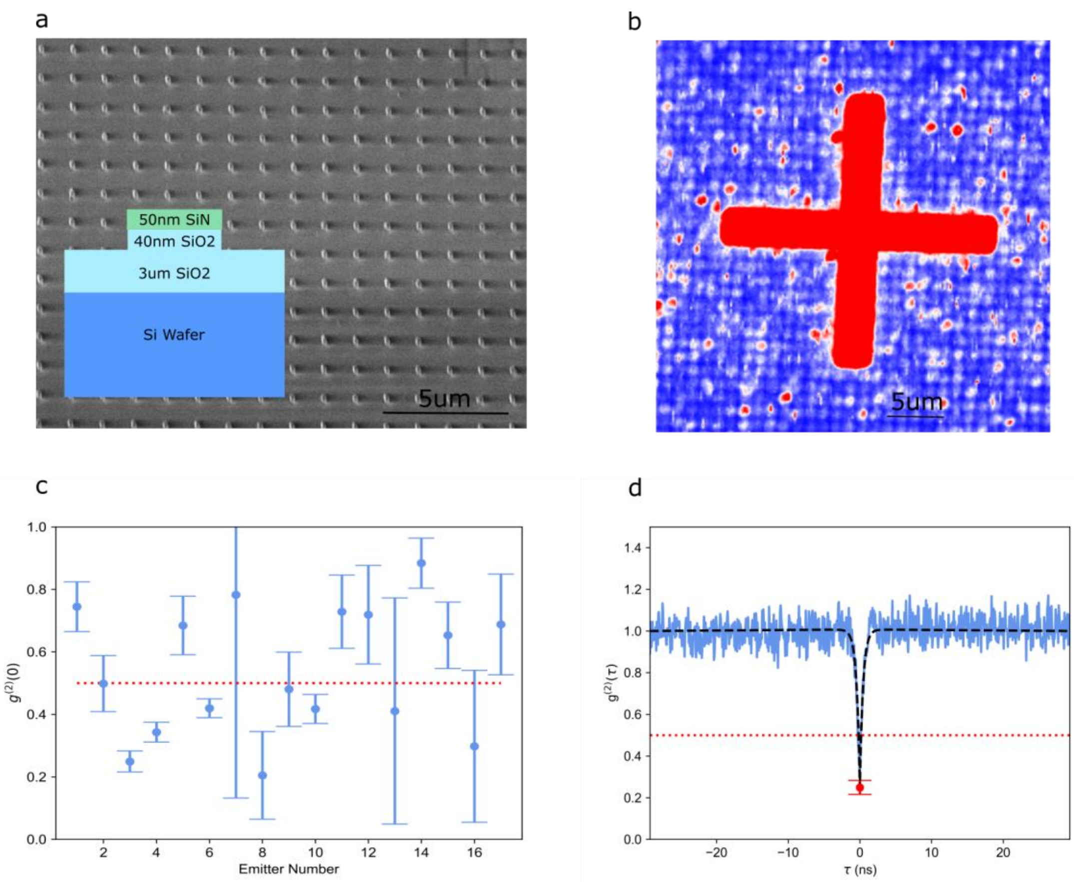

Figure 1. (a) A scanning electron microscope(SEM) image of the nanopillar array. Inset, a cross sectional diagram of the nanopillars shown in the SEM image. (b) A scanning photoluminescence map taken with an excitation wavelength of 532nm, the cross is an alignment marker, and the pillars are clearly visible in the PL map (c) A summary of the $g^{(2)}(0)$ values retrieved from 17 different pillars. The error bar shows the fit uncertainty. (d) The second-order autocorrelation measurement corresponding to emitter 3 from Fig 1(c). This emitter exhibits a $g^{(2)}(0)$ value of 0.25 without any spectra filtering or background correction, the red dotted line indicates a point at .

3. Conclusion

In conclusion, we have demonstrated a initial process for large-scale high yield creation of single photon emitters in SiN on SiO2 pillars. Additionally, these emitters may be fabricated with relatively high precision (±85nm). Further work needs to be done to improve the stability, yield, and brightness of the created emitters. Scalable integration of single photon emitters with silicon nitride quantum optical circuitry, plasmonic structures, and other types of photonic nanostructures promises to unlock both commercial applications and access to interesting physics.

References

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