SUPPLEMENTARY MATERIAL: III-NITRIDE PHOTONIC CAVITIES

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Sec. 1 Thin SiO_2 film coating of air-clad III-nitride microdisks and photonic crystal nanocavities

A thin SiO_2 layer was deposited using a silane and nitrous oxide plasma on samples heated to 300°C in an Oxford Plasmalab System 100 plasma-enhanced chemical vapor deposition (PECVD) reactor. Thick coatings were first deposited on test structures to check whether conformal PECVD SiO_2 films were within reach with a main focus on the bottom surface of microdisks and the inner surface of sub-100 nm diameter photonic crystal (PhC) holes. Scanning electron microscopy (SEM) cross-section images of thick conformal SiO_2 deposition on a cleaved structure having slits with varying sub-100 nm width are shown in Fig. S1. These images indicate that PECVD is compatible with conformally coating the underside of microdisk cavities but not the interior surface of PhC holes.

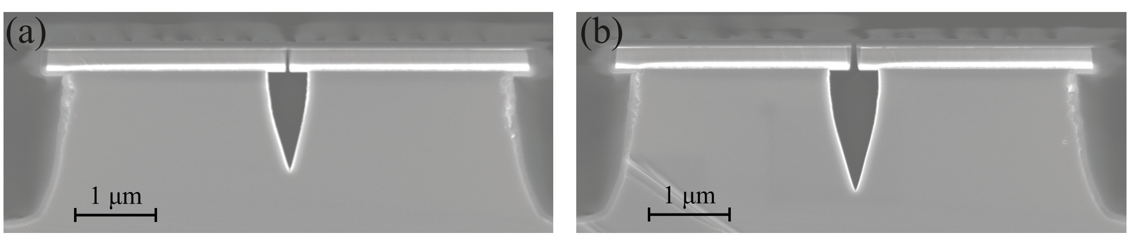

FIG. S1. SEM images of 100 nm of PECVD SiO_2 coated on a cleaved test sample. (a) 90 nm epilayer slit width reduced to 60 nm slit after SiO_2 deposition. (b) 170 nm epilayer slit width reduced to 60 nm width after SiO_2 deposition. We can notice the uniform coating thickness around the outer dimension.

To test the viability of the PECVD SiO_2 coating on microdisks, a 15-nm-thick SiO_2 layer was deposited on 3-μm-diameter GaN microdisks that have experienced the optimized rapid thermal annealing (RTA) treatment described in the main text. Figure S2 shows a comparison of the Q_{exp} values measured at 5 K under 1.6 kW.cm^{-2} continuous wave

HeCd illumination on coated and reference uncoated microdisk samples. Prior to any post-treatment, the maximal Q_{exp} values of the coated samples are poorer than those of the samples that have experienced the optimized surface treatment (Figs. S2(a) and S2(b)) and are similar to the BHF-treated surface (cf. Fig. 12(b) of the main text). However, annealing steps of 5' each in ammonia and oxygen at 750°C of the coated samples lead to maximal Q_{exp} values similar to those reported for RTA-treated bare surface microdisks (Figs. S2(a) and S2(c)).

Sec. 2 Gas tuning of photonic crystal nanobeam cavities

Optimized annealed 1D GaN PhC nanobeam cavity samples are optically characterized at room temperature using the following protocol: (i) UV-photoinduced gas desorption from the nanobeam surface takes place under vacuum using 4.5 kW.cm^{-2} continuous wave HeCd illumination for 40'. (ii) Connection to the vacuum pump is closed and 100 mbar of impurity gas is introduced. (iii) Microphotoluminescence (μPL) measurements are conducted initially under low intensity HeCd illumination (200 W.cm^{-2}) to monitor any shift in the cavity modes and then under high intensity (back to 4.5 kW.cm^{-2}) where μPL spectra are continuously recorded with 2 to 4" integration time until the modes do not shift anymore. The time-dependent energy and linewidth (FWHM) of the fundamental and first-order cavity modes extracted from Lorentzian lineshape fits are displayed in Fig. S3. A reference measurement ('Ctl.') was done to check whether any background atmospheric gas could enter the chamber and react with the surface in the absence of any active purging of the chamber by the vacuum pump. It is seen in Figs. S3(a) and S3(b) that the control and helium tuning curves exhibit the same results as expected for a noble gas.

Interestingly enough, only O_2 gas led to a spontaneous reaction with the surface, which was probed through the fast recovery of PhC cavity modes under low intensity illumination. It indicates that photoinduced adsorption takes place for all the other gases. In addition, the introduction of forming gas led to the complete disappearance of PhC cavity modes while the illumination of an oxygen-terminated surface in forming gas resulted in a PhC mode broadening and its decrease in amplitude without any redshift hinting toward a manifestation of the reducing nature of H_2 that counteracts the oxidizing behavior of O_2.

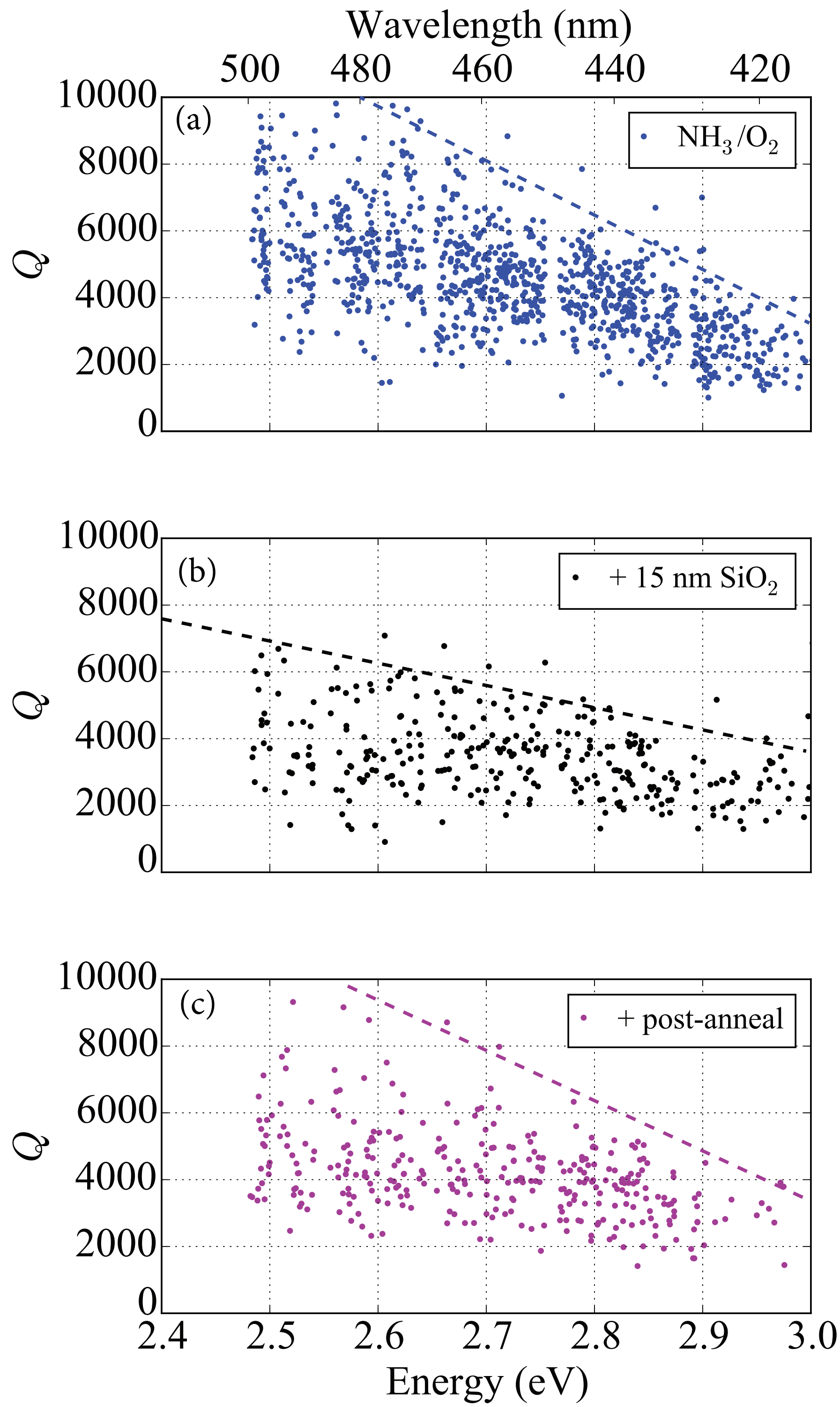

FIG. S2. Comparison of the same whispering gallery resonances for (a) the optimized RTA treatment, (b) after 15 nm SiO_2 deposition by PECVD, and (c) after a post-deposition RTA anneal. Measurements were performed at 5 K under 1.6 kW.cm^{-2} continuous wave optical pumping with a HeCd laser. No filtering of Q values was performed. Dashed lines are guides to the eye.

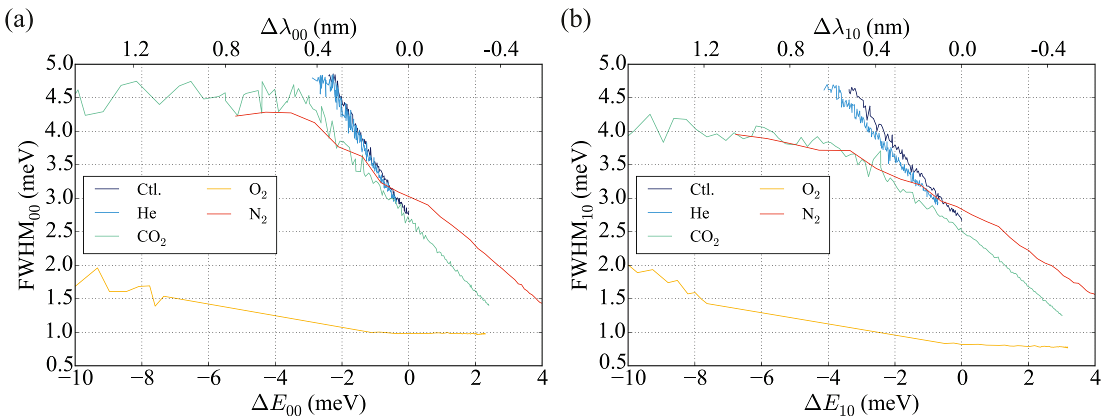

FIG. S3. Tuning of (a) fundamental and (b) first-order photonic crystal cavity resonances by photoinduced gas adsorption using continuous wave HeCd illumination at 4.5 kW.cm^{-2}. Each gas pressure is 100 mbar.

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