Supplementary Information for

Integration of p-type β-In_2S_3 thin films on III-nitride heterostructures for multiple functional applications

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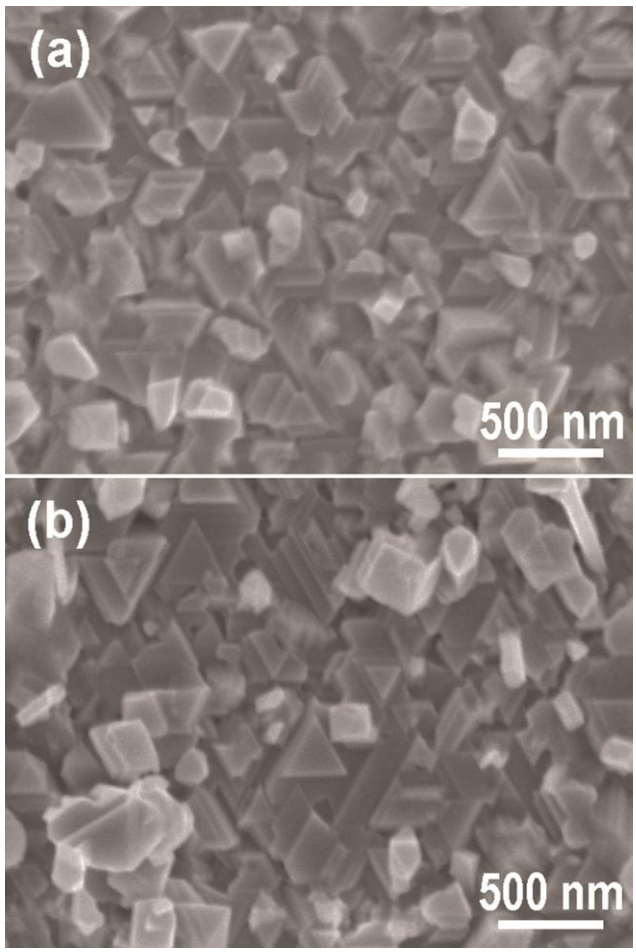

Figure S1 Typical SEM images recorded from InN thin films after thermal vapor sulfurization (TVS) at 700 °C (a) and 750 °C (b). The surfaces exhibit triangular facet structures without any distinguishable differences between (a) and (b).

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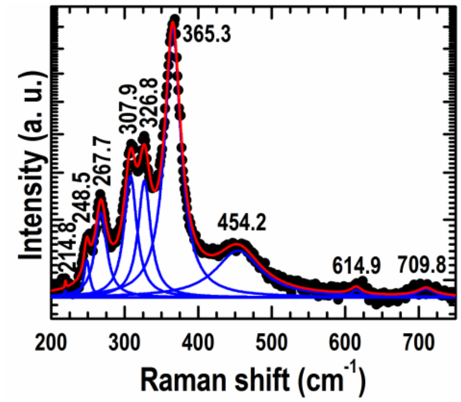

Figure S2 Raman-scattering spectrum and its feature fittings of InN thin film after thermal vapor sulfurization (TVS) at 700 °C. The spectrum was collected at room temperature using a 325-nm laser excitation.

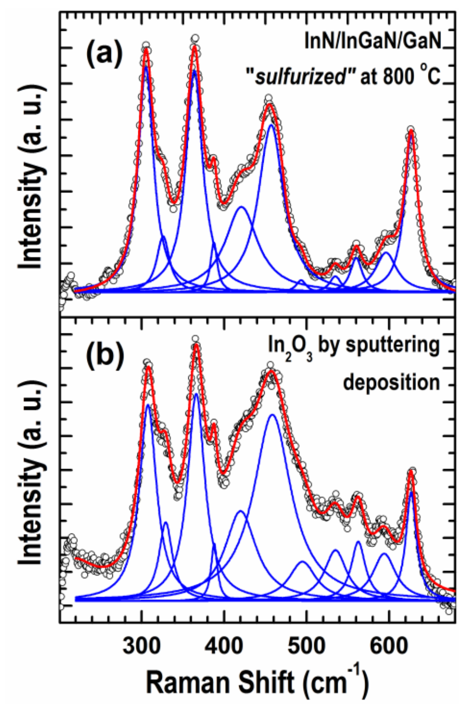

Figure S3 Raman spectra and their feature fittings: (a) InN thin film after thermal vapor sulfurization (TVS) at 800 °C and (b) In_2O_3 thin film deposited by magnetron-sputtering on GaAs (111) substrate at 350 °C (the deposition parameters can be found in Ref. 1). The similarity between the Raman spectra indicates an InN-to-In_2O_3 phase conversion occurred at T = 800 °C.

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[1] H. F. Liu, G. X. Hu, H. Gong. Growth mechanism and optical properties of In_2O_3 nanorods synthesized on ZnO/GaAs (111) substrate. J. Cryst. Growth, **311**, 268 (2009).

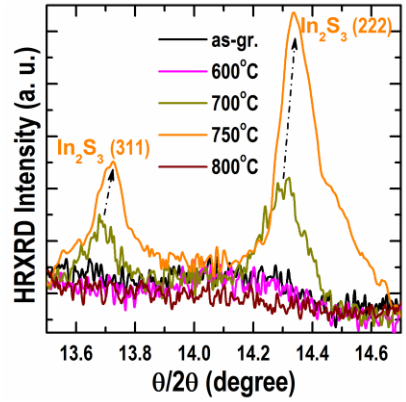

Figure S4 HRXRD θ/2θ scanning patterns of InN thin film before and after thermal vapor sulfurization (TVS) at various temperature for 30 min; the patterns cover the diffractions from β-In_2S_3 (311) and (222) (JCPDS 65-0459) atomic planes. It is seen that the β-In_2S_3 (311) and (222) diffractions appeared at T = 700 °C, increased and shifted to larger angles at T = 750 °C (indicated by the arrows), and disappeared at T = 800 °C.

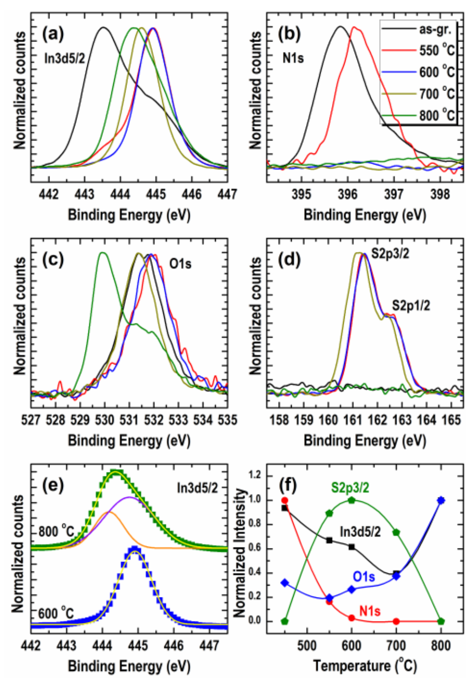

Figure S5 High-resolution XPS spectra of (a) $In3d_{5/2}$, (b) N1s, (c) O1s, (d) S2p, (e) comparison of $In3d_{5/2}$ for the samples after thermal vapor sulfurization (TVS) at 600 and 800 °C, and (f) peak intensity evolutions of N1s, O1s, $In3d_{5/2}$, and $S2p_{3/2}$ as a function of TVS temperature. Please note the disappearance of N1s at $T \geq 600$ °C, indicating the surface passivation, rather than phase conversion, of InN at lower TVS temperatures.

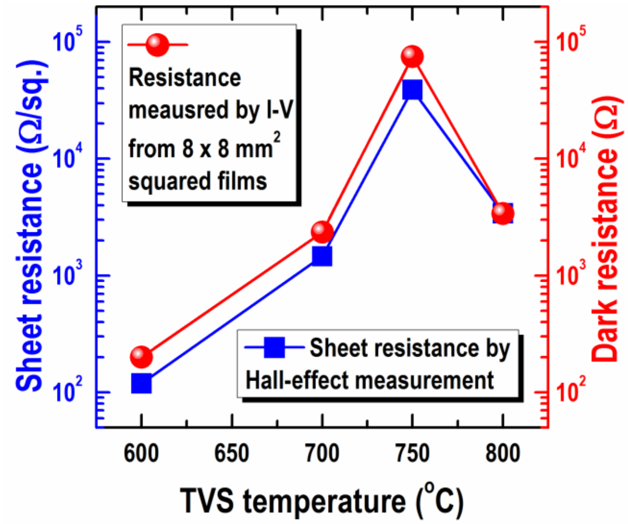

Figure S6 Correlation between sheet resistances measured by the Hall-effect method and dark-resistances of TVS-treated InN thin film samples; the dark-resistances were measured by I-V profiling from squared film of about 8×8 mm^2.

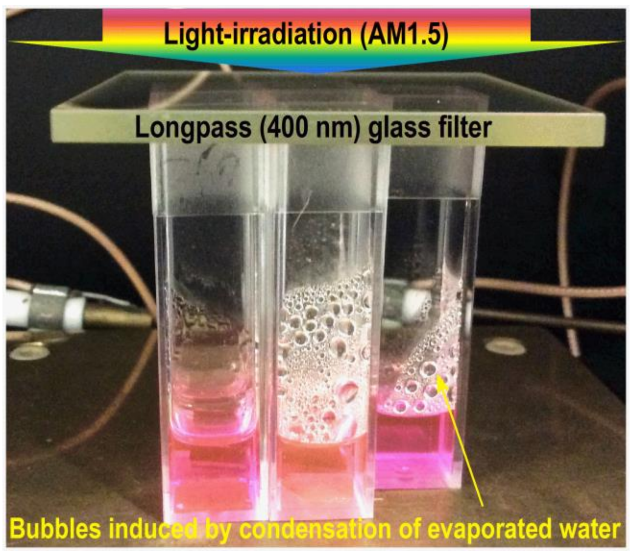

Figure S7 Photocatalytic reaction of RhB aqueous (1 ml, 2×10^{-5} M) with and without the TVS-treated thin sold films. Bubbles induced by condensation of evaporated water are clearly seen on the inner wall of the cuvettes.