Supporting Information

The synthesis and formation mechanism of nonpolar InN nanoplates

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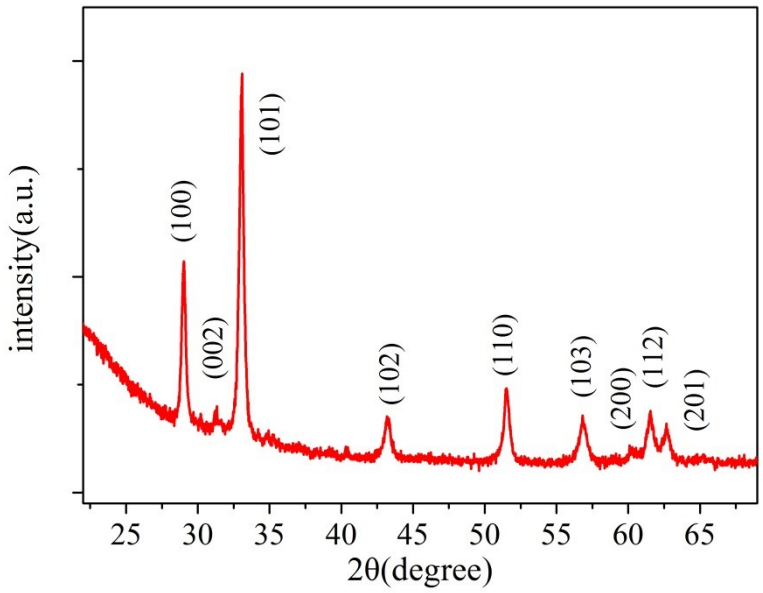
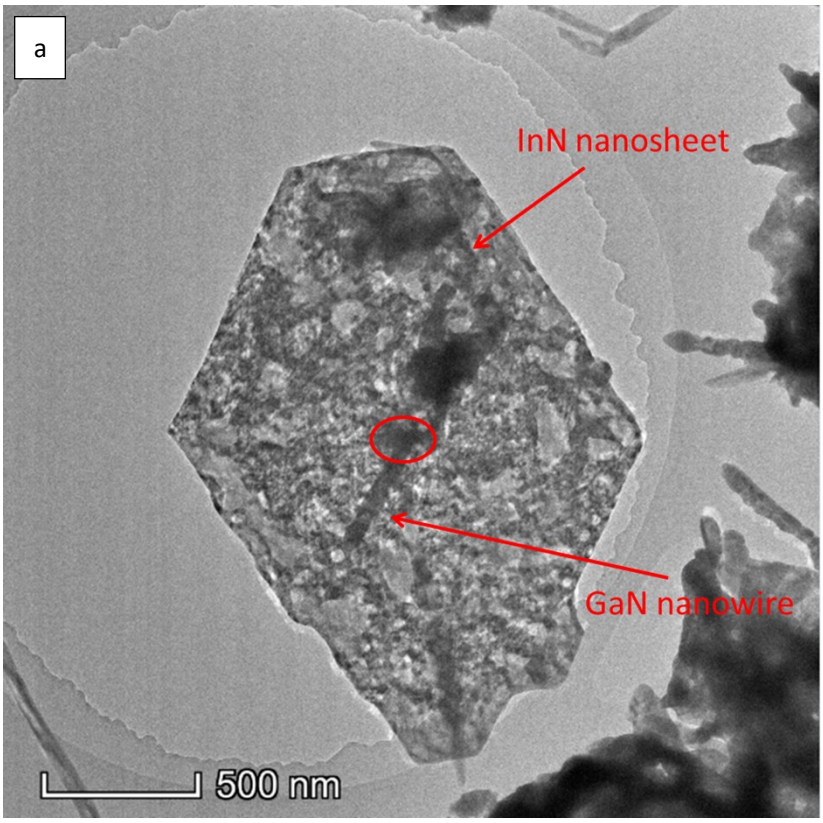


Fig. S1 the XRD spectrum of as-grown InN nanoplates

In Fig.S1, the result shows the diffraction peak of (0002) is too weak. It can be easily filtered out by the impurity peaks of the sample. All diffraction peaks can be indexed to (100), (002), (101), (102), (110), (103), (200), (112) and (201) planes of wurtzite structure InN (JCPDS Card No. 50-1239). No other impurity phases are found in our XRD spectrum.



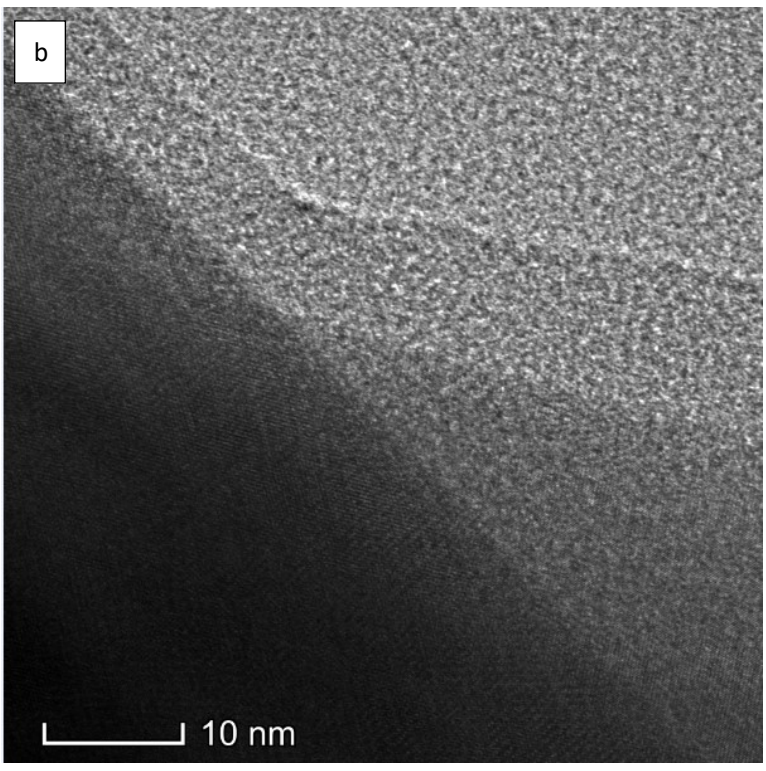


Fig. S2. the TEM of the GaN nanowire and InN nanosheeet connection, respectively.

Fig. S2 is the low resolution TEM of the GaN nanowire and InN nanosheeet. Obviously, from the red circle, we can see the GaN nanowire connect with InN nanosheeet. Fortunately, we observed the TEM connection of the GaN nanowire in the InN nanosheet to find possible characteristics about crystallographical. However, there are some overlapping spots in the selected area electron diffraction (SAED) pattern of the connection image.

It is clearly to find two parallel lattices of the groups crystals are very close to each other in Fig. S3. It results some overlapping spots. The similar observation about this situation is also reported in related paper C. Chi Yang [1].

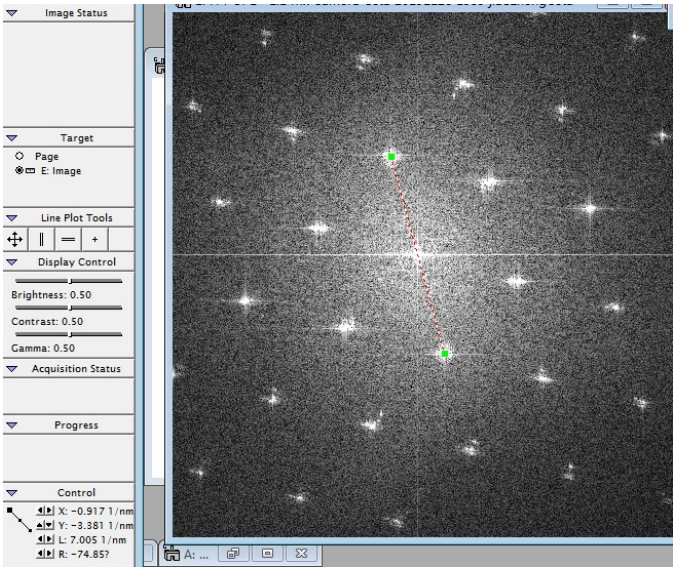
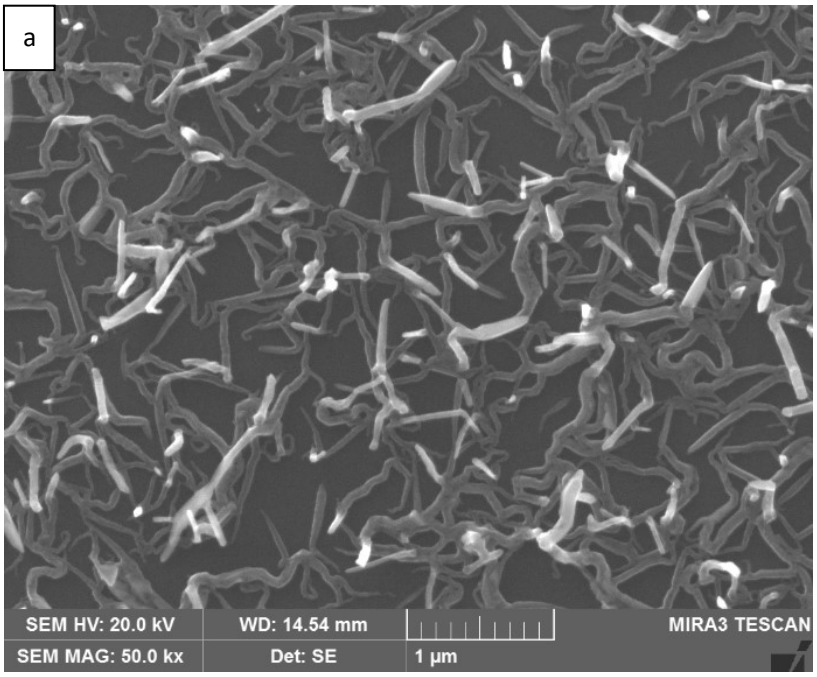
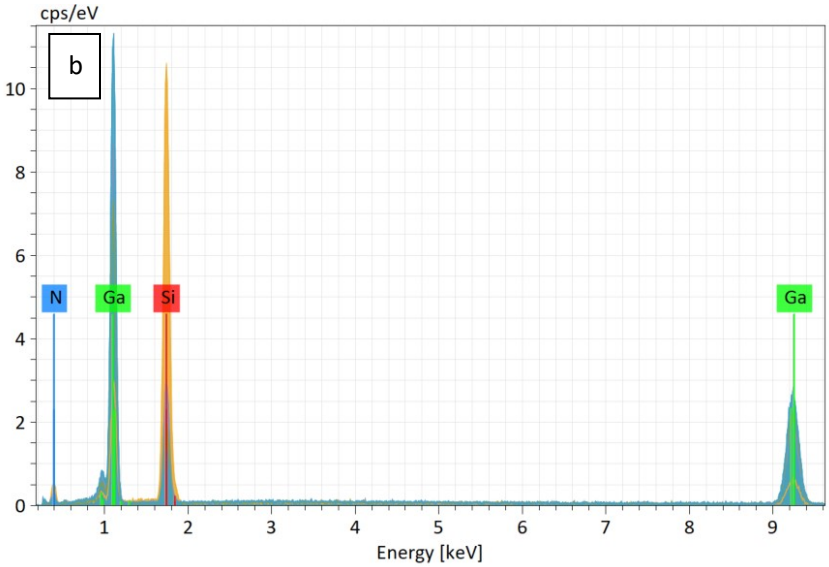


Fig.S3 two group parallel lattices of the crystals

Fig. S4a shows a large amount of GaN nanowires exist on the Si substrate. Many of the nanowires attach themselves tightly to the Si substrate. Only a small number of them pop out of their heads and extend outwards. We measured the EDS of GaN nanowire (Fig. S4b). The results confirmed the composition of nanowires only Ga and N, the Si is from the substrate (Fig. S4c).





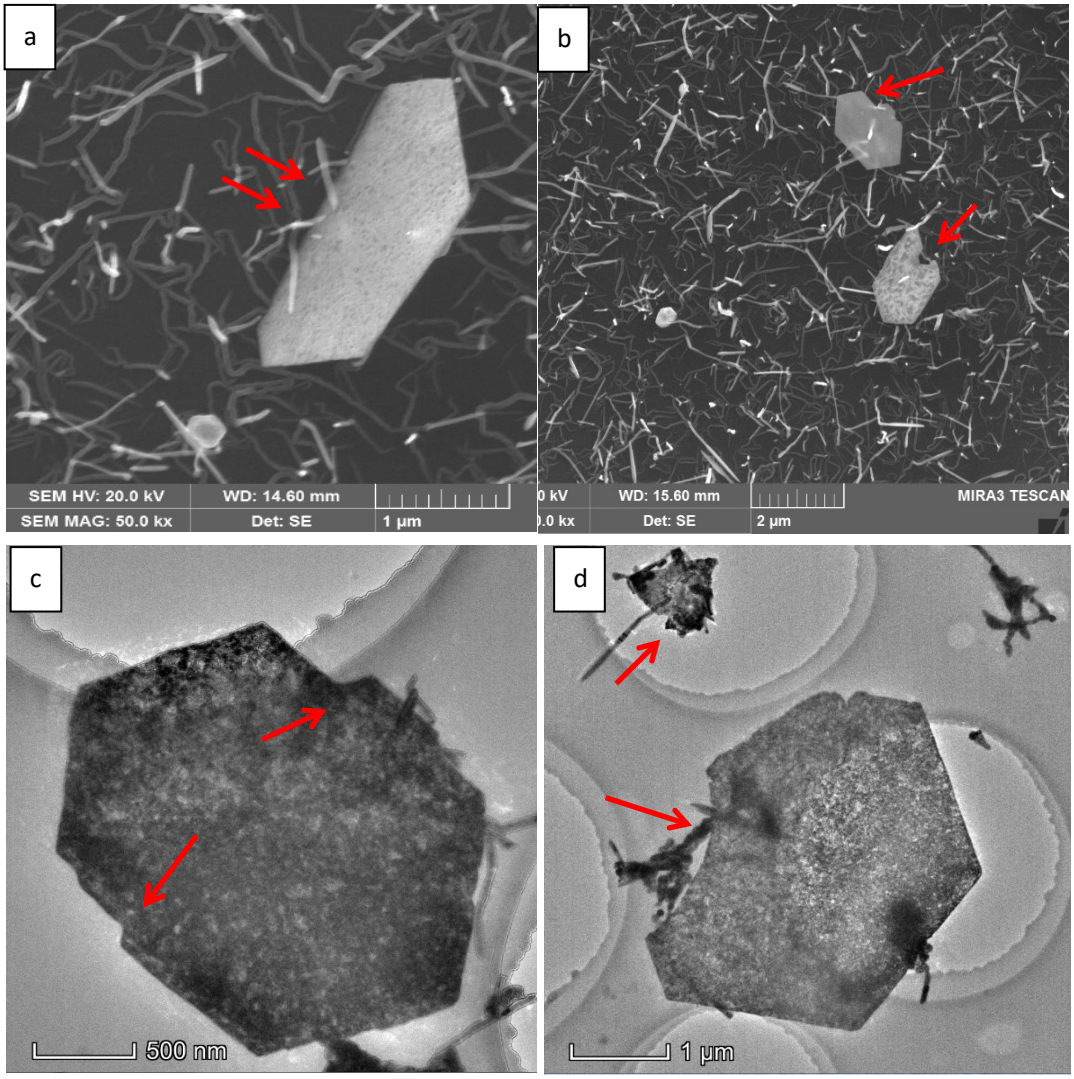
c

元素	原子数	净值	质量 [%]	归一化质量 [%]	原子 [%]	abs. error [%] (1 sigma)
N	7	391	12.97	19.80	55.13	3.95
Ga	31	11085	52.55	80.20	44.87	1.41
		总计:	**65.53**	**100.00**	**100.00**	

Fig.S4 (a) the SEM (b)the EDS and (c) the composition of GaN nanowires

More about the morphology of 2D InN nanosheets is shown in Fig. S5. From the SEM of synthesized sample, we can see that the morphology of sample has a half a hexagon, cutting angle of the hexagon, overlapping hexagon, round concave cutting angle of the triangle. The formation of the sample may result from the interaction of nucleation sites in close proximity to each other

during growth or from regrown along the edges of the formed M-plane of GaN nanowire. This is one of reasonable explanation for some picture display that the InN nanoplate's edge stand on top of GaN nanowire, while in the latter part, it seems nanoplates grow around the nanowires. The similar situation is also reported in the growth of other 2D nanostructures by related paper J. Shi [2] and Y. Xie [3], they reported that parallel-edged or aligned nanostructures usually present the same lattice orientation, which makes them probable for merging into large single-crystalline, regardless of their different nucleation sites. However, individual nanostructures with an intersection angle will not merge into single-crystalline.



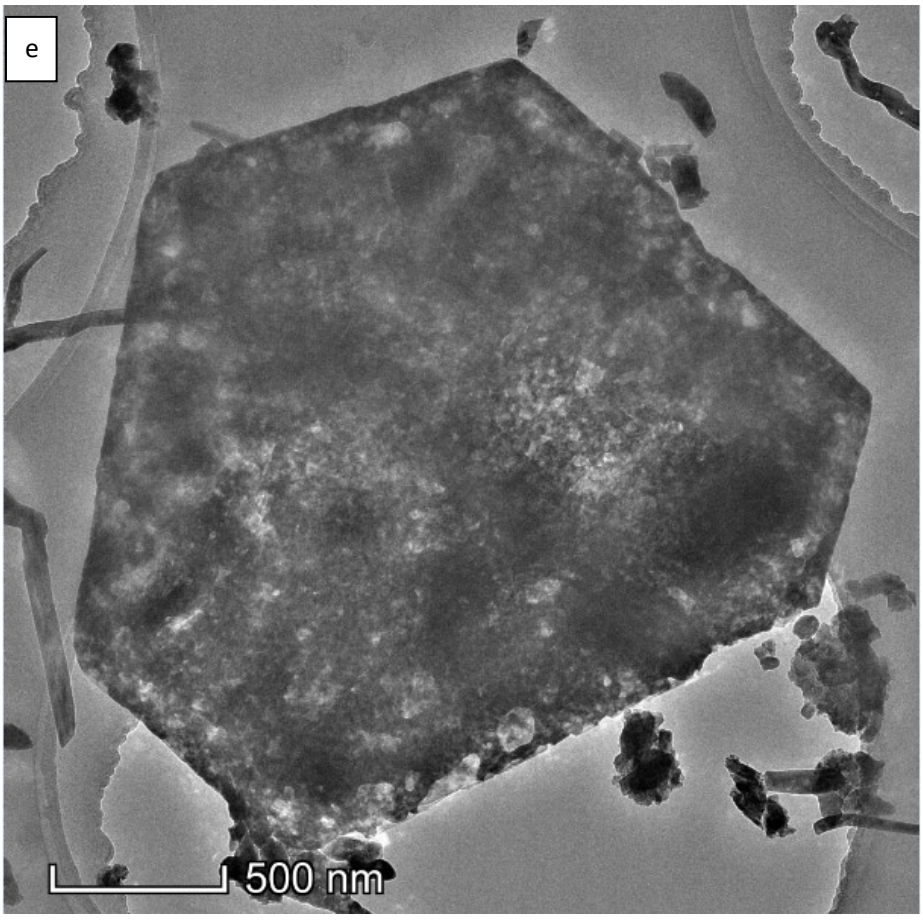


Fig.S5 More SEM and TEM about the morphology of 2D InN nanosheets

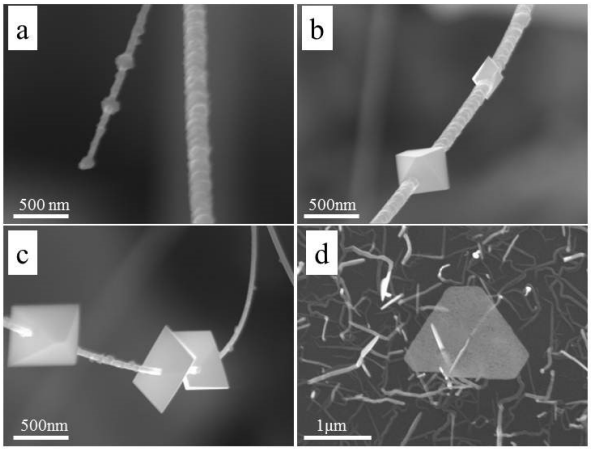


Fig.S6 Morphology evolution of InN nanoplates with varied growth time. (a) 60 min (b) 90min (c) 120min (d) 135min; (a) →(b) →(c) →(d)

In order to further understand the formation mechanism of nopolar InN nanostructures, the silicon (100) substrate with randomly orientation

GaN NWs are heated at 720 °C for different growth time. Fig. S6 illustrates the morphological evolution of InN nanopalate grown at varied growth time ranging from 60 to 135min. We speculate that the growth of nonpolar InN nanopalate is the vapor–solid (VS) and diffusion growth mechanisms, [4-5] which can be explained as follows. A single GaN nanowire with a thin layer coating of indium is obtained is shown in Fig. S6a. Some large indium nitride alloy particles are formed on the surface as the effect of stacking fault. [6] As the thermally evaporating time gradual increase, these particles gradually evolve into the Indium nitride crystallites. Due to high free energy in the side of spine In and N vapor can be condensed on either side and acts as nucleating sites for secondary growth, the formation of nanostructures with complex morphology via a vapor-solid (VS) method is shown in Fig. S6b. The thin layer coating of indium on GaN nanowires is left little and little by growing for a longer amount of time. The presence of Indium induced the appearance of hierarchical structures and more particles, [6-7] which assisted in the lateral growth of the InN low dimensional structures. [8] A flat square structure of the Indium nitride crystallites in Fig. S6c can prove this situation. Furthermore, we can estimate from the diameter changes of nanopalate that there is side-wall growth from Figure S6d and Figure 2d with the prolongation of growth time.

Reference

[1] C. Chi Yang, et al. Growth of InN hexagonal microdisks, AIP Advances 6, 085015 (2016)

[2] J. Shi, Y. Yang, Y. Zhang, D. Ma, W. Wei, Q. Ji, Y. Zhang, X. Song, T. Gao, C. Li, Monolayer MoS2 Growth on Au Foils and On-Site Domain Boundary Imaging. Adv. Funct. Mater. , (2015), 25(6), 842–849.

[3] Y. Xie, Z. Wang, et al. Controllable growth of monolayer MoS_2 by chemical vapor deposition via close MoO_2 precursor for electrical and optical applications. Nanotechnology, (2017), 28(8), 084001

[4] W. Song, J. Si, S. Wu, Z. Hu, L. Long, T. Li, X. Gao, L. Zhang, W. Zhu and L. Wang, Cryst. Eng. Comm. 2019, 21, 5356 -5362

[5] H. Liu, S. Xie, and G. Cheng, Cryst. Eng. Comm.2011, 13, 3649-3652

[6] A. Tiwari, S. J. Dhoble, Cryst. Growth Des. 2017, 17, 381-407.

[7] C. Tessarek, S. Fladischer, C. Dieker, G. Sarau, B. Hoffmann, M. Bashouti, M. Gö belt, M. Heilmann, M. Latzel, E. Butzen, S. Figge, A. Gust, K. Hö flich, T. Feichtner, M. Bü chele, K. Schwarzburg, E. Spiecker, and S. Christiansen, Nano Lett. 2016, 16, 3415-3425.

[8] X. Sun, D. Jiang, W. Liu, J. Zhu, H. Wang, Z. Liu, J. Zhu, Y. Wang, D. Zhao, S. Zhang, L. You, R. Ma, H. Yang, J. Appl. Phys. 106 (2009) 2779