Supporting Information

Self-assembly graphene nanomask for epitaxial growth of nonplanar and planar GaN

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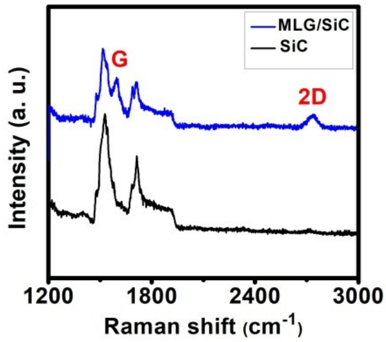

Figure S1. Raman spectrum of the MLG/SiC and pure SiC substrate at the wave number of 1200 to 3000 cm^{-1}. Clear G and 2D bonds of MLG and secondary bonds of SiC can be seen.

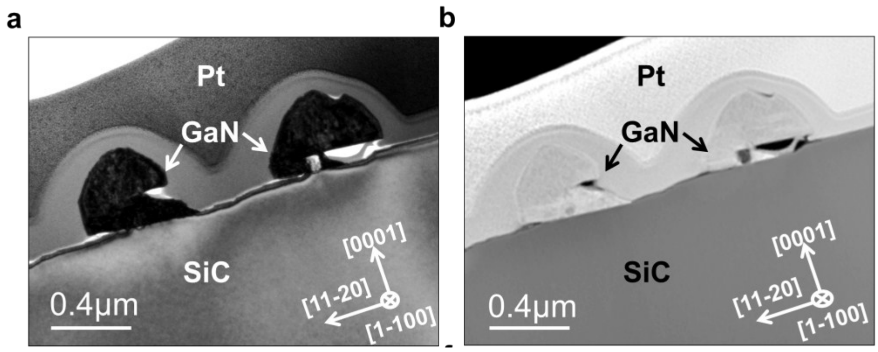

Figure S2. (a) TEM and (b) HAADF images of GaN nanowalls SNSAG on MLG/SiC.

Table S1. The difference of diffraction spots distance of GaN and SiC. (a and c: the lattice parameters; hkl: crystal indices; d: interplanar crystal spacing). The small Δ1/d results the SAED patterns of GaN and SiC are overlap.

	a [nm]	c [nm]	(hkl)	d [nm]	1/d [1/nm]	Δ1/d [1/nm]
GaN	0.3189	0.5185	(002)	0.259	3.857	0.122
			(-210)	0.159	6.272	0.237
SiC	0.3073	1.0053	(004)	0.251	3.979	
			(-210)	0.154	6.508	

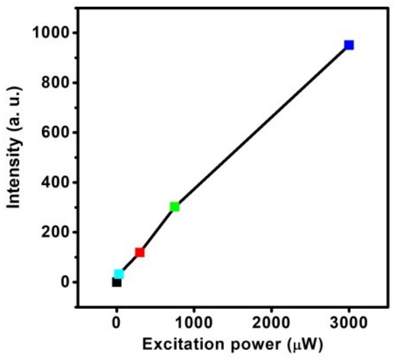

Figure S3. Plot of integrated intensity of the emission as a function of the excitation power.

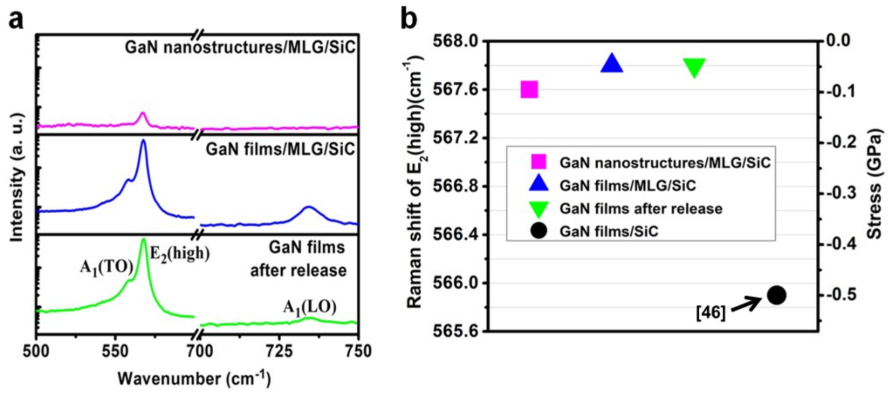

Figure S4. (a) Raman spectra of the GaN nanostructures/MLG/SiC, GaN films/MLG/SiC, and GaN films after release at the wavenumber of 500 to 750 nm. (b) Raman shift of E_2 (high) and stress of GaN. Black circle correspond to 1.65 μm-thick GaN films grown directly on 4H-SiC with similar miscut angle of 3.4°,[1] the stress was -0.5 GPa (10 times than that of GaN/MLG/SiC), and there were a lot of cracks formed in GaN/SiC.

Table S2. Stress of GaN nanostructures and films grown on MLG/SiC and after release.

Sample	E_2(high) [nm]	Stress[a] [GPa]
GaN nanostructures/MLG/SiC	567.6	-0.10
GaN films/MLG/SiC	567.8	-0.05
GaN films after release	567.8	-0.05

[a)] The stress is calculated by the formula as follow:

$$\sigma = \frac{\Delta\omega}{K}(cm^{-1}GPa^{-1})$$

where σ is the biaxial stress, Δω is the E_2 frequency shift and K is the Raman stress factor. The unstressed GaN E_2 (high) at 568.0 cm^{-1}, K=4.2 $cm^{-1}GPa^{-1}$.[2]

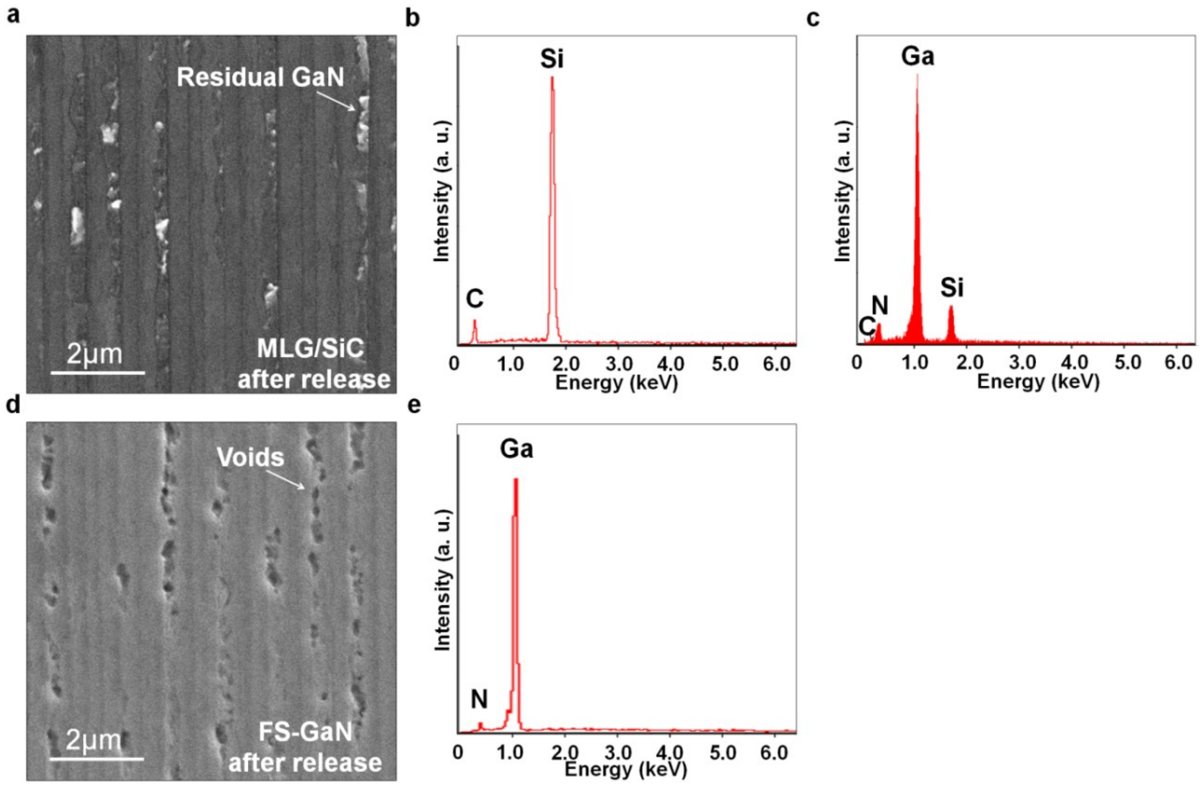

Figure S5. (a) Surface morphology of MLG/SiC after GaN films release. (b) and (c) EDX spectra of MLG/SiC and residual GaN on MLG/SiC after release. (d) Surface morphology of the back surface of FS-GaN after release. (e) EDX spectra of the voids on the surface of GaN microrod. It indicates that the GaN films are SNSAG on MLG/SiC.

Table S3. The crystalline quality of GaN films vdWE/RE/SAG/SNSAG on graphene.

Structure	Growth type	Thickness (μm)	Crystalline	FWHM(0002) (arcsec)	TDDs ($x10^8 cm^{-2}$)	Method	Ref.
$GaN/ZnO/graphene/SiO_2/Si$	vdWE	~5	Grain boundary	-	12~24	TEM	14
$GaN/ZnO/graphene/SiO_2/Si$	vdWE	~5	Grain boundary	-	13	TEM	15
$GaN/graphene/SiO_2/Si$	vdWE	10	Grain boundary	-	8-36	TEM	16
GaN/graphene/SiC	RE	2.5	Single crystalline	222	10	TEM	27
GaN/graphene/SiC	SAG	1.5	Inversion domain	-	30	TEM	28
GaN/graphene/GaN/sapphire	SAG	40	Single-crystalline	154	0.18	EPD	29
GaN/graphene/GaN/sapphire	SAG	20	Single-crystalline	276	1.7~1.8	CL	30
GaN/graphene/SiC	SNSAG	150	Single-crystalline	43	0.059	CL	This work

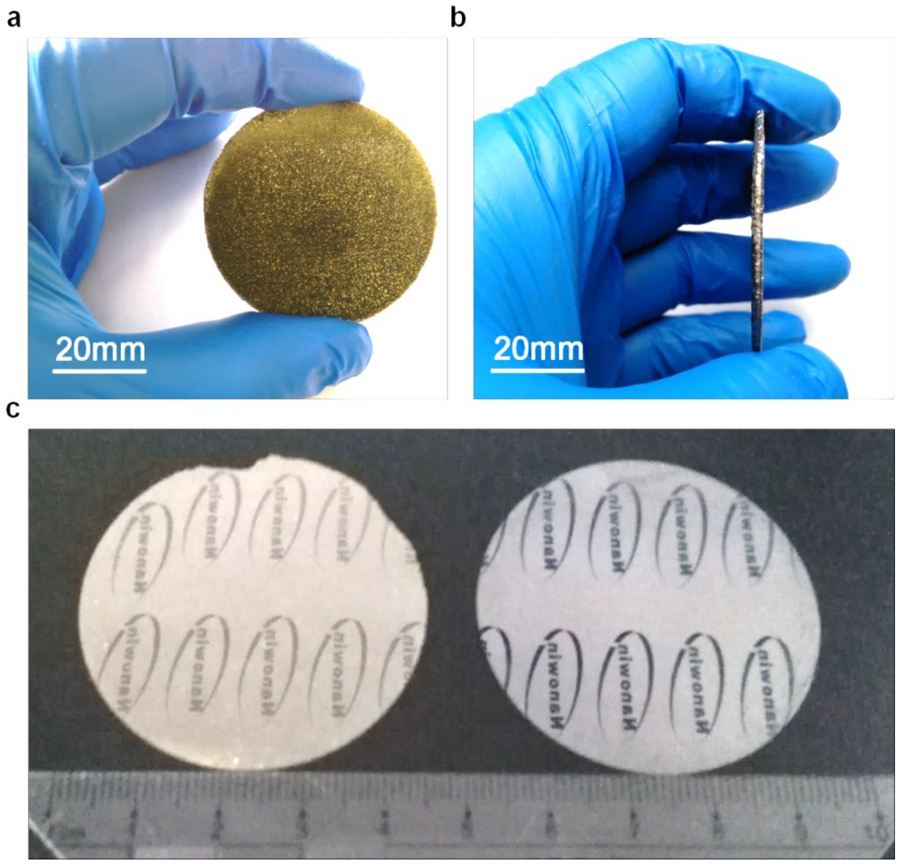

Figure S6. (a) Photograph of crack-free, 1.2 mm-thick GaN films SNSAG on MLG/SiC. (b) Cross-section photograph of the GaN films SNSAG on MLG/SiC. (c) Photograph of crack-free, mechanical exfoliated FS-GaN (left) after single side chemical mechanical polishing and the corresponding MLG/SiC substrate (right). Mirror reflection of Nanowin logo which was set above the samples when taking photo. The bow of the substrate was about 19 µm (radius of bowing is 17 m), which is lower than the one fabricated by laser lift-off (radius of bowing was 4.6 m and bow was about 70 µm).[3] Such low bow value may be caused by nearly-free stress of GaN films after growth.

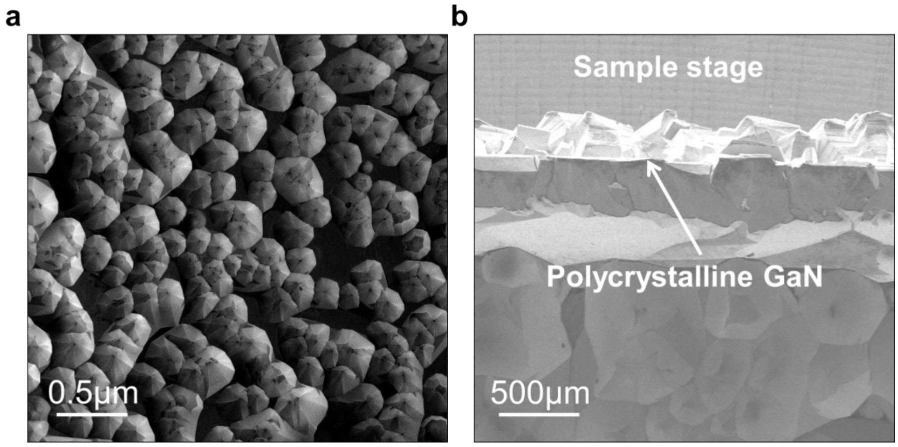

Figure S7. (a) SEM image of surface morphology of the GaN films SNSAG on MLG/SiC. (b) SEM image of the edge morphology of GaN films SNSAG on MLG/SiC. The surface of GaN films is not smooth as the surface deterioration of GaN films when thickness is more than 1 mm. In addition, because of polycrystalline GaN exists at the edges of substrate, directly mechanical exfoliation of GaN can not obtain FS-GaN without cracks. Therefore, polycrystalline GaN should be eliminated by cylindrical grinding machine, and then the GaN films can be mechanically exfoliated without any stressor layer.

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