

## SUPPORTING INFORMATION

### **S1: Graphene synthesis and transfer**

#### Monocrystalline graphene domains:

Monocrystalline graphene domains were synthesized on copper foils by pulsed-chemical vapor deposition (CVD) technique. To obtain hexagonal graphene domains, the experimental conditions are a gas pressure of 25 mbar, a growth temperature of 1000°C and the use of ten cycles of CH<sub>4</sub> (20 sccm, 5 s) and H<sub>2</sub> (960 sccm, 55 s). These conditions refer to the work of V. Bouchiat et al and were applied to our commercial Aixtron BlackMagic system. We can obtain isolated graphene domains which are mostly hexagonal, have one monolayer height and approximately 40 μm width. For larger domains, new graphene layers start to form at the center of the domains. The final morphology of a flake consists of several terraces forming a pyramidal structure.

1 cm<sup>2</sup> patch of isolated graphene domains were transferred by a wet transfer method to a silicon (100) substrate with a nominally 300 nm SiO<sub>2</sub> layer formed by dry oxidation. The graphene domains on copper foil were first spin-coated with a 350 nm-thick polymethyl methacrylate (PMMA) protective layer, and then dipped into (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution in order to etch the copper foil. The floating graphene covered by PMMA was transferred to deionized water and profusely rinsed, then deposited onto the SiO<sub>2</sub>/Si template, and the samples were naturally dried. The PMMA protective layer was removed by cleaning with solvents (acetone, isopropyl alcohol) and with deionized water.

#### Multi-domain monolayer and multilayer graphene:

Monolayer and few-layered graphene was grown by chemical vapor deposition (CVD) on copper foils and transferred on a silicon substrate with an oxide layer of 500 nm and a nickel layer of 100 nm, respectively. Details about the CVD growth of graphene can be found in literature<sup>2,3</sup>. The number of layers in few-layered graphene has been characterized by separate Raman and atomic force measurements. The average thickness is found to be equal to 4±1 monolayers.

1 cm<sup>2</sup> pieces of monolayer and few-layered graphene were transferred by a wet transfer method to a silicon (001) substrate with a nominal 25 nm SiO<sub>2</sub> layer formed by dry oxidation. To transfer monolayer graphene, the graphene on copper foil was first covered with 50 nm-thick polymethyl methacrylate (PMMA) protective layer, and the copper foil was etched using (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution. The floating graphene covered by PMMA was transferred to deionized water, then deposited onto the SiO<sub>2</sub>/Si template, and the samples were naturally dried. The PMMA protective layer was removed by cleaning with solvent (acetone, isopropyl alcohol) and deionized water. To transfer few-layered graphene, the same PMMA protecting layer was used. The Ni layer was wet-etched by FeCl<sub>3</sub>-saturated aqueous solution, and the floating graphene sheet was transferred to clean deionized water and then deposited on the SiO<sub>2</sub>/Si template and naturally dried. It should be noted that contrary to ref<sup>4,5</sup>, buffered oxide etch (BOE) of SiO<sub>2</sub> was not used to avoid modifying the graphene properties. The Ni layer was etched from the lateral surfaces for approximately 12 h. Before the MBE growth, to minimize the water residues at the graphene/substrate interface for both few-layered and monolayer graphene, the samples were annealed at 130 °C using a slow temperature ramp on a hot plate in ambient conditions during 1 h.

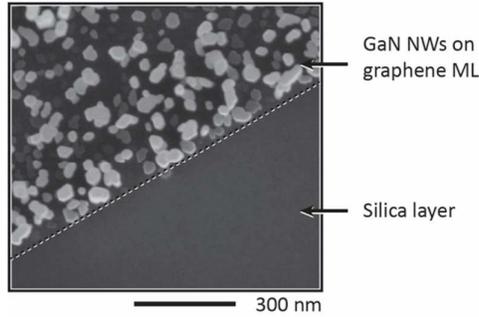
### **S2: GaN nanowire growth by PA-MBE**

Nanowires (NWs) were grown by plasma-assisted molecular beam epitaxy (PAMBE) under nitrogen-rich conditions. The Ga flux was supplied by an effusion cell and the active N species were generated by a radio-frequency plasma source. In-situ monitoring was done by reflection high energy electron diffraction (RHEED). For all growth experiments, a Ga flux of 8.8x10<sup>-7</sup> Torr was used, corresponding to a planar growth rate of 0.62 monolayers of GaN per second (ml/s), calibrated under N-limited growth conditions. The N<sub>2</sub> flow was 0.52 sccm with a 350 W plasma source power, resulting in a background pressure during growth of 8.3x10<sup>-6</sup> Torr. This corresponds to an effective N/Ga flux ratio of 1.1. This value is established in reference to the stoichiometric condition (effective N/Ga ratio equal 1) determined by observing the saturation of the GaN growth rate (monitored by RHEED intensity oscillations) upon increasing the Ga flux and keeping the N flux fixed. During NWs growth, the substrate temperature was measured using an infra-red pyrometer and maintained constant at 800°C unless otherwise specified. The absolute temperature was calibrated by observing the transition from a 1x1 to a 7x7 reconstruction of a Si (111) surface during sample cooling. Before

introducing the Si substrates into the MBE system or the oxidation oven, the substrates were chemically cleaned using solvents and a short diluted HF 10% bath to remove the native oxide. No specific cleaning steps were used on graphene substrates before introducing into the MBE chamber.

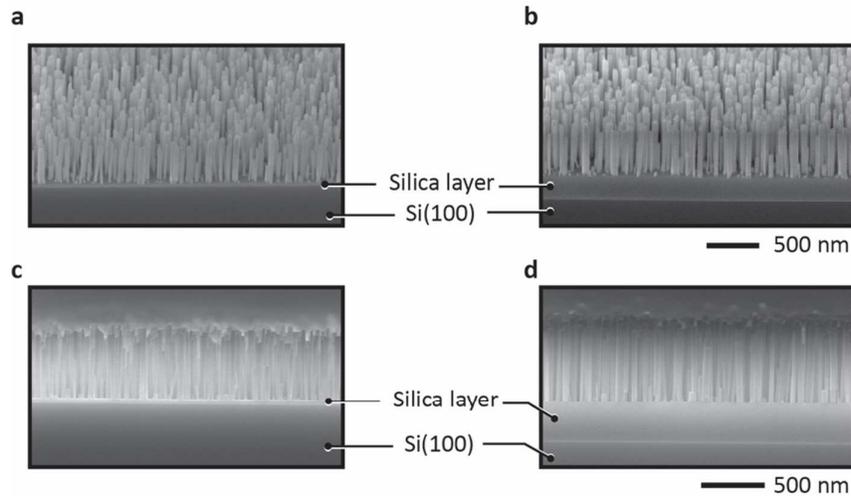
Selectivity:

For the NWs grown on 1 cm<sup>2</sup> patch ML of graphene (shown in fig. 1), there is a high selective growth of GaN NWs with respect to the silica layer surrounding the patch.



**Fig S1:** Top-view SEM image of GaN NWs at the graphene-Silica border for 1 cm<sup>2</sup> patch of ML graphene sample.

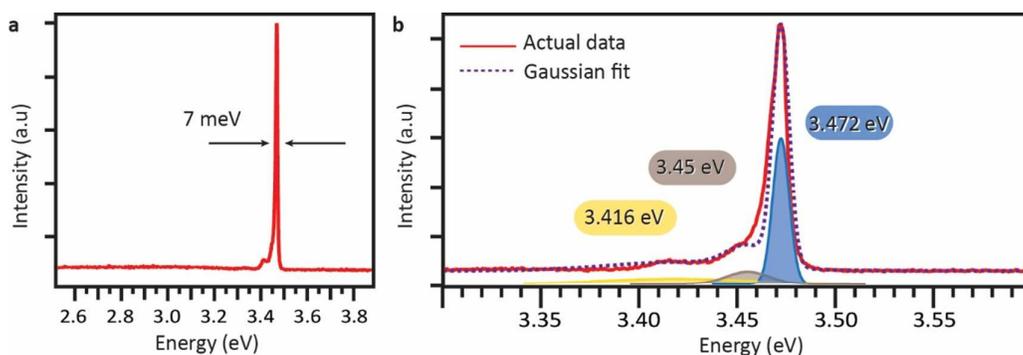
**S3: Thickness of SiO<sub>2</sub> carrier layer**



**Fig S2:** SEM images of GaN NWs grown on (a)(c) 50 nm and (b)(d) 300 nm SiO<sub>2</sub> carrier layer, taken in (a)(b) 45° tilted view and (c)(d) cross sectional view. Panel (a) has the same scale as (b) and panel (c) has the same scale as (d)

In order to study the influence of thickness of SiO<sub>2</sub> carrier layer on NW verticality, 1 ML graphene was transferred on two different samples with SiO<sub>2</sub> thickness of 50 nm (sample i) and 300 nm (sample ii). Fig. S2 shows 45° tilted view and cross-sectional view of these two samples. Both the samples are grown at 800°C growth temperature, with a V/III ratio of 1.1 and growth time of 2 hours. As can be seen from the SEM images, NWs have identical morphology, with good verticality, on both the samples. The morphology is also the same as in growth experiments on a 25 nm thick SiO<sub>2</sub> layer described in the main text. The slight difference in NW heights and densities is attributed to small variations in growth temperatures and molecular fluxes between two growth experiments. The thickness of SiO<sub>2</sub> does not seem to have an influence on the vertical alignment of GaN NWs.

#### S4: Photoluminescence of GaN NWs on graphene domains



**Fig S3:** (a) Photoluminescence spectra taken at 4K for GaN NWs grown on graphene domains; (b) Gaussian fitting of the near-band-edge emission evidencing three spectral contributions at 3.42eV, 3.45 eV and 3.472 eV

The spectrum presents the GaN near band edge (NBE) emission peaked at 3.472 eV with a FWHM of 7 meV. Gaussian fit of this peak allows to identify three spectral contributions peaked at 3.472 eV, 3.45 eV and 3.416 eV with FWHMs of 6 meV, 15 meV and 51 meV respectively. These results are comparable to the spectra shown in the main text for GaN NWs on 1 ML graphene.

#### References

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