Supplementary Information for the manuscript: "Light Emitting GaAs Nanowires on a Flexible Substrate"

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The GaAs core-shell nanowires are grown on a full 3" p-type (111) silicon wafer with the native oxide, which is later cut into pieces. The density of the nanowires is about 1.8×10^8 cm^{-2} and the surface appears completely black, with absorption above 90%, for the as-grown sample, see Figure 1, main manuscript. This nanowire density is at the top end of achievable densities for nanowire growth, hence the transfer method described in this work should be consistent with lower densities in terms of using capillary action to fill the regions between the nanowires with the dielectric, although additional optimization may be required.

In the main text, the broad background observed in the Raman spectra for the dielectric embedded nanowire sample is attributed to the presence of the polymer layer. Here we show reference Raman spectra for a bare silicon substrate and a silicon substrate with a layer of the same dielectric solution (polymer) deposited with a similar thickness to that used to embed the nanowires. Figure S1 shows these Raman spectra and compares them to a spectrum of the dielectric embedded nanowire sample. Comparing the spectrum of the silicon substrate (purple) with that of the substrate plus dielectric layer (green) it is clear that the featureless background, which rises in intensity from 200 to 600 cm^{-1}, is due to the dielectric layer. The addition of the dielectric layer gives the same background as observed for the nanowire sample (red) confirming its origin as the dielectric. Both the silicon substrate and silicon substrate plus dielectric spectra show the silicon optical phonon mode at 518 cm^{-1}. That the

nanowire sample does not exhibit this feature indicates that the incident laser light does not penetrate through to the Si substrate following growth of the nanowires. It is likely that the shortwave length light used to excite the Raman spectra is strongly absorbed by the GaAs clusters formed between the nanowires.

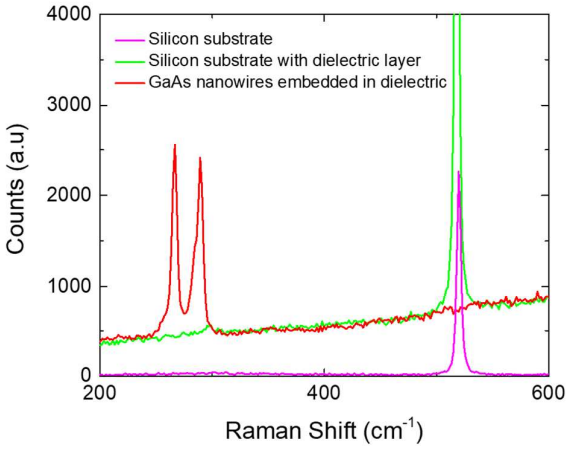

Figure S1: Comparison Raman spectra. – Reference Raman spectra of a bare silicon wafer (purple), a silicon wafer with a deposited dielectric layer (green) and the dielectric embedded nanowires (red). The rising background which appears following the deposition of the dielectric layer confirms the origin of this feature, which is also observed in the nanowire samples.

Initial μPL characterisation of the samples consisted of a spatial mapping to identify regions with a strong nanowire emission. PL spectra were recorded over a square grid at points spaced by 0.5 μm and a total area between 35x35 and 70x70 μm^2. PL maps were constructed for the as-grown sample, the dielectric embedded sample and the sample transferred to a plastic substrate. An excitation power of 1 μW and a sample temperature of 6 K were used. Figure S2 shows two typical spectrally resolved μPL spectra from a nanowire rich region on a flexible substrate. These spectra were recorded from the spatial positions PL1 and PL3 marked in Figure S3, bottom right false-coloured map. The blue and red

spectral regions of Figure S2 determine the nanowire and cluster integrated PL intensities, respectively.

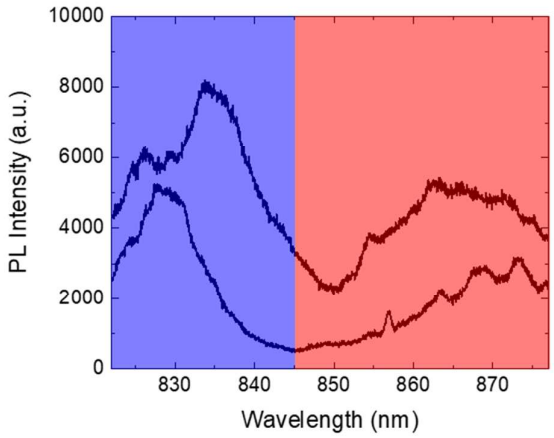

Figure S2: Typical µPL spectra for nanowire rich areas – µPL spectra measured between 822.1nm and 877.7nm for two nanowire rich areas on a flexible substrate. Blue and red areas show the spectral ranges associated with the nanowires (822.1 to 845 nm) and clusters (845 to 877.7 nm) emission. These spectra were obtained from the spatial positions marked PL1 and PL3 in Figure S3.

The first row of Figure S4 plots the intensity of the spectrally integrated PL, from 822.1nm to 877.7 nm. This spectral region includes the nanowire emission and the majority of the cluster emission. The integrated PL intensity for all three structures is inhomogeneous, consisting of bright regions surrounded by darker areas.

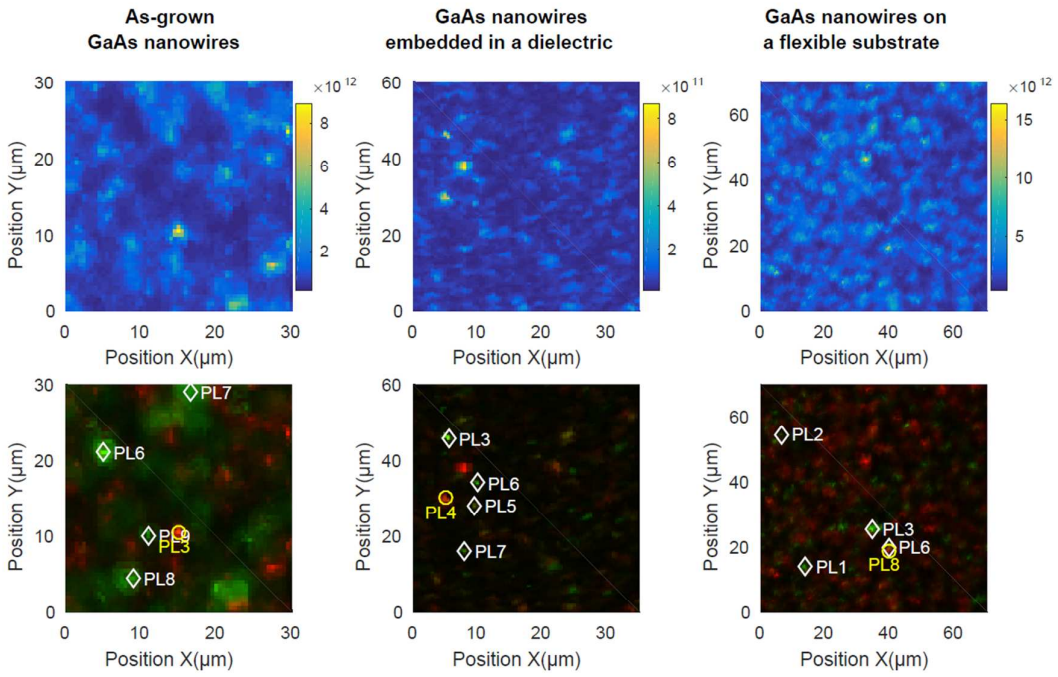

Figure S3: μPL colour maps – First row: Colour plots of the total integrated PL intensity between 822.1 nm and 877.7 nm. Second row: False-colour plots with the intensity of green and red representing the integrated PL intensity in the spectral ranges associated with the nanowire (822.1 to 845 nm) and cluster (845 to 877.7 nm) emission respectively. White diamonds and yellow circles mark the spatial positions used to record μPL spectra shown in Figures 4 and 5 of the main manuscript and Figures S3 and S5 from the SI.

From the individual μPL spectra false-colour intensity maps were created. These are shown in the second row of Figure S3. In these maps red represents the spectrally integrated PL between 845 and 877.7 nm, due to the cluster emission, while green represents the integrated PL between 822.1 and 845 nm due to the nanowires. Both integrated PL intensities were normalised to the maximum value observed for the respective spectral range and sample. Marked spatial positions (white diamonds and yellow circles) indicate the positions where μPL was measured to produce the photoluminescence data presented in this work.

From the spatial mapping it is possible to distinguish regions with either a strong nanowire or cluster emission. Figure S4 shows μPL spectra recorded from nanowire rich and cluster

rich regions for three steps of the fabrication process: as-grown sample, the nanowires embedded in the dielectric but still attached to the silicon substrate and the nanowires transferred to the flexible substrate (nanowire tips away from the substrate).

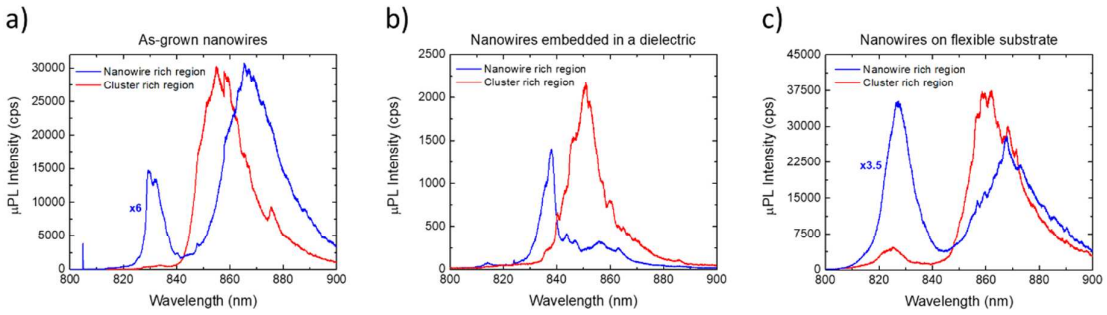

Figure S4: μPL spectra recorded for nanowire rich and cluster rich spatial position. a) as-grown nanowires sample b) dielectric embedded nanowires sample c) nanowires transferred to a flexible substrate sample. The laser power is ~ 3 μW.

The longer wavelength ($\gtrsim$ 840nm), broad emission is attributed to the clusters and the sharper, shorter wavelength emission to the nanowires. Even in nanowire rich regions strong cluster emission is present, with the exception of the dielectric embedded sample. For all three samples the nanowire emission occurs predominantly below the low temperature bandgap of GaAs as discussed in the main manuscript.

For a given stage of the processing the emission from nanowire rich regions shows some variation, this is demonstrated in Figure S5 which shows spectra recorded from three spatially separate nanowire rich regions for each of the three structures. Although a spatial inhomogeneity is observed, a number of previously discussed features are common to the different processing steps: the as-grown structure shows a number of sharp features attributed to emission from single nanowires, the emission of the dielectric embedded and structure on a flexible substrate are shifted to longer and shorter wavelengths respectively (by

approximately +5 and -10 nm (≡ -9 and +18 meV)), the substructure of the nanowire emission for the dielectric embedded and flexible substrate is less well defined.

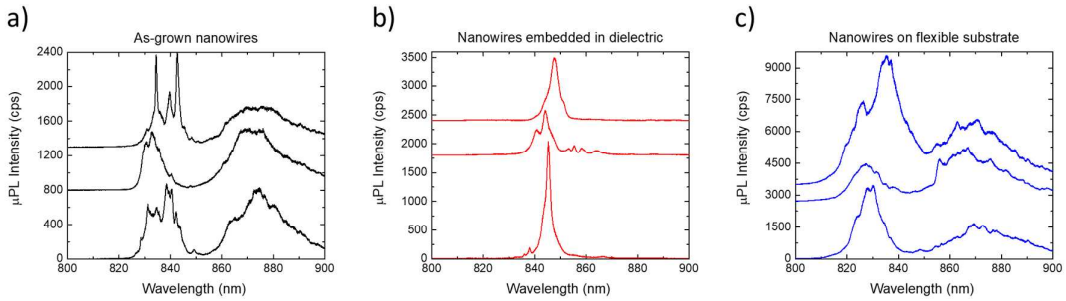

Figure S5: μPL measurements of GaAs nanowires from different steps of the fabrication process. μPL from three areas with strong nanowire emission. a) μPL from the as-grown sample. b) μPL from the dielectric embedded nanowire. c) μPL from the transferred nanowires on a plastic substrate. The laser power is ~ 0.6 μW.

It is also noticeable when comparing the spectra of Figure S5 that the cluster emission is very weak or absent for the dielectric embedded structure. The reason for this is unclear. Cluster emission is observed for this structure when exciting away from nanowire rich regions (see Figure S4) and can be observed from nanowire rich regions at higher excitation powers as discussed in the main manuscript. Although this structure has a thick dielectric layer, this should not affect the emission properties as the dielectric only absorbs strongly for wavelengths below 500 nm. Figure S5 also shows that the peak nanowire emission intensity is greatest for the structure on a flexible substrate.