Supplementary material: “Straining nanomembranes via highly mismatched heteroepitaxial growth: InAs islands on compliant Si substrates”

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Finite Element Modeling (FEM) calculations

In order to show the effect of a reversed radial strain distribution of the nanostressors along the membrane we have performed similar FEM simulations as for the results depicted in Fig. 7 of the work. For this strain profile, we have considered that the strain transfer to the membrane is larger at the membrane edge and smoothly evolves to no strain transferred at the membrane center – basically inverting the lateral strain distribution depicted in the blue curve of the inset of Fig. 7.

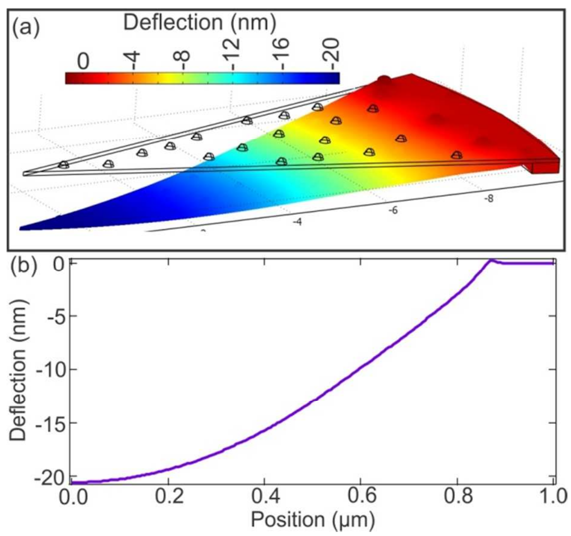

Fig. S1 (a) Model of nanostressors for 1 ML InAs deposited with a reversed lateral strain distribution using the best profile of Fig. 7 of this work. The strain distribution in the islands with respect to the position inside the membrane is reversed with respect to the blue profile seen in the inset of Fig. 7. (b) Nanomembrane deflection profile as a function of distance from the constrained edge.

The simulated strain distribution is a mirror of the blue curve gradient of Fig. 7 of the main text. In this case the larger strain transfer at the membrane edge produces an upward bending moment at this position, while no moment is registered at the membrane center. These effects add up to generate the z-displacement profile of Fig. S1(a), where the membrane buckles down. A cross section of the profile is shown in fig S1(b), where one can observe that a ca. 20 nm deep buckling of the membrane.

This result supports our conclusion that the buckling up - observed experimentally - results from a larger strain transfer from the islands at the membrane center.

Transmission Electron Microscopy (TEM)

To cross-check the crystalline quality as well as to investigate the lattice coherence of the deposited islands, cross-section TEM was carried out.

To prepare a selected area of the freestanding membrane, we used a focused ion beam instrument (nVison, Zeiss, Germany). A freestanding part was identified in the SEM and covered with a Pt layer. Thereafter, a focused Ga beam was used to cut out a thin lamella, which was then attached to a TEM grid. To become transparent for electrons and to allow high resolution transmission electron microscopy (HRTEM) the lamella was thinned to less than 100 nm using the several polishing steps of the focused ion beam preparation. (HR-)TEM was carried out in a FEI Tecnai F30 using an acceleration voltage of 300 kV.

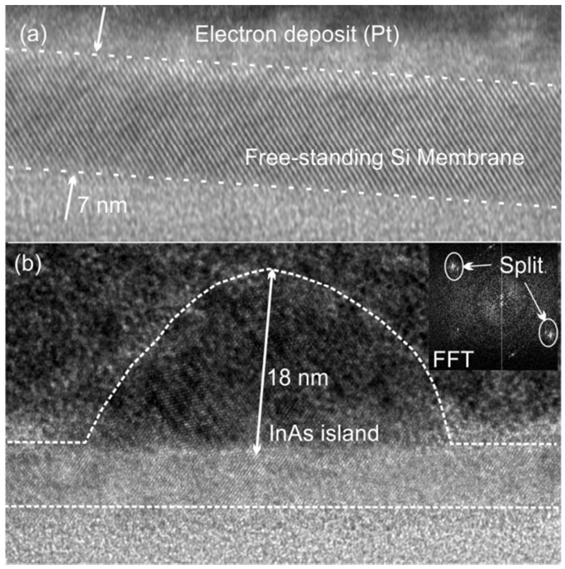

Fig. S2 (a) HRTEM cross-section image of the free-standing membrane. The membrane is embedded into the electrodeposited Pt and has a thickness of 7 nm. The visibility of lattice fringes proofs that the crystal lattice of the membrane stays intact throughout the growth process. (b) HR TEM cross-section image of an InAs islands deposited on the freestanding membrane. Lattice fringes can be observed for the islands as well as for the Si membrane. The inset shows the Fast Fourier Transformation (FFT) of the image indicating that we have two distinct lattice parameters in one direction of the island visible due to the satellite near the one spot. This image indicates some relaxation of the dot but proofs lattice coherence in some other parts (island is partly relaxed).

Figure S2(a) shows a cross-section HRTEM image of a freestanding part of the membrane. Lattice fringes are visible in the 7 nm thick membrane embedded into the electron deposited Pt from the focused ion beam preparation. The measured thickness agrees well with the expected thickness of the membrane from sample preparation. The lattice fringes show that the membrane remains a single crystal throughout the preparation and growth process. The image in Fig. 2(b) shows a HRTEM image depicting an InAs island on top of the Si membrane. Due to the embedment into the electron deposited material, the island contrast is reduced in the image (its contour is indicated by a white, dahed line). Nevertheless, lattice fringes are observable for the underlying membrane as well as the InAs island, which has a height of 18 nm. This height indicates that the cross-section observed in the figure most probably cuts through the center of the island (see height histogram in Fig. 4, main text). To analyze the lattice coherence between the substrate and the island, a Fast Fourier Transformation (FFT) of the image was carried out (inset Fig. S2(b)). The FFT exhibits the typical spots observed for a single crystalline lattice. A careful investigation of the spot shows a satellite near the main spot indicating that there are areas with different lattice parameters. Such difference in lattice parameters is ascribed to a (partial) relaxation of the InAs island losing the coherence to the Si lattice of the membrane. This agrees with our XRD results, which also indicated a partial relaxation of the InAs islands.