SiGe stressors for tensile strain in Ge membranes by top-down e-beam lithography

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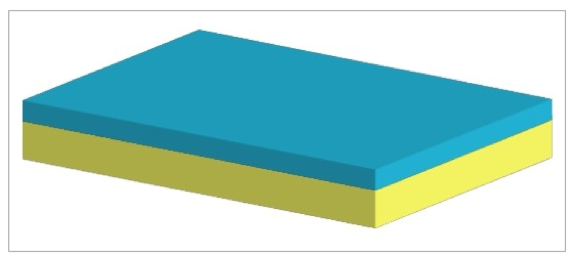
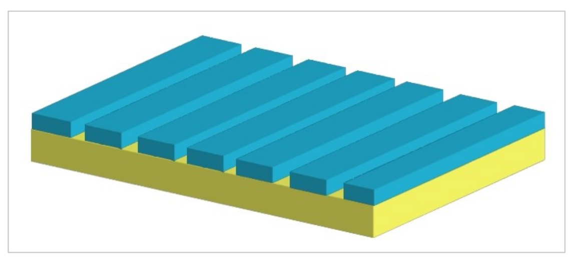
We use top-down SiGe structures, fabricated by nanolithography, as stressors for the creation of strong deformation fields and high strain in both Ge bulk substrates and Ge membranes. Finite-element method simulations suggest that a stressor patterned on a free-standing membrane instead of a substrate increases the projected strain from 4% up to 6%. This increase should be a very important step towards obtaining direct-gap Ge for opto-electronic devices. So, suspended-bridge and substrate-anchored SiGe/Ge membranes on a Si(001) substrate have been fabricated by using a combination of dry and wet-anisotropic etching. The wet etching parameters have been systematically analyzed in order to optimize the etching rate, anisotropy, and selectivity to Si or SiGe alloys in order to realize free-standing Ge structures for a new class of tensile Ge micro substrates.

Top-down SiGe stressors on Ge...

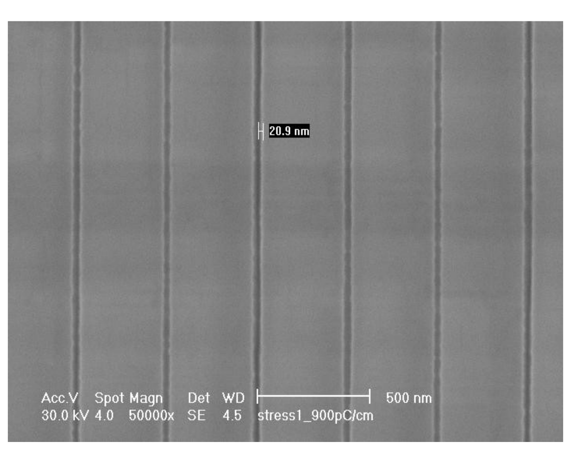


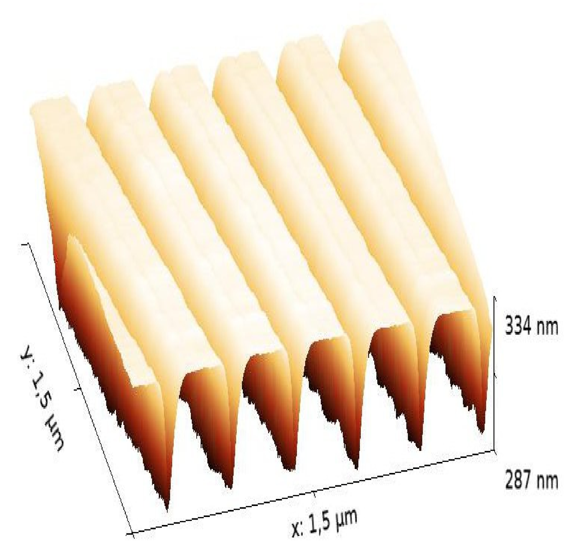
Low-Energy Plasma-Enhanced Chemical Vapor Deposition



Electron Beam Lithography
+
Reactive Ion Etching

...and characterization



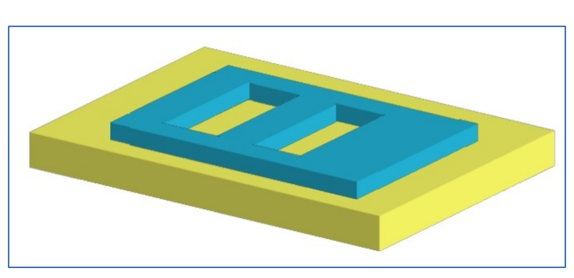


SEM and AFM images shows the obtained patterning: long ridges separated by gaps of a few tens of nanometers.

Fabrication of SiGe/Ge suspended bridge on Si(001)

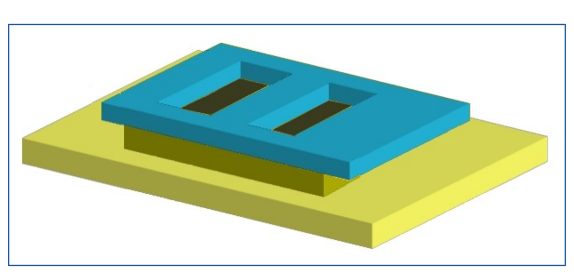
A combination of dry and wet-anisotropic etching has been used.

- First, a hard mask is created



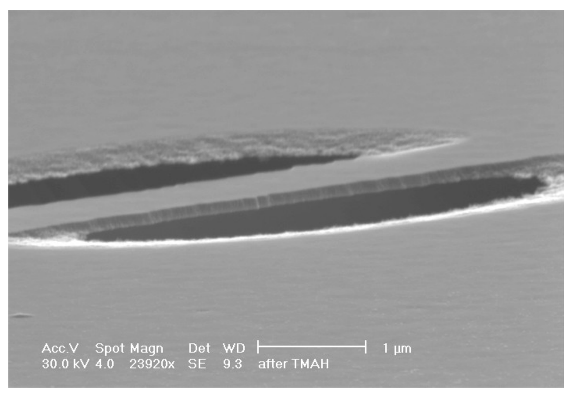
Electron Beam Lithography
+
Reactive Ion Etching

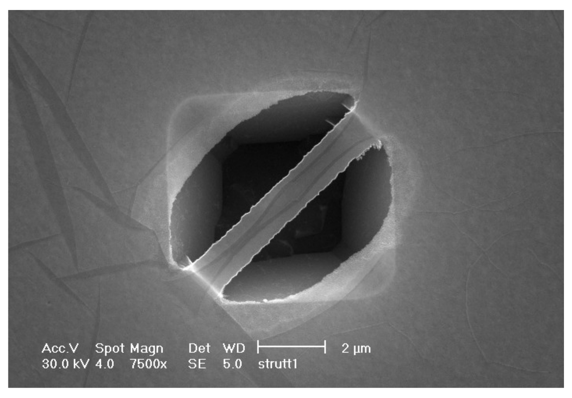
- Then, the bridge is suspended



TMAH @ 180°C

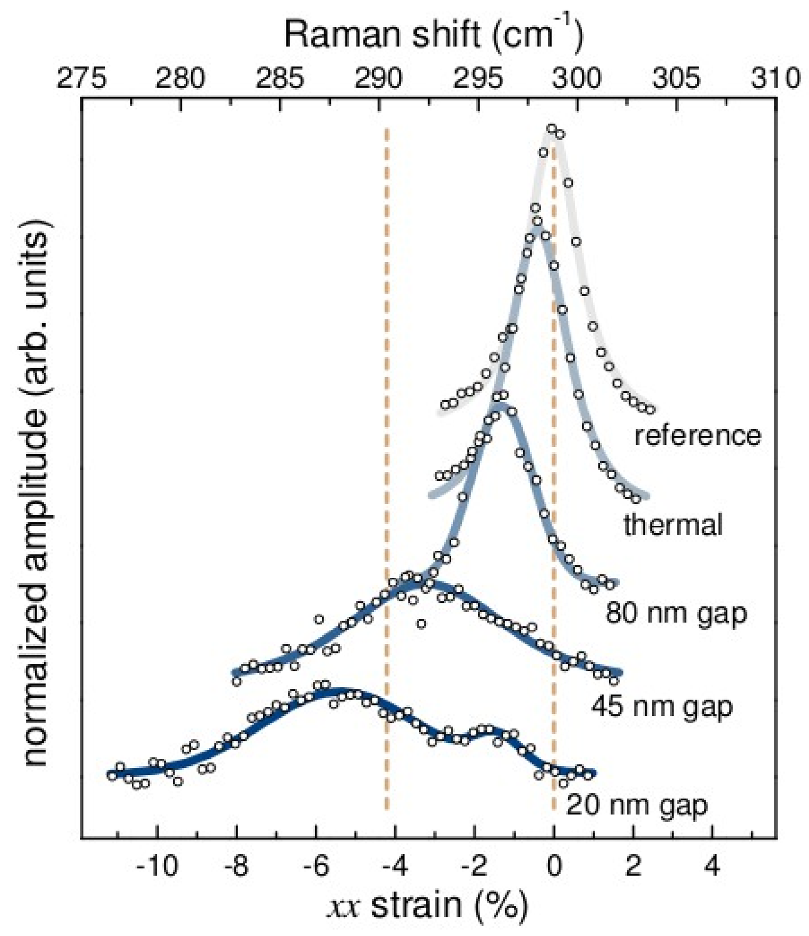
Suspended bridges 0.1-3 µm wide, 10 µm long, and 100 nm thick are obtained!





Micro-Raman spectroscopy

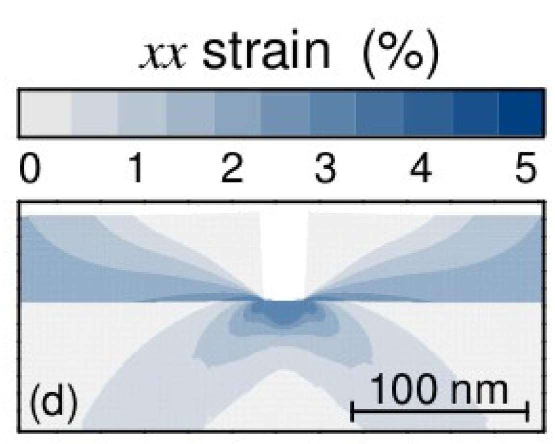
It has been used to obtain information on the strain state within the pattern for a sample with a SiGe film with a Ge content of ~ 50%.



a uniaxial tensile strain of the order of 4% has been observed

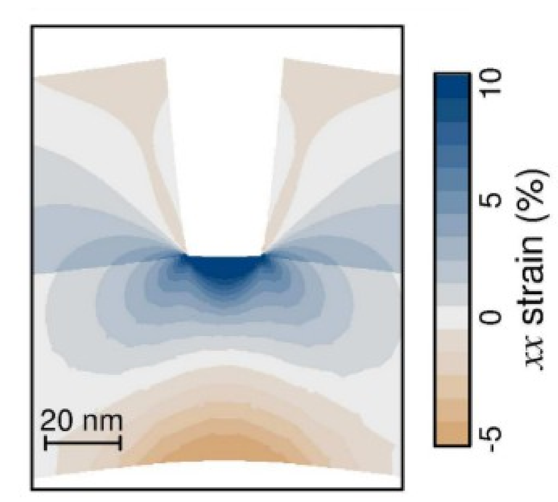
Direct gap Ge is obtained!

FEM simulations suggest that a stressor patterned on a free-standing membrane instead of a virtual substrate increases the projected strain from 4% up to 6%:

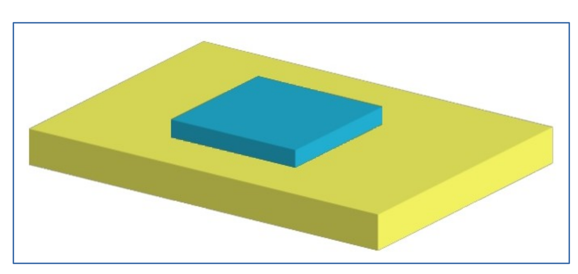


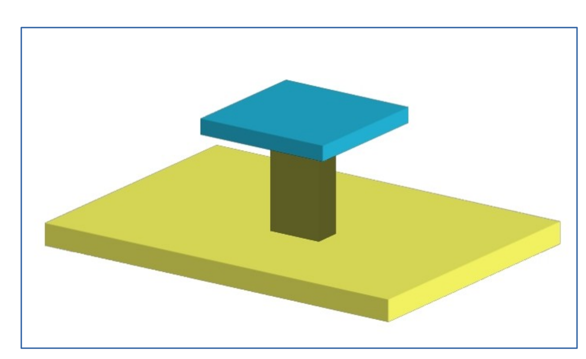
Ge bulk:
Strain ~ 4%

Ge membrane:
Strain ~ 6%

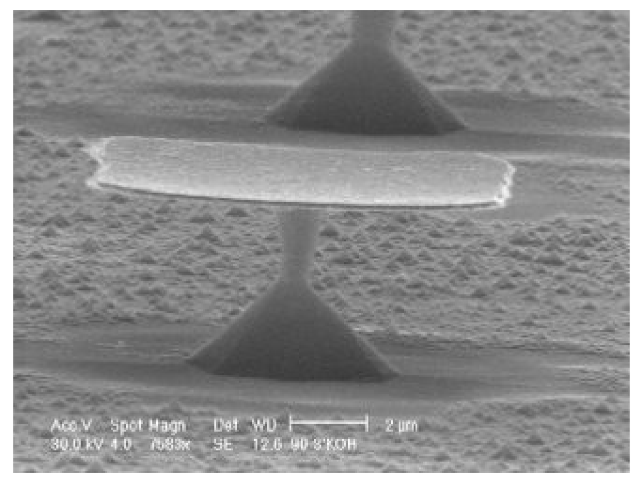


Fabrication of SiGe/Ge substrate-anchored membranes on Si(001)



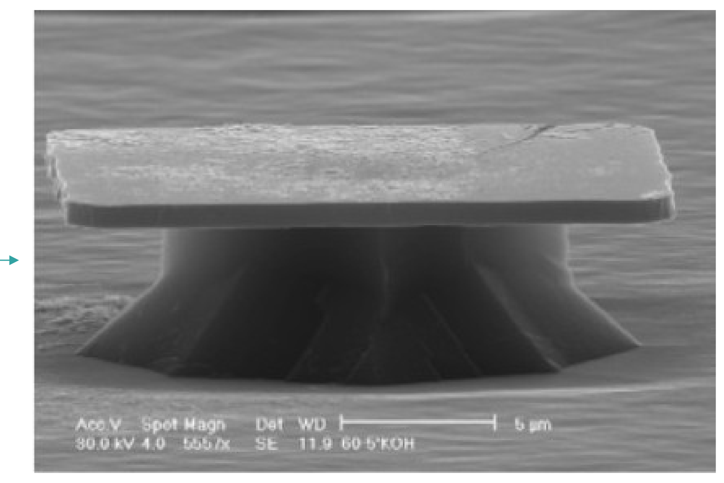


Optical Lithography
+
Reactive Ion Etching
+
KOH @70°C



Width ~10 µm
Thickness ~ 100 nm

Width ~20 µm
Thickness ~ 1 µm



Substrate-anchored membranes are obtained!

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References

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