

Strain engineering and mechanical assembly of silicon/germanium nanomembranes



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ABSTRACT

Silicon (Si) and/or germanium (Ge) nanomembranes (NMs) play crucial roles in various applications, including conventional microelectronics, as well as recently emerging high-performance flexible/stretchable electronics. Because of their superior mechanical properties, such as flexibility, strain-ability, and bond-ability, Si/GeNMs can be strain-engineered, functionalized, and assembled into two/three-dimensional (2D/3D) micro/nano-architectures and devices. These features offer significant opportunities in nanoscience and for the development of nanotechnology. Strain engineering of semiconductor NMs enables the modification of their physical properties, in particular those of Si and Ge (e.g., carrier mobility, band structure), thus creating enormous potential for use in high-speed rigid/flexible electronics, optoelectronics, and nanophotonics. The mechanical properties of NMs allow large deformations at the micro/nano-scale, via self-assembly or guided self-assembly, leading to 3D micro/nano-architectures, including tubes, wrinkles, buckles, and mesostructures. The transformation from 2D planar NMs to 3D micro/nano-architectures again strongly influences physical properties (e.g., mechanics, optics, and electronics), providing fascinating applications in sensing, energy harvesting, bio-integration, and flexible/stretchable electronics. In this Review, the recent progress in strain engineering and mechanical assembly of Si/GeNMs is reviewed, ranging from fundamental principles to device applications.

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Contents

1. Introduction	3
2. Properties of Si/GeNMs	4
2.1. Energy band structures	4
2.2. Electrical conductivity	4
2.3. Opto electronic properties	5
2.4. Thermal conductivities and thermoelectric properties	5
2.5. Mechanical properties	8
3. Strategies to synthesize and assemble Si and GeNMs	8
3.1. Synthesis methods	8
3.2. Assembly approaches	9
4. Strain engineering of Si/GeNMs	11
4.1. Strain engineering of 2D Si/GeNMs	11

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4.2.	Strained-Si technology	11
4.3.	Tensilely strained Ge	12
4.3.1.	Energy band structures <i>versus</i> strain	12
4.3.2.	Optoelectronic applications	12
5.	3D assembly by strain engineering	14
5.1.	Rolled-up nanotechnology	14
5.2.	Wrinkled-up nanotechnology	16
5.3.	Principles of rolling or wrinkling?	16
5.4.	Compressive Wrinkling/Buckling	17
5.5.	Popped-up mesostructures	18
6.	Properties and applications for 3D strain-engineered Si/GeNMs	19
6.1.	Properties	19
6.2.	Applications	21
6.2.1.	Sensors and transducers	22
6.2.2.	Micro/nanorobotics	22
6.2.3.	Bio-Platforms	23
6.2.4.	Optoelectronic devices	23
6.2.5.	Energy harvesting	24
6.2.6.	Flexible electronics: from bendable to stretchable, twistable, and foldable	25
7.	Summary and outlook	26
	Acknowledgements	27
	References	27

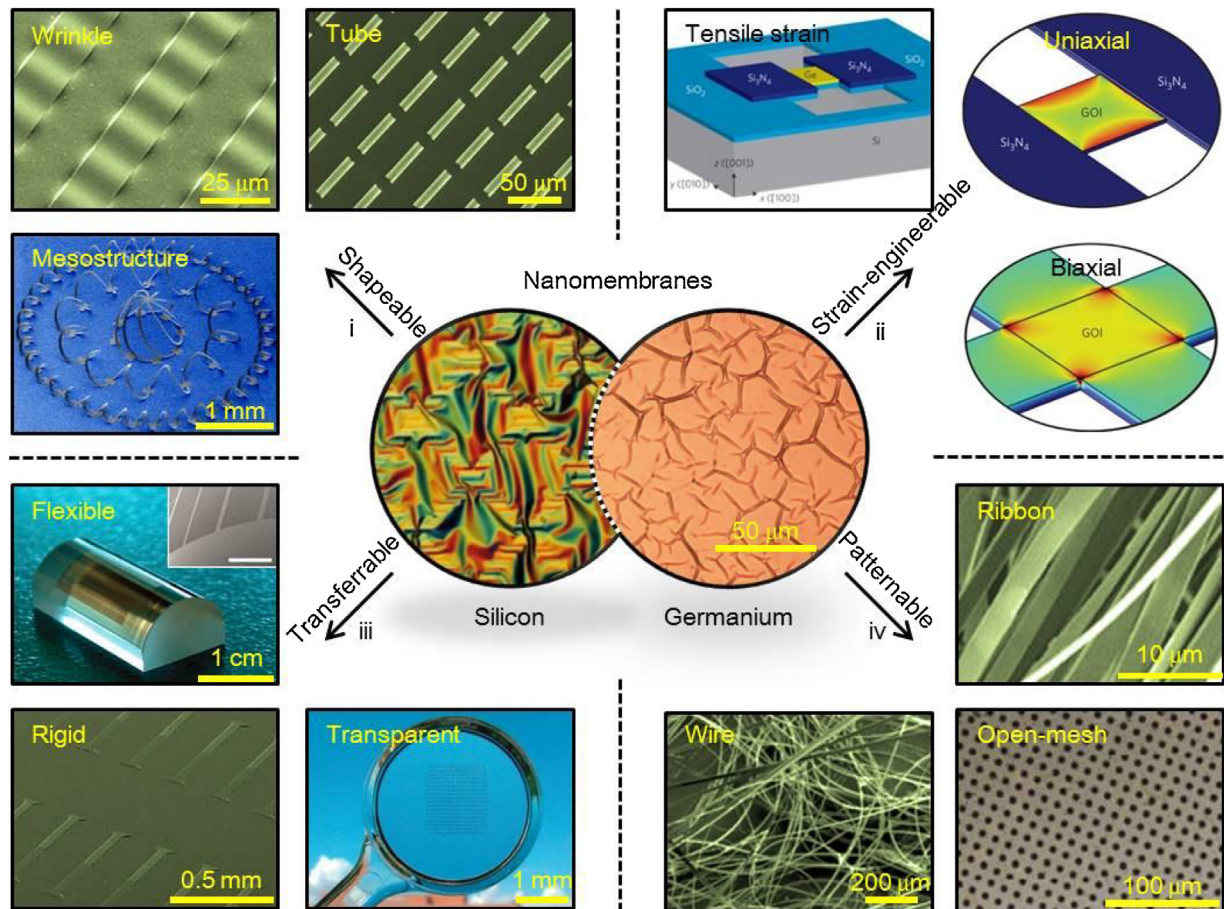


Fig. 1. Main features of single-crystalline Si/GeNMs: (i) shapeable: geometry transformation from 2D planar NMs to 3D micro/nano-architectures, including wrinkles/buckles [15], rolled-up tubes/helices [13], and pop-up origami mesostructures [14]; (ii) strain engineerable: tuning the physical properties of Si/GeNMs under tensile uniaxial or biaxial strain for enhanced charge-carrier mobility of Si [12,19,22,23], or energy-band engineering of Ge [20,21]; (iii) transferrable: integration onto either flexible or rigid (including transparent) substrate [18], depending on intended application; a demonstration of a SiNM-based array on a double-convex polycarbonate magnifying glass [18], which demonstrates potential for applications in transparent electronics; (iv) patternable: Si/GeNMs processed into wires [10], ribbons [24], open meshes [12], and other complex structures.

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