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Strain engineering and mechanical assembly of silicon/germanium nanomembranes

Qinglei Guo[a,d], Zengfeng Di[b,*], Max G. Lagally[c,*], Yongfeng Mei[a,*]

[a] Department of Materials Science, State Key Laboratory of ASIC and Systems, Fudan University, Shanghai, 200433, People's Republic of China
[b] State Key Laboratory of Functional Materials for Informatics, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, Shanghai, 200050, People's Republic of China
[c] Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, WI, 53706, United States
[d] Department of Materials Science and Engineering, Frederick Seitz Materials Research Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States

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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.

Contents

* Corresponding authors.
E-mail addresses: zfdi@mail.sim.ac.cn (Z. Di), lagally@engr.wisc.edu (M.G. Lagally), yfm@fudan.edu.cn (Y. Mei).

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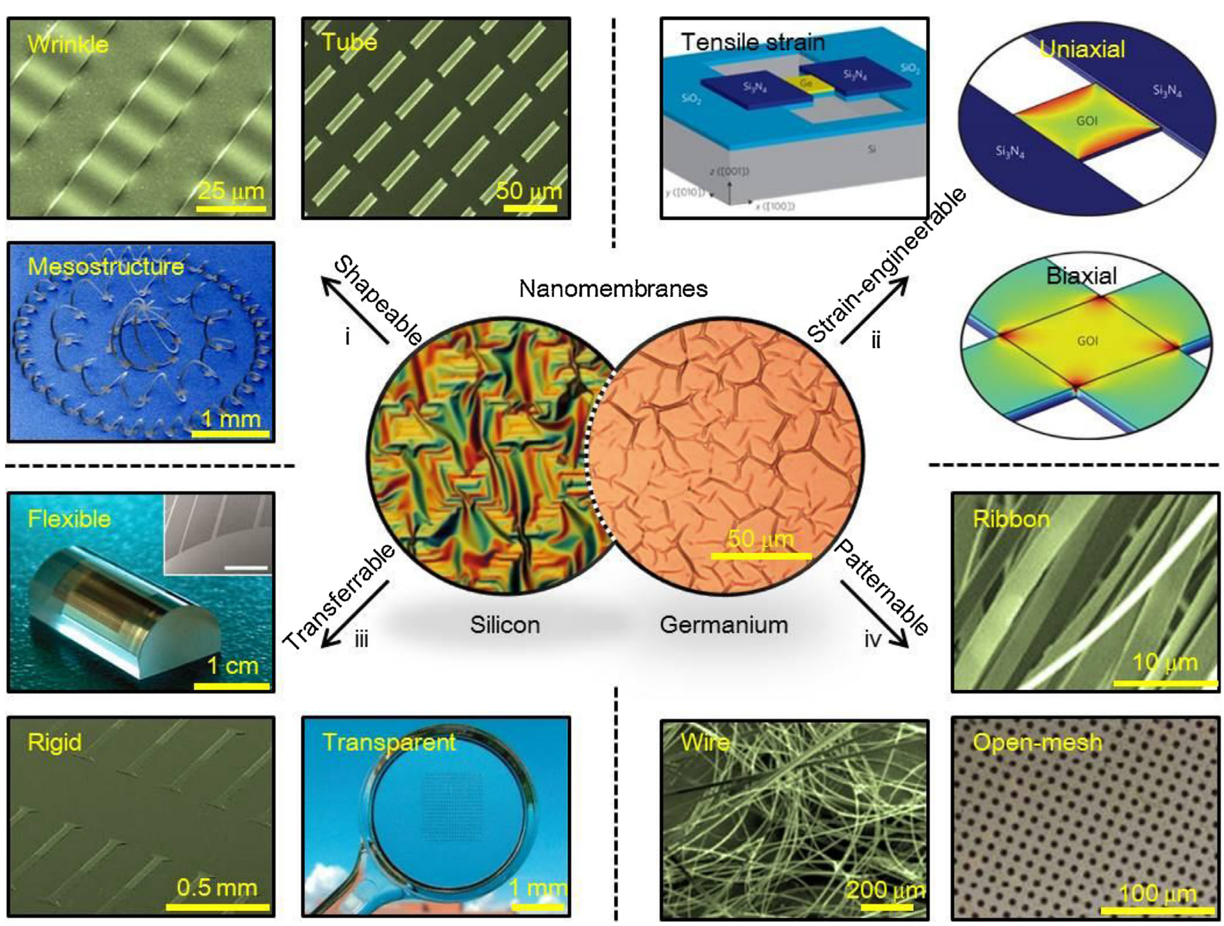

Fig. 1. Main features of single-crystalline Si/GeNMs: (i) shapeable: geometry transformation from 2D planar NMs to 3D micro/nano-architectures, including wrinkles/buckles [15], rolled-up tubes/helixes [13], and pop-up origami mesostructures [14]; (ii) strain engineerable: tuning the physical properties 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.