# Bio-Nano Crystallization of Amorphous Si Thin-Film for MEMS Devices

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Si thin-films are widely used in micro electromechanical systems (MEMS). Using Si thin-film allows MEMS devices to be integrated with ICs on a same substrate. However, crystalline defects degrade the mechanical properties of the Si thin-film. When a Si thin-film MEMS device is actuated, the energy supplied for actuation is dissipated by the internal friction at the crystalline defects. To reduce the energy loss in the device, the crystalline defects should be decreased. We are developing low-energy-loss MEMS devices using bio-nanotechnology [1,2]. Here, we present metal-induced lateral crystallization (MILC) of amorphous Si thin-film employing Ni nanoparticles which are biomineralized within apoferritin supramolecules (Bio-Nano Crystallization) [1-3].

A thin-film cantilever resonator was fabricated to analyze how the crystalline defects affect the resonance characteristics [Fig.1(a-d)] [2]. Apoferritin molecules with Ni nanoparticles (ϕ7nm) were patterned on an amorphous Si film. The sample was heat-treated under $O_2$ gas flow to eliminate the protein moieties and annealed under Ar gas flow for MILC. Structures of cantilever resonator were patterned by reactive ion etching. The resonator was released from the substrate by etching sacrificial layer ($SiO_2$) [Fig.1(d)]. From the resonance curve, quality factor ($Q$ factor), which is defined by the ratio of stored energy to the dissipated energy per oscillation cycle, was evaluated ($Q = f_r / \Delta f_{-3dB}$). A reference device, which was fabricated without MILC, had small grains and reached $Q$ = 12000 [Fig.1(e-g)]. In contrast, the resonator treated by MILC had well-crystallized large grains and reached $Q$ = 26000 [Fig.1(h, i)]. Indeed, two-fold reduction of energy loss was achieved.

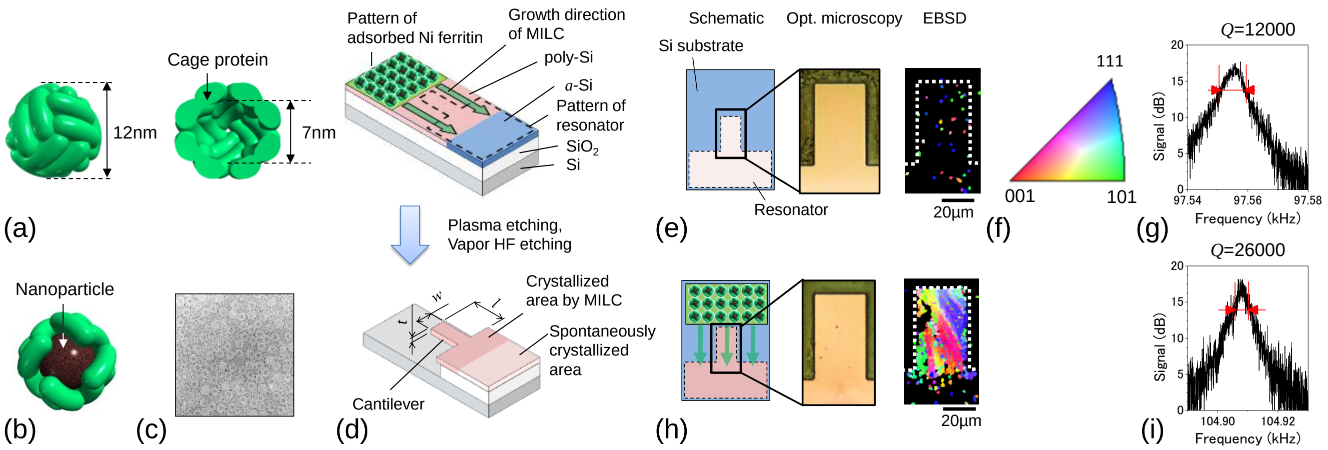


**Fig. 1. (a) Schematic drawing of apoferritin. (b) Apoferritin with nanoparticle core is called ferritin. (c) TEM image of Ni nanoparticles accommodated within apoferritin. (d) Fabrication sequence of a cantilever resonator. (e, h) Schematic, optical microscopy, and EBSD images of reference and MILC resonators (f) Crystalline orientation of EBSD image. (g, i) Resonance curves of reference and MILC resonators.**

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