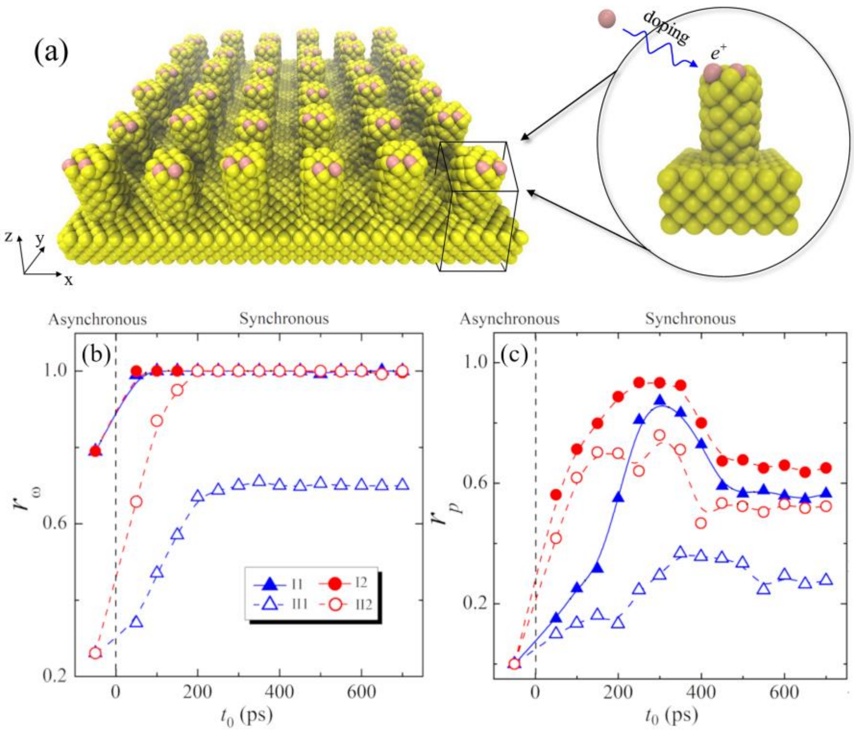
Thermal self-synchronization of nano-objects

IIS, Univ. of Tokyo[1], Univ. of Tongji[2], °Zhongwei Zhang[1], Yangyu Guo[1], Jie Chen[2], Masahiro Nomura[1], and Sebastian Volz[1]
E-mail: zhongwei@iis.u-tokyo.ac.jp

Self-synchronization is a ubiquitous phenomenon in nature, in which oscillators are collectively locked in frequency and phase through mutual interactions [1, 2]. While self-synchronization requires the forced excitation of at least one of the oscillators, we demonstrate that this mechanism spontaneously appears due to the activation from thermal fluctuations. By performing molecular dynamics simulations, we demonstrate self-synchronization in a platform supporting charged silicon resonator nanopillars having different eigenfrequencies (See Fig. (a)). We find that pillar's vibrations are spontaneously converging to the same frequency and phase due to the coulomb interaction among the nanopillars (See Figs. (b-c)). In addition, the dependencies on intrinsic frequency difference and coupling strength agree well with the Kuramoto model predictions [3]. More interestingly, we find that a balance between energy dissipation resulting from phonon-phonon scattering and potential energy between oscillators is reached to maintain synchronization. While microscopic stochastic motions are known to follow random probability distributions, we finally prove that they also can yield coherent collective motions via self-synchronization.



(a) Pillared silicon membrane with electron doping (pink atoms) on the top of pillars. Pillars behave as resonators activated by thermal phonons. Synchronization degree in (b) frequency (r_ω) and (c) phase (r_p) versus evolution time for four systems.

References

[1] D. Zhang, Y. Cao, Q. Ouyang, Y. Tu, Nat. Phys., 16 (2019) 95-100.
[2] J.D. Touboul, C. Piette, L. Venance, G.B. Ermentrout, Phys. Rev. X, 10 (2020) 011073.
[3] Y. Kuramoto, I. Nishikawa, J. Stat. Phys., 49 (1987) 569-605.