Theoretical Analysis of the Influence of Aspect Ratio and Density of Nanorod Arrays for Piezoelectric Energy Harvesting

Nagoya Univ.[1], PRESTO[2], °(D)Jundong Song[1], Tomoaki Yamada[1,2], Masahito Yoshino[1], and Takanori Nagasaki[1]

E-mail: t-yamada@energy.nagoya-u.ac.jp

【Introduction】

Piezoelectric energy harvesting has been expected to be a promising application of powering trillions of miniaturized sensors in recent years. In this study, we focused on a novel structure of aligned piezoelectric nanorods for the energy harvesting application, and evaluating the output power of this structure using finite-element method. It is shown that using rod-shaped materials will increase the piezoelectric constant d_{33} by 33% compared with using a film with the same thickness, owing to less substrate clamping. In addition, for the case of applying normal force, the stress is easy to concentrate into nanorods. Therefore, the nanorod structure can generate an output power one or more orders of magnitude higher than films within the same volume. The results indicate that this nanorod array will play an important role in the integration with miniaturized sensors in the off-resonant mode.

【Numerical analysis】

The output voltage and power of aligned nanorods, made of [001]-oriented lead zirconate titanate, are calculated by *COMSOL Multiphysics*. The open-circuit condition is used for investigating the effect of aspect ratio of a single nanorod, and the circuit with optimal resistance is used for evaluating output power of the nanorod array. A thin-film-based cantilever beam is also modeled, and its output performance is simulated as a comparison in this study.

【Results & discussion】

The effect of aspect ratio of nanorods on output voltage is shown in Fig. 1(a). It is clear that the piezoelectric unit with large aspect ratio t_0/L will output higher voltage than films owing to less substrate clamping in lateral directions. Furthermore, decreased contact areas between the piezoelectric materials and substrates enhance the induced stress into nanorods. As a result, for the case of applying the same vibration force, the output power of the nanorod array will exceed that of the film with the same dimension by one or more orders of magnitude [Fig. 1(b)], despite the smaller capacitance. The output power is also compared with that of a cantilever beam under the vibration at 100 Hz, as shown in Fig. 2. The output of the nanorods increases with decreasing device length and is expected to exceed that of the film cantilever in the d_{31} mode when the length is less than 700 μm.

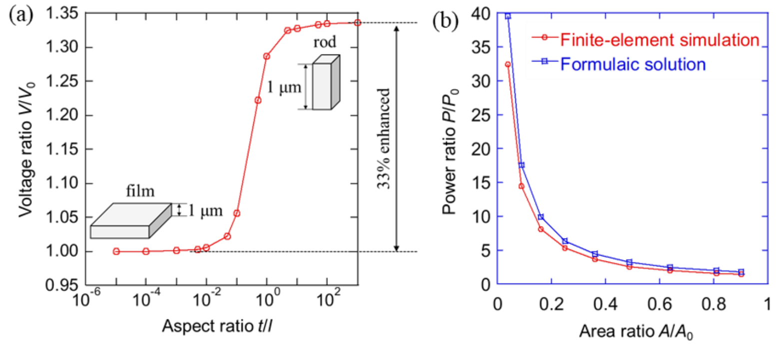

Fig. 1 (a) Dependence of aspect ratio on the output voltage of the single nanorod. (b) Dependence of area ratio on the output power of the nanorod array

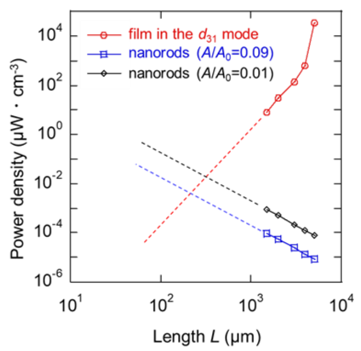

Fig. 2 Dependence of output power density on the length of the device

© 2019年 応用物理学会