化学と機械工学の融合が拓くエネルギーハーベスティングの未来

（東大院工 [1]）○鈴木 雄二 [1]・三好智也 [1]・鈴木邦子 [1]

Future of energy harvesting opened up by fusion of chemistry and mechanical engineering

([1]*School of Engineering, The University of Tokyo*) ○Yuji Suzuki,[1] Tomoya Miyoshi[1], Kuniko Suzuki[1]

Energy harvesting from human walking is a suitable power supply for powering battery-less wearable devices. Due to the fact that low-frequency 3-D vibration with 3-axis rotation is dominant for human motion, rotational energy harvesters (EHs) have advantages over vibration EHs. Among various transduction mechanisms, electret generators are advantageous in terms of higher output power at low frequencies and their low-profile structures. In this talk, after giving the overview of energy harvesting technologies, developments of new materials for electret EHs and their application to rotational electret EH are introduced.

In the present study, a novel high-performance amorphous fluorinated polymer electret based on quantum chemical analysis is proposed. With a 15 μm-thick film, a record-high surface charge density of -4 mC/m^2 with extremely-high thermal stability of implanted charged has been obtained. In addition, when nematic liquid crystal with anisotropic permittivity is introduced between electrets and electrodes, the output power is much enhanced by increasing the device capacitance while suppressing the parasitic capacitance. Importance of developing new functional materials for energy harvesting is discussed.

Keywords : Energy harvesting; Vibration; Electret; Fluorinated polymer; Anisotropic permittivity

歩行からの環境発電（エネルギーハーベスティング）は，電池レス・ウエアラブルデバイスに適した電源である．特に，低周波数・３次元の振動・回転が主であるので，単振動型よりも回転型の発電機が向いていると考えられる．低周波数領域かつ低背サイズの発電原理としては，エレクトレットが他の原理よりも優れている [1)]．本報では，環境発電技術について概観したのち，エレクトレット発電機のための新しい材料の開発 [2-4)]，およびその回転型発電機への応用 [5)]について報告し，環境発電における機能材料開発の重要性について議論する．

本研究では，量子化学計算を用いて，新規性の高い高性能アモルファスフッ素樹脂のエレクトレット材料を提案した [2-4)]．15μm 厚さの膜に対して，これまでの最高の-4 mC/m^2 の表面電荷密度と，非常に高い電荷の熱的安定性を実現した．また，異方性誘電率を持つネマチック液晶を電極・エレクトレット間に挿入すると，デバイスの容量は増加させつつ寄生容量を抑制することによって，発電量を顕著に増大させることができることを明らかにした [6)]．環境発電における新しい機能性材料開発の重要性について解説する．

1) Suzuki, Y., “Recent Progress in MEMS Electret Generator for Energy Harvesting,” IEEJ Trans. Electr. Electr. Eng., Vol. 6, No. 2, pp. 101-111 (2011).
2) Kim, S., Suzuki, K., Sugie, A., Yoshida, H., Yoshida, M., and Suzuki, Y., “Effect of Terminal Group of Amorphous Perfluoro-Polymer Electrets on Electron Trapping,” Sci. Tech. Adv. Mater., Vol. 19, No.

1, pp. 486-494 (2018).
3) Kim, S., Melnyk, A., Andrienko, D., and Suzuki, Y., "Solid-state Electron Affinity Analysis of Amorphous Fluorinated Polymer Electret," J. Phys. Chem. B, Vol. 124, No. 46, pp. 10507-10513 (2020).
4) Kim, S., Suzuki, K., and Suzuki, Y., "Development of A High-performance Amorphous Fluorinated Polymer Electret Based on Quantum Chemical Analysis," J. Phys.: Conf. Ser., Vol. 1407, 012031 (2019).
5) Miyoshi, T., Adachi, M., Suzuki, K., Liu, Y., and Suzuki, Y., "Low-profile Rotational Electret Generator Using Print Circuit Board for Energy Harvesting from Arm Swing," 31th IEEE Int. Conf. Micro Electro Mechanical Systems (MEMS'18), Belfast, pp. 230-232 (2018).
6) Kittipaisalsilpa, K., Kato, T., and Suzuki, Y., "Characterization of Fluorinated Nematic Liquid Crystal for High-power Electret Energy Harvester," J. Phys.: Conf. Ser., Vol. 1052, 012044 (2018).

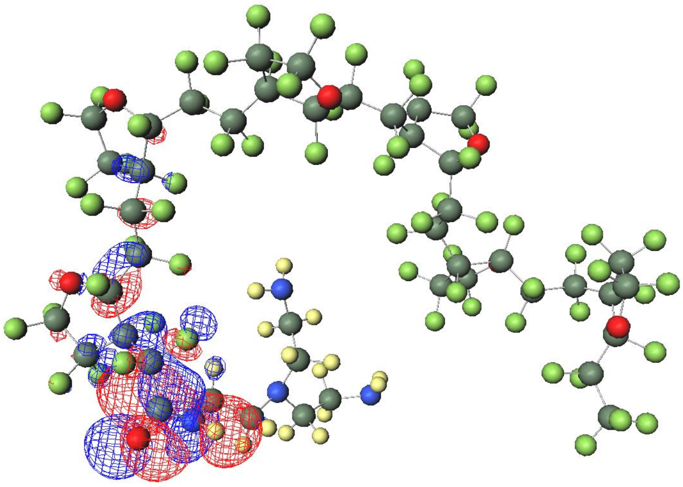

Figure 1: Distribution of excess electron in amorphous fluorinated polymer electret showing localized charge trap near the end group[4].

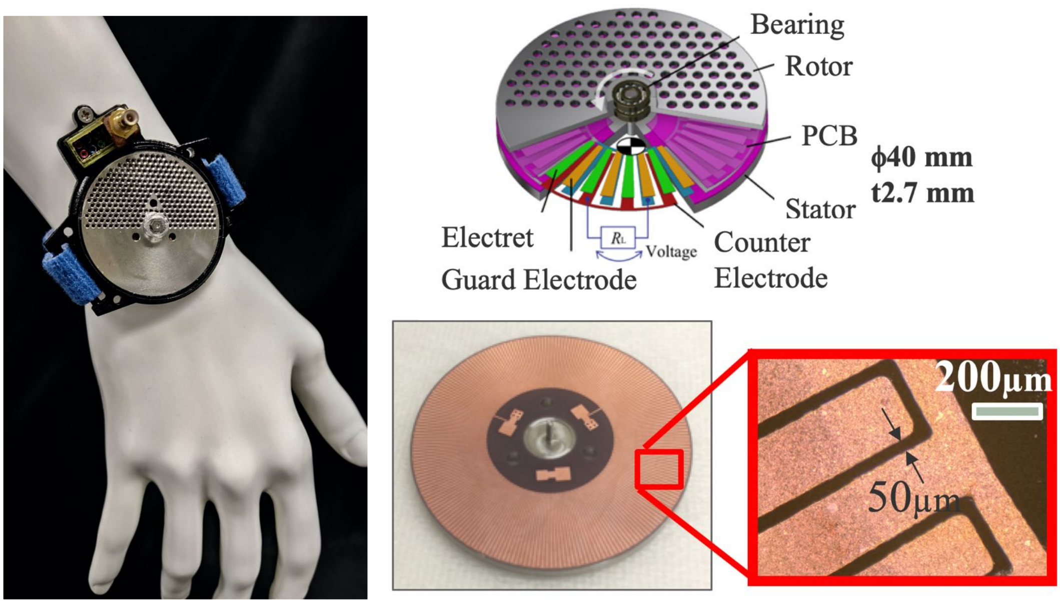

Figure 2: Rotational electret energy harvester[5].