# 博 士 論 文 の 内 容 の 要 旨

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| 論文題目 | Study on moisture-induced electricity generation of graphene oxide-based film<br>（酸化グラフェン系フィルムの水分誘起発電に関する研究） |

（博士論文の内容の要旨）

Green energy conversion is the first choice in solving contemporary energy pollution and shortages. Harvesting energy from clean and inexhaustible widespread small-scale water in nature environment, is promising choice to alleviate the energy crisis. Graphene oxide (GO) is rich in oxygen-related functional groups such as hydroxyl and carboxyl groups and has good application prospects. Interested in potential applications in electronics, energy-related devices, and smart systems that are highly dependent on flexible regulation of oxygen content. Ultraviolet (UV) irradiation treatment, as a clean and effective method can remove oxygen-containing groups (OCGs) of GO. OCGs in GO is beneficial to hydrophilic, so GO-based films with regionally hydrophilic difference can be obtained by UV treatment.

Firstly, GOF was reduced by UV irradiation for different times, and based on the reduction degree and surface hydrophilicity, 3 h was considered as a good option. The RGF has considerable hydrophilicity and conductivity differences in its two surfaces, which endow it the application potential in moisture-induced power generation. RGF could generated electricity in humid environment. The RGF-based generator showed good output performance in high humidity which can generated electricity of 424 mV, 9.2 uA, and the generator with expandation could power a timer. Therefore, the UV reduced GO-based film with the hydrophilic difference is very promising in moisture induced electricity, and further use can be done to employ UV treated GO-based films for more applications.

However, the RGF-based generator has a short power supply time. Hence, developing a sustainably powered electricity generator based on UV-treated GO-based film should be conducted. Afterwards, a sustainably moisture-induced electricity generator which can supply considerable electrical power even when transferred to a dry condition was developed. GO film was simply region-treated by bilateral ultraviolet irradiation to obtain two special structural films—RGO/GO/RGO sandwich-like structural film (RGRSF) and RGRSF–GO composite films. The special sandwich-like structure endows films with the capability to easily transport water molecules and difficultly release moisture that improve the adaptability of generator to environmental change. A single MIEG could supply an open circuit voltage of 215.7 mV for more than 3 h. 9MIEGs successfully powered a LED in 1 h under moisture, and its total discharging process took about 5.5 h in a normal room condition, in which the LED kept lit for 1 h. Additionally, with outstanding flexibility, high stability, and reproducibility, the generator shows the potential in application of wearable electronics, and it can generate sustainable electricity in the face of suddenly changes in humidity.

Moisture from the breath is one of ubiquitous water energy sources. The inability to continuously provide water molecules limits its application in moisture-induced electricity generation. Developing a sustainable breath moisture-induced power generator is a challenge. MIEG presented above can only generate about 50 mV under 45%, and the charging time is too long which nearly took 50 mins. So, the sensitivity to low moisture of the generator should be improved to conduct high performance and fast response. Therefore, based on the sandwich structure that can help to slow down the discharging behavior, we first develop an electricity-sustainable breath-moisture-induced electricity generator (BMIEG) during intermittent exhalations. The generator is fabricated by the end-to-end connection of two equal asymmetric regional sandwich structural graphene oxide/carbon nanotube based composite films, making it continuously expandable without limit. The appropriate addition of CNT facilitates the establishment of a continuous CNT network channel and induces voltage when water flows through the surface of the CNTs to enhance the output performance. The BMIEG presents a slow discharging behavior when exhalation is stopped, and it continually lights up a light-emitting diode in the intermittent exhalation

process with a simple size expansion of a series of array arrangements. Additionally, the BMIEG is freely assembled using a capacitor to achieve variable voltage and/or stabilized voltage electricity supply. The flexibility and reusability of the generator show its considerable application prospects in wearable electronic products. Additionally, the generator obtained application prospects in respiration sensors because the VOC signal changed stably in obvious differences under different respiratory frequencies. Because of the excellent flexibility and reusability of the BMIEG, it can be employed as a power supply for wearable electronics and mask built-in breathing monitors.

In conclusion, UV treatment can be used to obtain various the GO-based films with reginal difference in hydrophilicity which is promising in the field of moisture-induce electricity generation. Based on the regionally hydrophilic difference of GO-based films, environmental and breath moisture-induced power generators which could continuable power were developed. Besides, UV treated GO-based films show many advantages such as well controllable, flexible, and wearable. In the further research, sunlight can be considered to replace UV irradiation as a source to obtain similar good effect and other different regional treatments can be discussion for more applications.