Sustainable Energy Harvesting in Aeration Tank Using Flexible Piezoelectric Membrane

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This study developed a high-performance poly(vinylidene fluoride) (PVDF) piezoelectric membrane using the Non-solvent Induced Phase Separation (NIPS) method combined with graphene doping, with the goal of enhancing energy recovery from low-frequency mechanical sources. The influence of graphene incorporation on membrane structure and piezoelectric phase formation was systematically investigated. The results demonstrated that graphene effectively promoted the formation of the polar crystalline phase in PVDF. However, the piezoelectric output showed a non-linear dependence on graphene concentration. An optimal doping level of 0.75 wt% graphene achieved the highest peak-to-peak voltage of 5.64 V, indicating maximized polarization and improved energy conversion efficiency. To evaluate its practical applicability, the optimized membrane was tested under simulated oscillatory conditions, confirming its ability to stably convert low-frequency mechanical energy into electrical energy. In particular, wastewater treatment plant aeration tanks continuously generate stable and sustained surface waves due to constant air injection. These waves represent an underutilized and renewable mechanical energy source. By integrating the proposed PVDF piezoelectric membrane system into aeration tanks, this study demonstrates the feasibility of recovering wasted hydrodynamic energy and converting it into usable electrical power. This approach provides a sustainable and practical strategy for enhancing energy efficiency in wastewater treatment facilities while contributing to green energy development.

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