Structure–Property–Device Correlation in Functionalized Rubber–Graphene Composites for TENG Applications

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Flexible and self-powered electronic systems require mechanically durable, high-permittivity elastomers capable of efficient mechanical-to-electrical energy conversion. In this work, we report the development of a device-oriented nanocomposite based on functionalised natural rubber reinforced with modified graphene for energy harvesting applications.

The performance of rubber–graphene composites in flexible energy-harvesting systems is strongly governed by interfacial compatibility between the elastomer matrix and the nanofiller. Natural rubber was chemically modified to introduce polar functionalities along its backbone, with the objective of improving affinity toward graphene and enabling controlled interfacial interactions. This interfacial engineering strategy facilitates systematic investigation of filler dispersion, matrix–filler coupling, and network formation while preserving elastomeric flexibility.

A fundamental study was conducted to examine the viscoelastic behaviour of the filled systems and to establish correlations between mechanical response, dielectric characteristics, and triboelectric nanogenerator (TENG) performance. The influence of rubber modification and graphene incorporation on dynamic mechanical properties, interfacial polarisation mechanisms, and charge generation behaviour was analysed to understand structure–property–device relationships. Particular emphasis was placed on linking viscoelastic energy dissipation and dielectric response to triboelectric output under cyclic mechanical excitation.

This work provides a materials-level framework for correlating elastomer physics with energy-harvesting functionality, offering insight into how matrix modification and nanofiller engineering govern the electromechanical performance of graphene–rubber composites for self-powered systems.

References

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