Novel Kinetic Energy Harvesting Solutions: Integrating Dynamics, Materials, and Nature-Based Approaches

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The increasing demand for completely self-powered devices, autonomous sensor nodes, and improved performance of battery-free sensors and transducers has spurred significant research into smart power harvesting devices and innovative measurement systems. Energy harvesting can be achieved from various sources, with a particular focus on mechanical ambient vibrations. These vibrations include naturally occurring noise sources, induced oscillations, vehicle motions, multi-tone vibrating systems, and noisy environments.

A common energy harvesting approach involves using vibrating mechanical bodies that collect energy through self-generating materials to charge a battery and power a specific sensor. While these systems perform well at their natural frequency, they are generally unsuitable for energy recovery across a wide spectrum of frequencies, as ambient vibrations typically encompass a broad range.

To address this challenge, several methods for optimizing the harvested energy from environmental vibrations (such as weak kinetic vibrations) have been developed. These methods include advancements in energy conversion, extraction mechanisms, and the exploitation of nonlinearities to enhance device performance, enabling them to supply or sustain specific sensors or transducers.

Special emphasis is placed on leveraging nonlinear dynamics in autonomous measurement systems and materials, also considering green aspects and nature-based solutions. These systems can store converted energy even in the presence of weak vibrations, measure external physical quantities, and transmit data. Notably, the proposed solutions operate passively on ambient vibrations, requiring no external power or control systems.