

# Preface

For more than a decade, the research field of mechanical energy harvesting for low-power electricity generation has received growing interest by academia and industry. The ultimate goal in energy harvesting research is to enable energy-autonomous small electronic devices that can scavenge ambient mechanical energy and convert it to electrical power. The potential applications of energy harvesting technologies span over many different industries and areas of applications including: wireless sensor networks employed to monitor civil infrastructure systems, unmanned aerial vehicles, battery-free medical sensors implanted in the human body, and long-term sensors used for animal tracking.

By potentially eliminating the need to replace or periodically recharge the batteries in autonomous electrical devices, the research in energy harvesting has the potential to not only allow unprecedented monitoring of engineered and natural systems over almost arbitrarily long periods of time but also to achieve this goal both economically and sustainably.

Research into energy harvesting started with the fundamental and conceptual efforts for converting simple harmonic vibrations into electricity. However in the last couple of years, research efforts have focused on converting other forms of mechanical energy, such as impulse-type kinetic energy from human gait, random ambient vibrations, surface strain energy of civil engineering structures, wind and water flow energy, and acoustic energy of air-borne and structure-borne waves. Alternative materials and transduction mechanisms have also been investigated for mechanical-to-electrical energy conversion in addition to the developments in MEMS power harvester architectures and fabrication methods. Novel electrical architectures have allowed for improved mechanical to electrical conversion, and developments in ultralow-power integrated circuits have focused on being able to achieve greater electronic functionality with less electrical power.

Our aim with this volume is to bring together research advances in energy harvesting by focusing on different transduction mechanisms and forms of mechanical excitation. The title *Advances in Energy Harvesting Methods* therefore refers not only to the conversion (i.e., transduction) methods but also to the physical nature of the excitation and the system-level energy conversion problem (which is often a

multi-physics problem), such as the harvesting of random vibrations through base excitation of a piezoelectric cantilever or that of airflow energy harvesting through aeroelastic vibrations based on various fluid–structure interaction mechanisms.

It is worth adding that this book is essentially focused on the harvesting of kinetic or strain energy induced within the harvester in a variety of multi-physics problems (through direct vibrations, flow excitation, sound waves, etc.) and excludes other contemporaneous energy scavenging methods, such as solar and thermoelectric energy harvesting. Likewise, the focus of the book is specifically placed on low-power energy harvesting. In this regard, for instance, the harvesting of flow energy discussed herein is not an alternative to replace large windmills and wind turbines, but it could rather be a component powering the wireless structural health monitoring sensors of such large systems to reduce their inspection and maintenance costs.

The state-of-the-art research efforts predominantly covered in this book include examples of energy scavenging using piezoelectric transduction, electromagnetic induction, electrostatic transduction, as well as electroactive polymer harvesting. Each one of these alternative methods of mechanical energy harvesting has its own advantages (and disadvantages) depending on the specific application that is being considered; for example, in many cases geometric scale of the application as well as the form and characteristics of the mechanical energy input could dictate the best transduction mechanism. To further elaborate on this point, a specific example is the case of piezoelectric transduction. In the last couple of years, most research in energy harvesting has focused on piezoelectric transduction due to its high-power density and ease of application. However, electrostatic energy conversion has peculiar advantages for MEMS fabrication and implementation while a magnet-coil arrangement that exploits electromagnetic induction can outperform piezoelectric transduction for low-frequency and large-displacement oscillations.

Although early efforts on vibration-based energy harvesting focused on simple tuned oscillators for exploiting the resonance phenomenon under harmonic excitation, researchers have recently directed their attention toward more sophisticated and commonly encountered forms of excitation such as ambient random vibrations. As could be expected, these more sophisticated forms of excitation (e.g., varying frequency or broadband excitation) require more advanced energy harvester configurations for effective power generation. Recent research in vibrational energy harvesting has thus focused on nonlinear scavenging systems with potentially improved performance under broadband (or wideband) excitation in comparison with their linear resonant counterparts. This book also devotes a number of chapters to recent efforts on broadband energy harvesting methods by exploiting nonlinear dynamic phenomena.

First we would like to thank the authors for their high-quality contributions. We would also like to thank Michael Luby and Merry Stuber of Springer for their interest and enthusiasm throughout the editing process of this volume. We sincerely hope you enjoy reading this collection of leading advances in energy harvesting.

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Niell Elvin  
Alper Erturk

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Elvin, N.; Erturk, A. (Eds.)

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