Proceedings of the 8th International Conference of Recent Trends in Environmental Science and Engineering (RTESE 2024)
Chestnut Conference Centre - University of Toronto, Toronto, Canada – June 13 - 15, 2024
DOI: 10.11159/rtese24.003

Multifunctional Metamaterials: A New Paradigm for Sustainable Energy Production

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Extended Abstract

In an era where global energy demands continue to rise, the pursuit of sustainability has never been more critical. According to the International Energy Agency, the world's total energy consumption is projected to grow by 1% annually through 2040, driving an unprecedented demand for innovative solutions that enhance energy efficiency and resource conservation. Smart multifunctional metamaterials represent a revolutionary class of solutions, offering not only significant opportunities for energy saving but also a host of other transformative advantages. Among alternative energy materials, *ferroelectric* and *triboelectric* multifunctional materials have gained a great deal of interest. On the one hand, *ferroelectricity* allows the generation of electrical power from mechanical oscillations and temperature fluctuations. On the other hand, *triboelectricity* enables contact electrification on certain insulators after being separated from a material they are contacted or rubbed; this contributes to the conversion of ambient mechanical energy into sustainable electricity. Tailoring the underlying microarchitecture of ferroelectric and triboelectric materials imparts a promising route for enhancing their ferroelectric and triboelectric performance. This keynote talk presents the latest developments in the field of ferroelectric and triboelectric metamaterials, rationally-designed in the Advance Multifunctional and Multiphysics Metamaterials Laboratory at McGill and realized by 3D printing technologies. The introduced design strategies unlock the application of smart energy metamaterials in high-performance pressure and thermal sensors, intelligent building blocks for smart infrastructures, self-powered and self-monitoring sports equipment, smart soft robots, and large-scale energy harvesters.