Tiny generators turn waste heat into power

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The second law of thermodynamics is a big hit with the beret-wearing college crowd because of its implicit existential crunch. The tendency of a closed systems to become increasingly disordered if no energy is added or removed is a popular, if not depressing, "things fall apart" sort-of-law that would seem to confirm the adolescent experience.

Now a joint team of Ukrainian and American scientists has demanded more work and less poetry from the second law of thermodynamics, proposing a novel "pyroelectric" method to power tiny devices using waste heat.

Using tiny structures called ferroelectric nanowires, they can rapidly generate an electrical current in response to any change in the ambient temperature, harvesting otherwise wasted energy from thermal fluctuations. Their report appears in the Journal of Applied Physics.

Explains lead researcher Anna Morozovska of the National Academy of Sciences of Ukraine, "The second law of thermodynamics rules modern life: Through all kinds of industry, humans consistently produce an enormous amount of waste heat. However, the laws of thermodynamics do not exclude rescuing some of this energy by harvesting the thermal fluctuations to produce electricity."

Pyroelectrictricity can play key role in consumer electronics, says Morozovska, and recovering this heat in the form of pyroelectric energy may bring about a new era of "tiny energy." Pyroelectric nanogenerators could be extremely useful for powering specific tasks in biological

applications, medicine and nanotechnology, particularly in space because they perform well in low temperatures.

In an investigation of the pyroelectric properties of ferroelectric nanowires, the team analyzed how the pyroelectric coefficient corresponds to the radius of the wire and its coupling. They found that the smaller the wire radius, the more the pyroelectric coefficient diverges until a critical radius at which the response changes to paraelectric (above the Curie temperature). This so-called "size effect" could be used to tune the phase transition temperatures in ferroelectric nanostructures, thus enabling a system with a large, tunable, pyroelectric response.

In theory, the use of rectifying contacts could enable the polarized ferroelectric nanowire to generate a giant, pyroelectric, direct current and voltage in response to temperature fluctuations that could be harvested and detected using a bolometric detector. Such a nanoscale device would not contain any moving parts and could be suitable for long-term operation in ambient applications such as in-vitro biological systems and outer space. The researchers calculate that these little nanogenerators would have very high efficiency at low temperatures, decreasing at warmer temperatures.

More information: The article, "Pyroelectric response of ferroelectric nanowires: Size effect and electric energy harvesting" by Anna N. Morozovska, Eugene A. Eliseev, George S. Svechnikov, and Sergei V. Kalinin appears in the *Journal of Applied Physics*.
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