Supercompatibility and the direct conversion of heat to electricity

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I survey examples of materials whose recent discovery was based in an essential way on mathematical ideas. These are solid materials that undergo phase transformations from one crystal structure to another, without diffusion. The main mathematical idea concerns "compatibility" – the fitting together of the two phases. As we explain, compatibility has a profound affect on the reversibility of the phase transformation, measured either by its hysteresis, or by the number of times one can go back and forth through the phase transformation before some property is degraded by a certain specified amount.

These transformations exhibit a change of crystal structure and lattice parameters. Properties like ferromagnetism or ferroelectricity are very sensitive to lattice parameters. So, for example, a nonmagnetic crystal can suddenly become a strong magnet as it passes through the phase transformation. Such materials can be used for the "direct" (i.e., no separate electrical generator) conversion of heat to electricity. We give a mathematical model for the conversion process and discuss issues such as efficiency and power output. The resulting devices provide interesting possible ways to recover the vast amounts of energy stored on earth at small temperature difference. They move heat produced by natural and man-made sources from higher to lower temperature and therefore contribute negatively to global warming.

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