Organic and hybrid thermoelectrics

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Exactly two centuries ago, in 1821, the physicist Thomas Johann Seebeck discovered that a voltage appears at the junction between two materials subjected to a temperature gradient. About one decade later, in 1834, Jean Charles Athanase Peltier discovered the mirror effect, namely, the presence of heating or cooling at a junction of two different conductors traversed by an electric current. Both these phenomena are exploited in thermoelectric materials. The Peltier effect is widely used to fabricate small cooling elements or fridges, whereas the Seebeck effect is essential for the design of radioisotope thermoelectric generators that were, for example, used to power the Pioneer and Voyager spacecraft from NASA.[1]

For decades, the field of thermoelectricity has been dominated by inorganic materials. The working horse among inorganic thermoelectric materials, Bi_2Te_3, shows one of the highest reported values of the thermoelectric figure of merit ZT beyond 1 near room temperature.[2] However, the increasing requirements for efficient energy management opened new perspectives for alternative organic/hybrid thermoelectric materials that are abundant and easy to process at low cost over large areas as compared to inorganic materials. They could help recover some usable energy from waste heat, eventually in combination with other energy sources, such as light. An alternative application field of these hybrid/organic compounds would be in small-scale power supplies for stand-alone applications where batteries or photovoltaic solutions are problematic.

In 2011, Crispin *et al.* demonstrated that conducting polymer based materials, such as poly(3,4-ethylenedioxythiophene):tosylate (PEDOT:Tos), can show promising thermoelectric figures of merit $ZT > 0.1$ and reasonable stability.[3] This achievement triggered considerable interest in organic and hybrid thermoelectric materials during the last 10 years. In that short period of time, organic/hybrid thermoelectrics emerged as a new and promising branch in "plastic electronics" and materials science in general.

In this context of emerging new organic/hybrid materials for energy generation, we organized the present Special Issue in *Applied Physics Letters* entitled "Organic and Hybrid Thermoelectrics."

This special issue provides an overview of state-of-the-art organic/hybrid thermoelectric materials and related physical and physico-chemical phenomena, such as charge transport and doping. This research field is by essence highly interdisciplinary, as it encompasses materials science, physics, chemistry, computer science, and engineering. For this special issue, we have selected articles that give a representative picture of the progress over the past decade in this topical area.

Most of the articles address well identified topics, such as the following:

- Device architectures and systems,[4–6]
- New hybrid materials for thermoelectrics,[7–15]
- Material processing and structure-property correlations,[16–19]
- Doping mechanisms in p- and n-type thermoelectric materials,[20–26]
- Charge transport and related electronic phenomena.[27–30]

Aside from these dominant topics, some papers also focus on the way to tune the thermopower by designing new polymer architectures or new hybrids and thermoelectric generators. We hope this collection of papers will invigorate this flourishing research field, serve as a source of inspiration, and catch the attention of new researchers and students.

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