Solution-Based Hybrid Thermoelectric Materials

Commercial Analysis

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LAWRENCE BERKELEY NATIONAL LABORATORY

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Technology

Thermoelectrics are materials that convert electricity directly into heating or cooling. Conversely, thermoelectrics can also funnel excess heat from energy inefficient systems, such as car engines or power plants, by recovering this ‘waste heat’ and turning it into electricity. The nature of the solution-based hybrid thermoelectric material allows it to be easily scalable, thin, transparent, and flexible, potentially opening up new markets that conventional thermoelectric technologies have been unable to enter.

There is a strong competitive advantage for solution-based hybrid thermoelectric materials because of the reduced material and manufacturing costs as well as the ability to scale. These advantages can make solution-based hybrid thermoelectrics cost competitive with other generation or cooling technologies – providing the opportunity to displace incumbent thermoelectric technologies and offer a potentially clean source of energy to reduce fuel consumption and CO2 emissions.

At Berkeley Lab, scientist constructed a nanoscale composite material by wrapping a polymer that conducts electricity around a nanorod of tellurium—a metal coupled with cadmium in today’s most cost-effective solar cells. This composite material is then easily spin-cast or printed into a film from a water-based solution. In parallel to its ease of manufacture, this hybrid material also has a thermoelectric figure of merit thousands of times greater than either the polymer or nanorod alone—a crucial factor in boosting device performance.

The hybrid TE material is also potentially cost effective at low temperatures (<200˚C) where there is considerably less effort in recovering the waste heat compared to higher temperature range (>200˚C). The temperature range of the material, however, also limits the use of the material due to the thermal degradation temperature of the polymer (~250˚C).

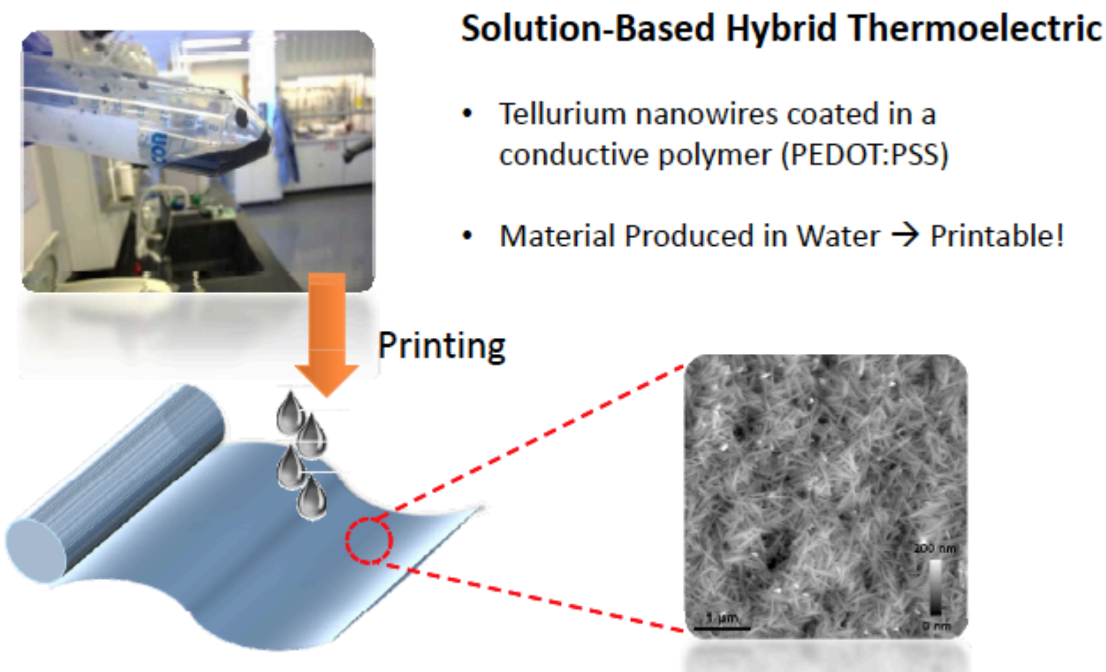

Figure 1 - Berkeley lab solution based hybrid thermoelectric technology

Applications

Thermoelectric technology can create significant value in its two primary uses as a heat pump or an electric generator. There are four categories to which this pertains: power generation, electronics, industrial processes, and biological, as presented in Figure 3.

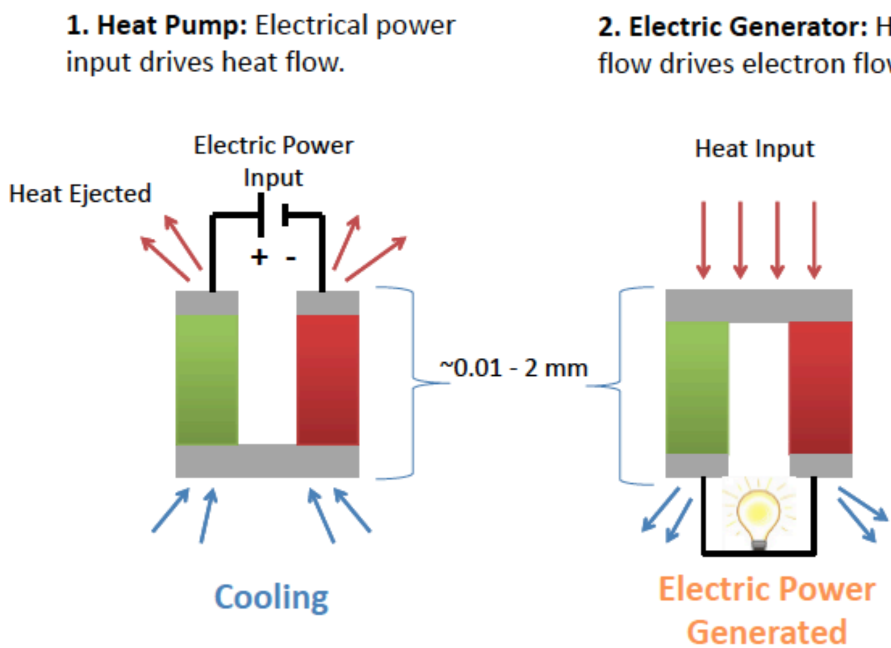

Figure 2 - Primary uses of thermoelectric material

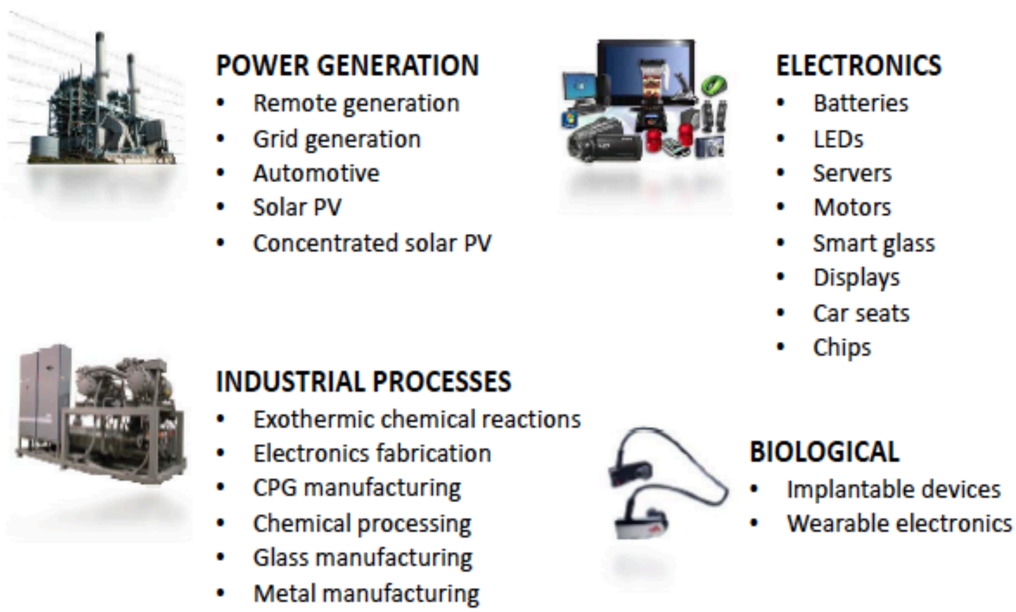

Figure 3 - List of various potential markets evaluated for the hybrid TE technology

Market

Those markets that have historically captured significant interest from thermoelectric industry due to their market size, namely, grid scale waste heat scavenging, industrial process waste heat scavenging, and automotive waste heat scavenging, are not necessarily good fits for the initial market introduction of hybrid TE materials. This is primarily because of complexity of integrating thermoelectrics into these applications and the lack of willingness to pay for the value created by the thermoelectric device. However, five market applications (shown in Figure 4) rise to the top and are described in further detail below.

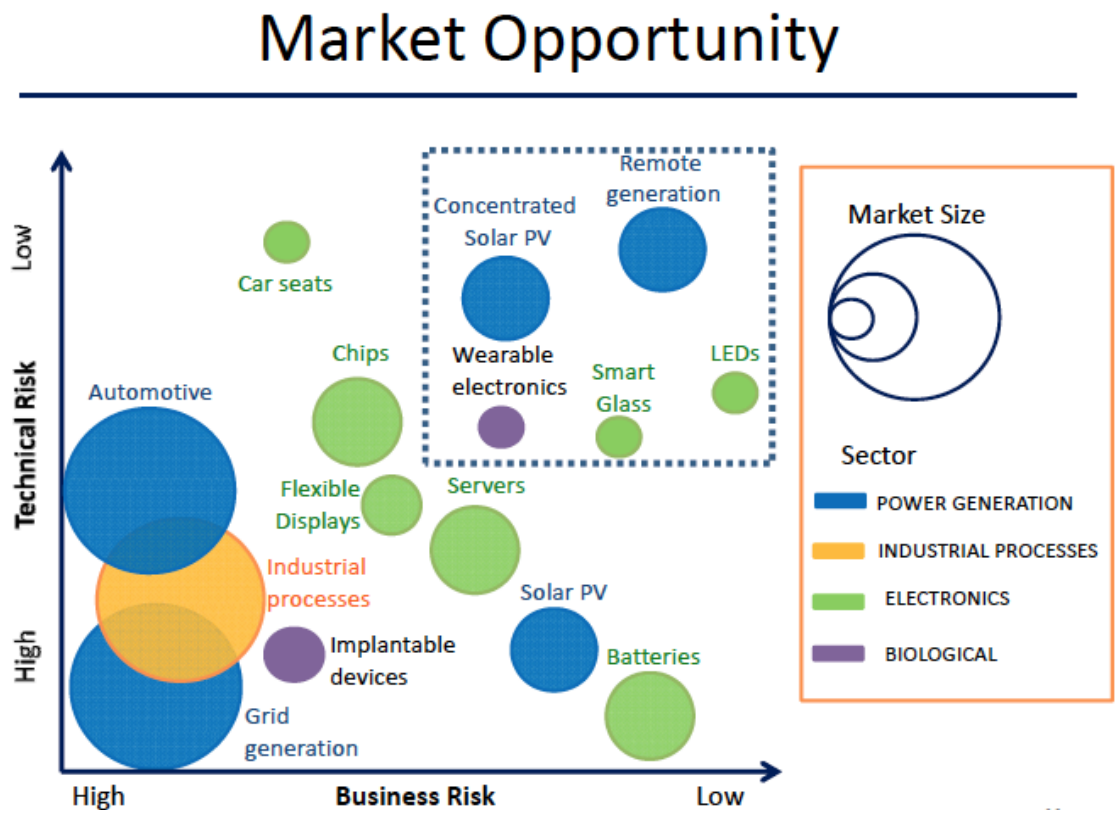

Figure 4 - Mapped applications based on technical and business risks and market size

Smart Glass

Smart glass refers to a category of glass products that change their light transmission properties when an external stimulus such as heat or a voltage is applied. Smart glass currently represents only a small fraction of the $75 billion glass market. However the global market for smart glass-based products increased to over $1 billion in 2008 with sales projected to double by 2013. Smart glass products for transportation currently account for the largest share of the market, followed by smart glass products for architectural, residential, and commercial buildings.[1]

Remote Power Generation

Remote power generation refers to a mode of power generation that provides electricity when the electrical grid is inaccessible. A category within this general market segment that is of particular interest is diesel generator sets, which can provide power for off-grid military outposts, mining sites, and various rural developing world locations. The estimated total market for diesel generator sets in the world is valued at approximately $6.5 billion and projected to grow to approximately $10 billion by 2015. However, there are many ways in which this market

[1] BCC Research "Smart Glass: Technologies and Global Markets" (February, 2009)

can be segmented. The remote generation market can be segmented by the function the diesel generator performs, these being: Prime/Continuous, Peak, and Back-Up power. The segments into which thermoelectrics are likely to be installed are in the Prime/Continuous and Peak segments.

Wearable Electronics

Wearable electronics is a very broad market category, which can be simply defined as any garment that is worn or fitted around a human being that contains electronics. There are a wide variety of functions that these electronics can serve, whether it is to provide heating or cooling, collect data, supply power to auxiliary units or measure physiological functions. The function that is of particular interest for the technology in discussion is to provide power to those functions that require it; thus the submarket of interest is wearable electronics that deliver power.

Concentrated Solar PV

Concentrated solar PV (CPV) provides an opportunity for thermoelectric co-generation due to the presence of a significant energy source (solar gain) and existing balance of systems (heat sink and power electronics). A thermoelectric device can scavenge the solar gain waste heat, thereby increasing the efficiency of the CPV system by converting a higher percentage of the sunlight's energy into electricity.

LED Cooling

Removing the heat generated from a LED is another cooling application. LEDs offer energy efficient lighting solutions with an extremely long product lifetime (40,000 hrs.) in comparison to incandescent (2,000 hrs.) and fluorescent (10,000 hrs.) lighting. However, heat buildup in LEDs can significantly limit lifetime, and is of major concern to LED manufacturers. Aluminum heat sinks using natural convection and forced air-cooling have been the traditional means of removing heat from LEDs. Incorporating a thermoelectric cooler into LED heat management systems adds value to the LED manufacturer by allowing for the size of the heat sink to be reduced, as well as improving the reliability of the LED. The world LED market was valued at $6.9B in 2009, and is expected to grow to $14.2B in 2013. There are currently three main players in the LED market - GE, Philips, and Sylvania. Title 24 in California is also one example of how future public policy will mandate LED use.

Economics

Figure 5 below shows the relative cost contribution of components compared to the assumed cost of printing the hybrid TE material onto a substrate.

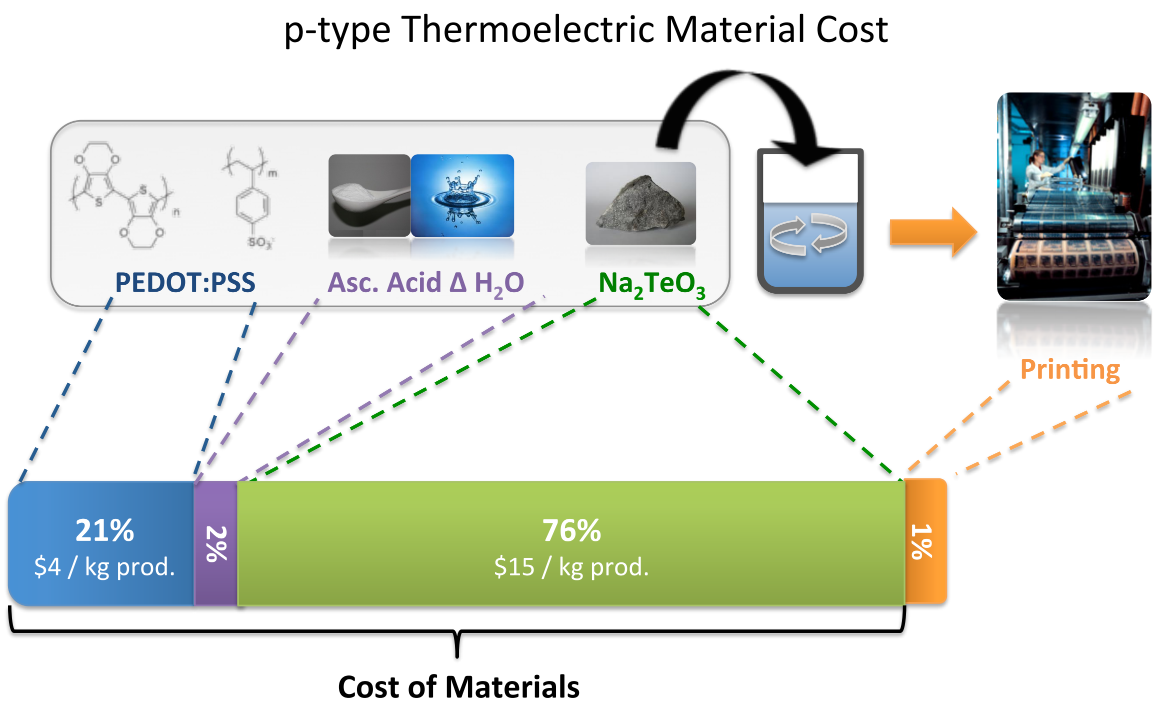

Figure 5. Ingredient relative cost contribution for hybrid p-type TE material

Using Bi_2Te_3 as a benchmark, the hybrid TE material enables a dramatic reduction in the cost of the material and module assembly. The balance of system costs is application dependent, and fixed costs dependent on organizational efficiency. Therefore, it is more difficult to quantify any cost advantage the technology brings in these areas. Nevertheless, hybrid TE material still brings a significant cost reduction over traditional Bi_2Te_3 thermoelectric devices. This cost reduction is shown in Figure 6 below.

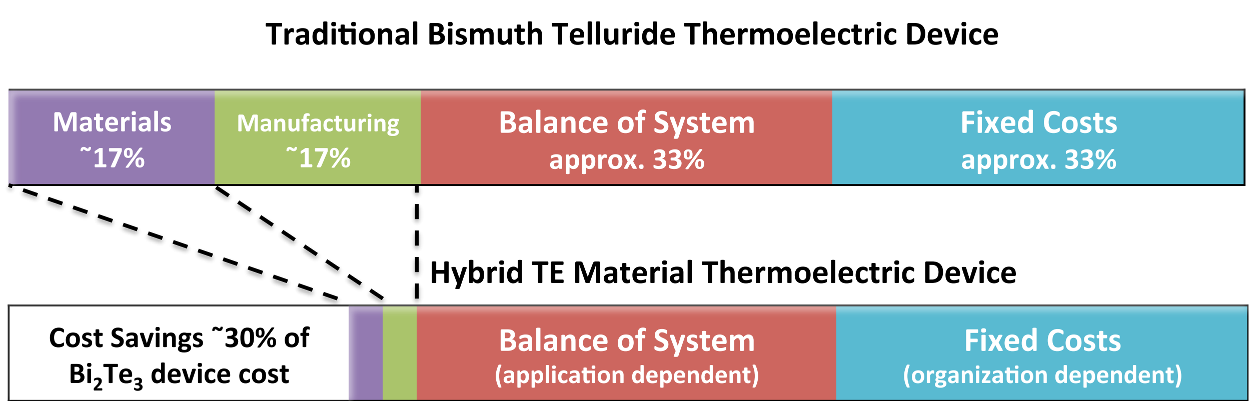

Figure 6. Estimated relative cost comparison between traditional bismuth telluride thermoelectric device and hybrid TE material thermoelectric device

Competitive Landscape

Hybrid TE material falls between the thin and thick-film range, while the operating temperature runs from 200˚C down to ambient temperature. Although there are many companies producing thermoelectric devices that operate in this temperature range, *none* of these companies use printing technology to manufacture thermoelectric devices. Printed manufacture is a key differentiator between the hybrid TE material and incumbent technology. This differentiator has the potential of dramatically the costs for devices made with hybrid TE material relative to the other thermoelectric devices currently found in the market.

Driving Forces

The influences of external market forces include competing, and complementary technologies, energy prices, materials prices, and potential policy changes. While there is a great deal of uncertainty in how external forces will behave, the cost of material components is expected to decrease, providing a positive influence to the scientists' hybrid TE technology. Rising energy prices are also another positive influence. Since policy changes are difficult to predict, and there are currently no policies directly related to thermoelectric technologies, it perhaps has the weakest external market influence. Finally, while new complementary and competitive technologies are likely to have the largest influence on our technology, its influence can be difficult to predict.

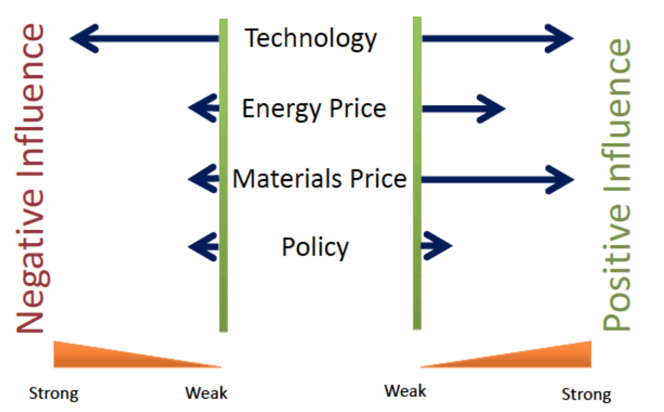

Figure 7 - External market forces

Intellectual Property

Published patent application WO2011149991 available at www.wipo.int. The technology is available for licensing or collaborative research.

Licensing Strategy

It is recommended that this IP being licensed by a company that produces transparent sheets of this hybrid TE material that can be sold in different sizes and thicknesses into a range of market applications.

Next Steps

Companies interested in licensing this technology may contact ttd@lbl.gov or call 510-486-6457.