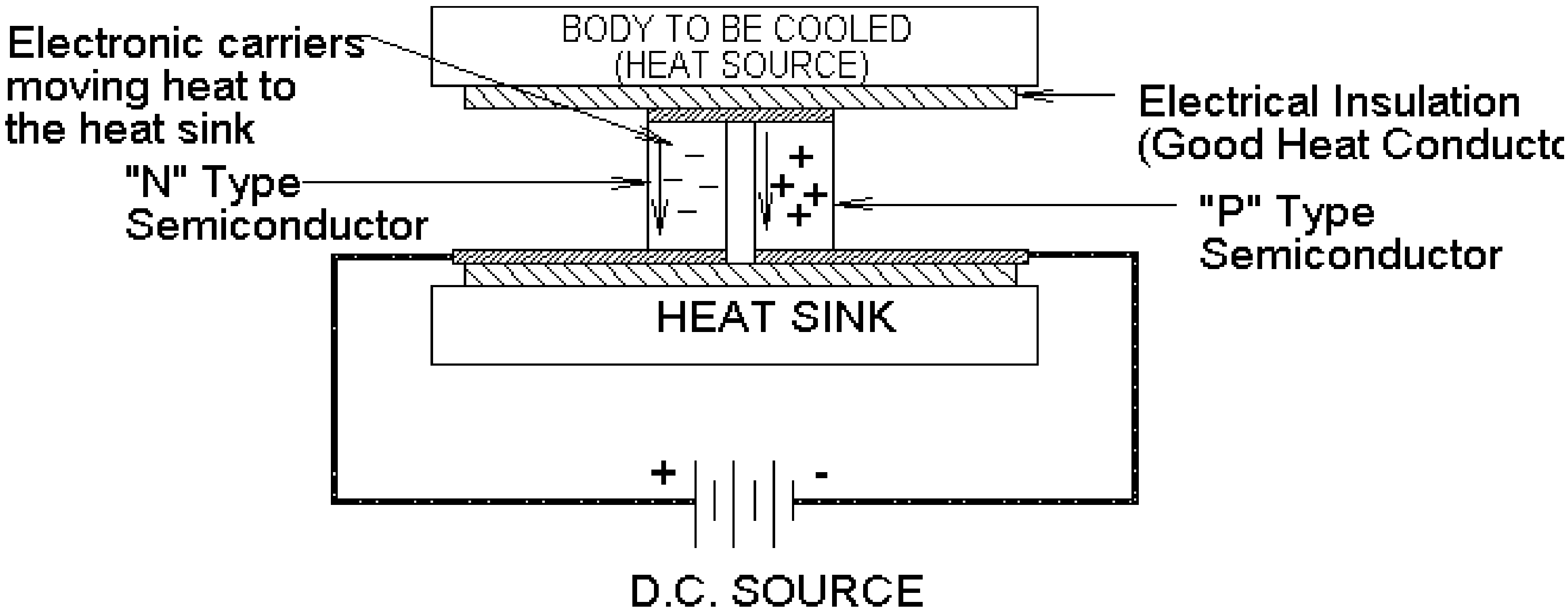
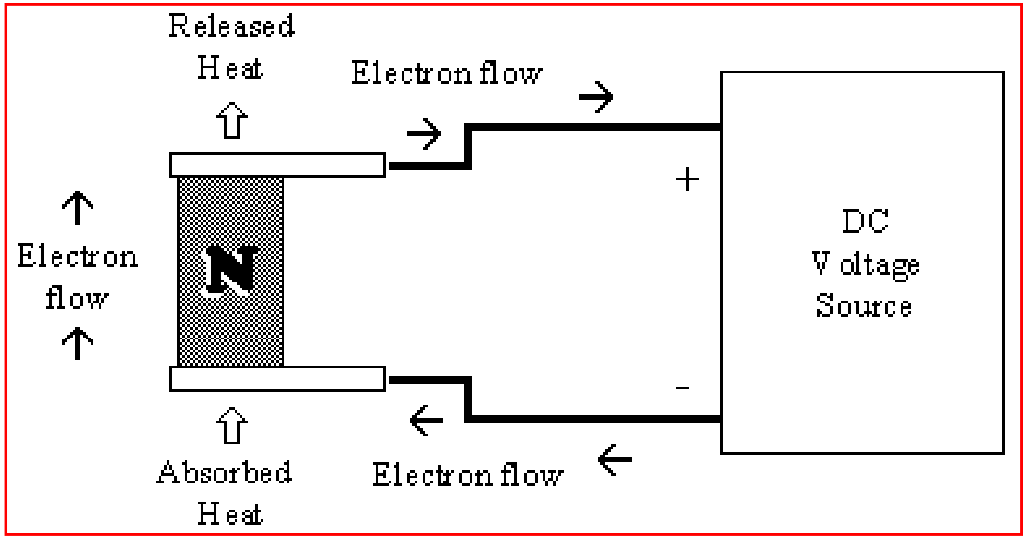
Thermo-Electricity

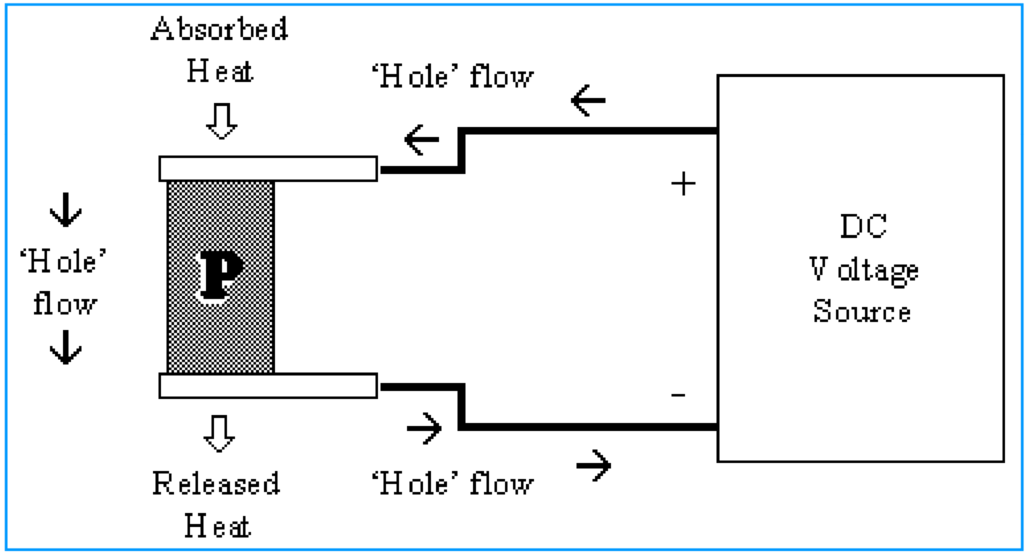
1. Generation of Thermoelectricity
2. Thermoelectric Cooling – Peltier effect



Thermo-Electricity - Principle

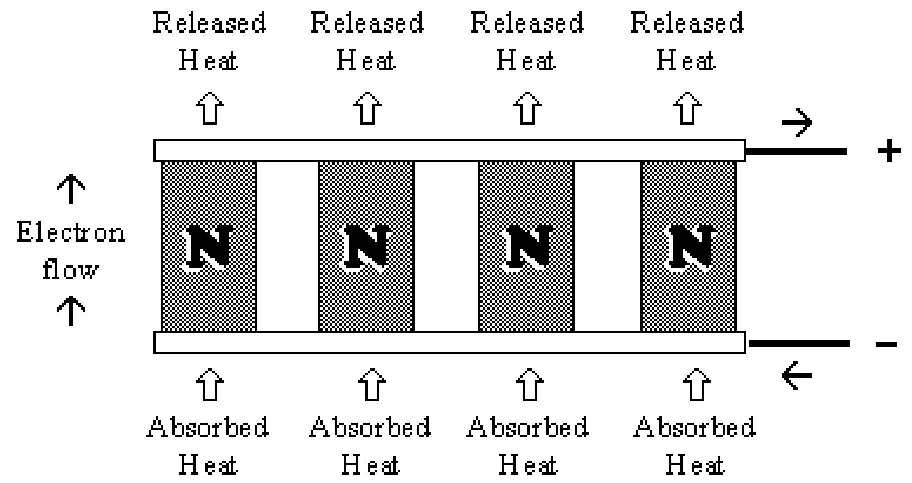


n- type semiconductor

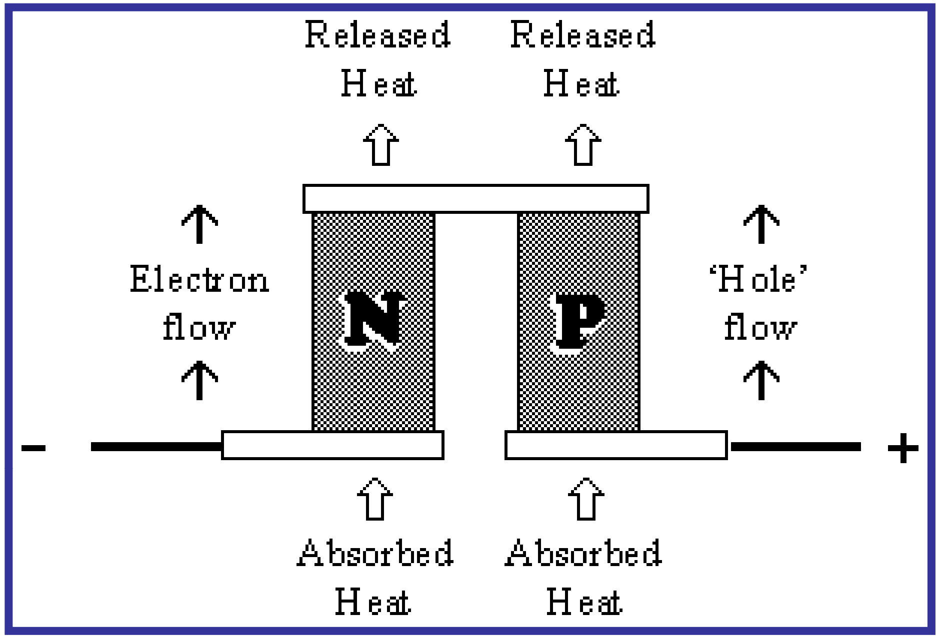


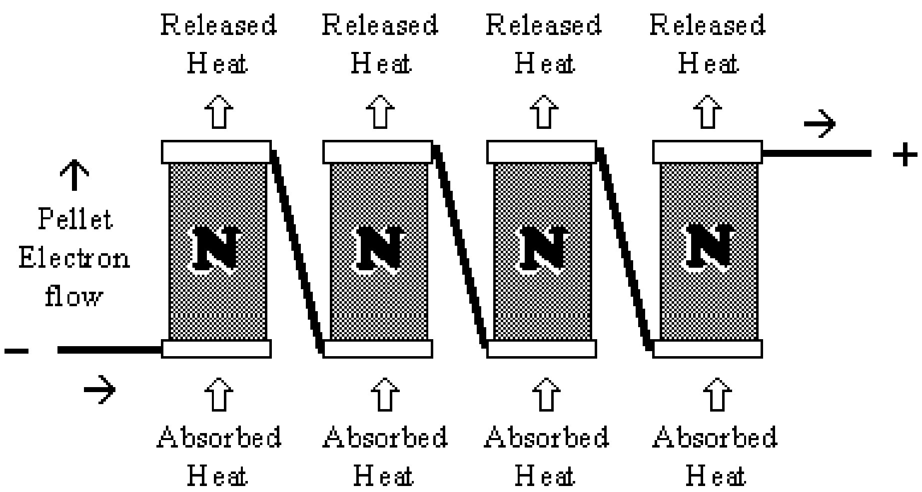
p- type semiconductor

Thermo-Electricity - Principle



High current – low voltage

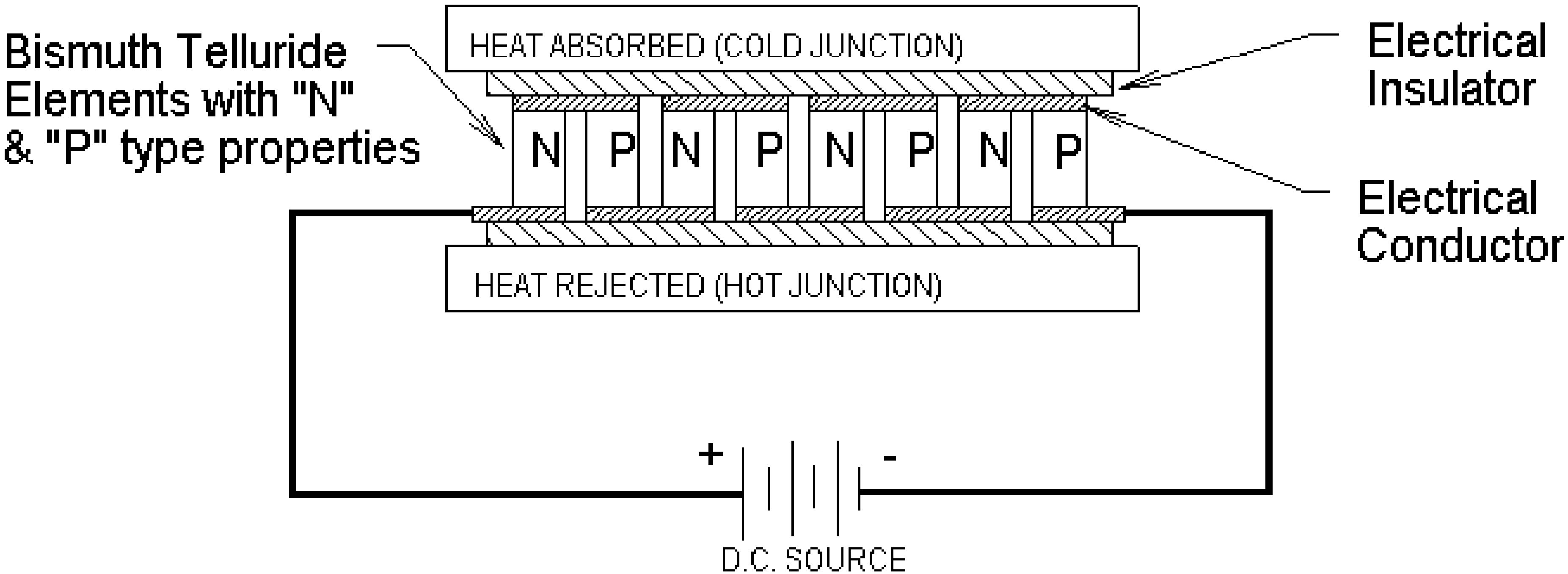




Contact heating

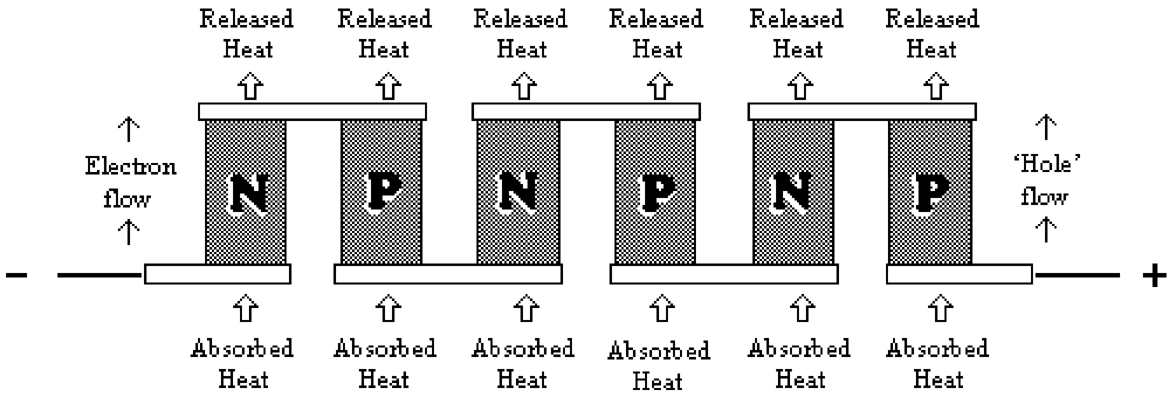
Thermo-Electricity - Materials

1. Generation of Thermoelectricity
2. Thermoelectric Cooling

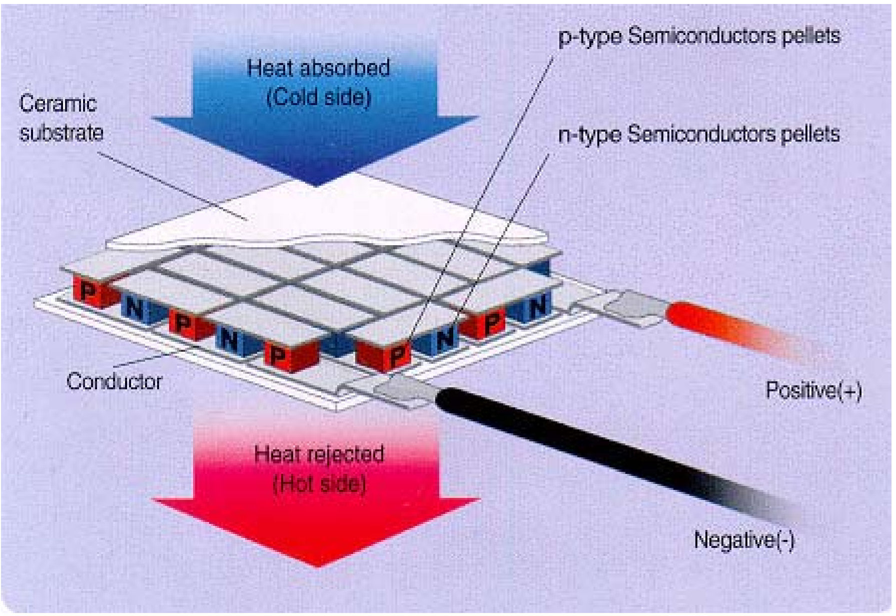


Elements Electrically in series & thermally in parallel

Thermo-Electric Devices



Multi-couple configuration increases heat-pumping capacity



High voltage - low current

Thermo-Electric Devices

electricity ➔ cool
electricity ➔ heat

Can Thermoelectric systems be used for heating as well?
Yes. One of the benefits of TE technology is that you can switch the direction of heat pumping by simply reversing the polarity of the applied voltage—you get heating with one polarity, cooling with the other. Thermoelectric modules make very efficient heaters—in fact, because of the unique properties of Peltier devices, any given TE system will have a greater capacity for heating a load than cooling it.

What type of products currently use this technology?
There are an increasing number and variety of products which use thermoelectric technology—from picnic boxes to water coolers, laser applications, and highly-specialized instrumentation and testing equipment. The compatibility of many TE's with automotive voltages, makes them especially suitable for small cooling jobs in that industry.

For heat-only applications, do thermoelectric devices have advantages over resistive heaters?
Yes. Resistive devices create heat solely by virtue of the power dissipated within them. TE devices, on the other hand, not only provide this I 2R heating, but also actively pump heat into the thermal load; this, potentially, makes them much more efficient than resistive heaters.

Thermo-Electric Devices

Δ T ➔ electricity

Nanostructured Thermoelectric Devices May Generate Power from Thermal Sources

A car's engine loses 70 percent of its energy as waste heat
➔ a way not only to recover that lost energy
➔ capture the power-producing potential of geothermal heat

Thermoelectric materials try to recover this energy by converting it to electricity, but they don't work very well if the flow of heat is uncontrolled.

➔ breakthrough involves controlling the motion of electrons using materials that are structured on the nanoscale.

Nanostructured Thermoelectric Devices May Generate Power from Thermal Sources

Δ T ➔ electricity

➔ if an electrical voltage is applied to an electrical system in addition to a temperature difference, it is possible to harness electrons having a specific energy.

This means that if a nanostructured material is designed to only allow electrons with this particular energy to flow, a novel type of equilibrium is achieved in which electrons do not spontaneously ferry heat from hot to cold.

Until now, the efficiency of such devices, which have no moving parts and can be small enough to fit on a microchip, has been too low (less than 15 percent of the Carnot limit for power generation) for use in all but a few specialized applications.

However, tailoring the electronic bandstructure in state-of-the-art thermoelectric materials made up of a huge number of nanowires.
If all goes well, nanostructured thermoelectric devices with efficiencies close to 50 percent of the Carnot limit may be realized.

Nanostructured highly effective Thermoelectrics

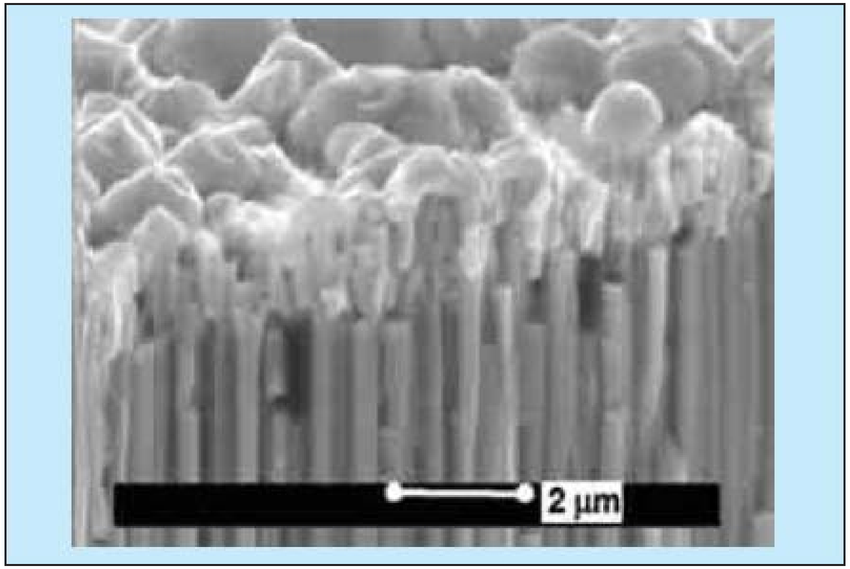


Figure 1. Thermoelectric Nanowires of n-Type Bi_2Te_3 with a diameter of 10 nm and length of 40 µm were grown in an alumina template. The thermoelectric material was allowed to grow onto the top of the template, forming caps that make contact with each other. In a production version, the overgrowth and part of the template would be polished away and metal contacts deposited as in Figure 2.

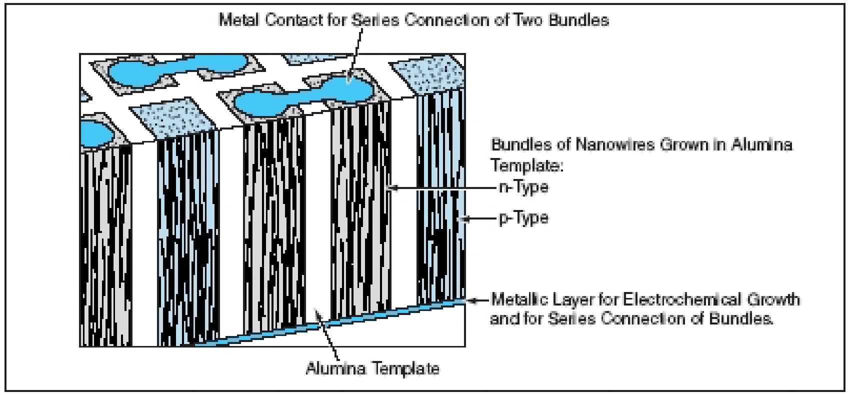


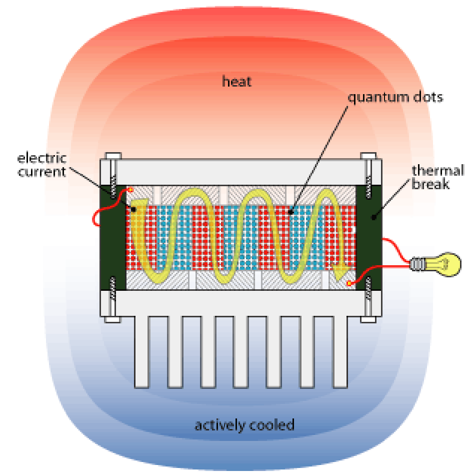
Figure 2. Bundles of Nanowires would be grown electrochemically in an alumina template. The nanowires in each bundle would be electrically connected in parallel and the bundles electrically connected in series by metal contacts grown electrochemically on the ends of the bundles.

fabricated by electrochemical growth

may contain nearly a billion elements (wires) per square centimeter

Nanowires have been grown in alumina templates with pore diameters of 100 and 40 nm

The predicted net effect of reducing diameters to the order of tens of nanometers would be to increase its efficiency by a factor of 3

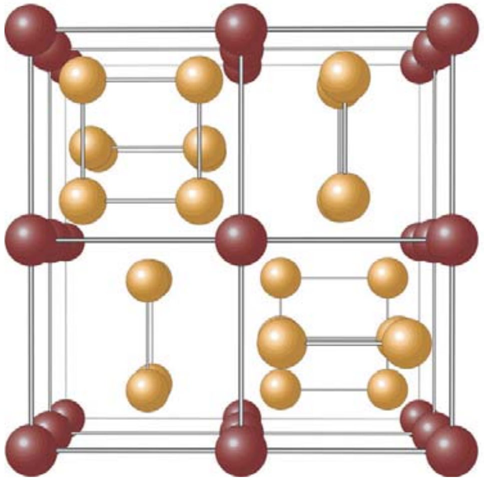


Prerequisites for Good Thermoelectric Materials

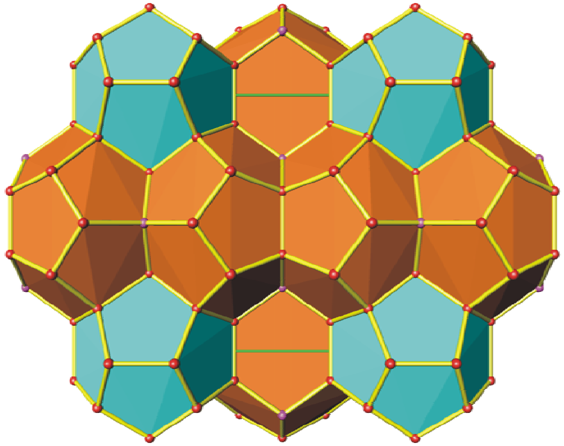
1. Semiconductor	**1. Right band gap**
2. Low carrier concentration	**2. Bad thermal conductor**
3. High Carrier Mobility	**3. Good electronic conductor**
4. Low Thermal conductivity	**4. Scatter lattice vibration**

Nanostructured highly effective Thermoelectrics

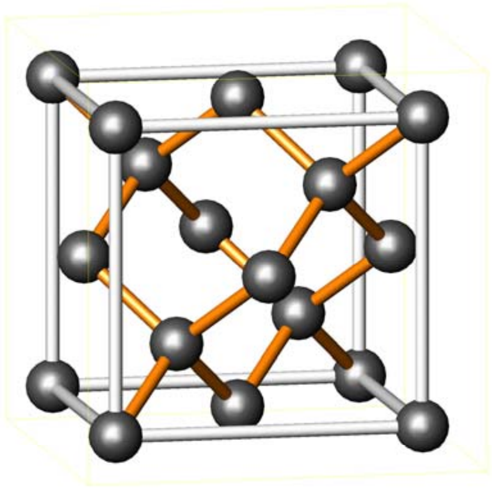
Δ T → electricity



Skutterudites **-** (Co,Ni)As_{3-x}

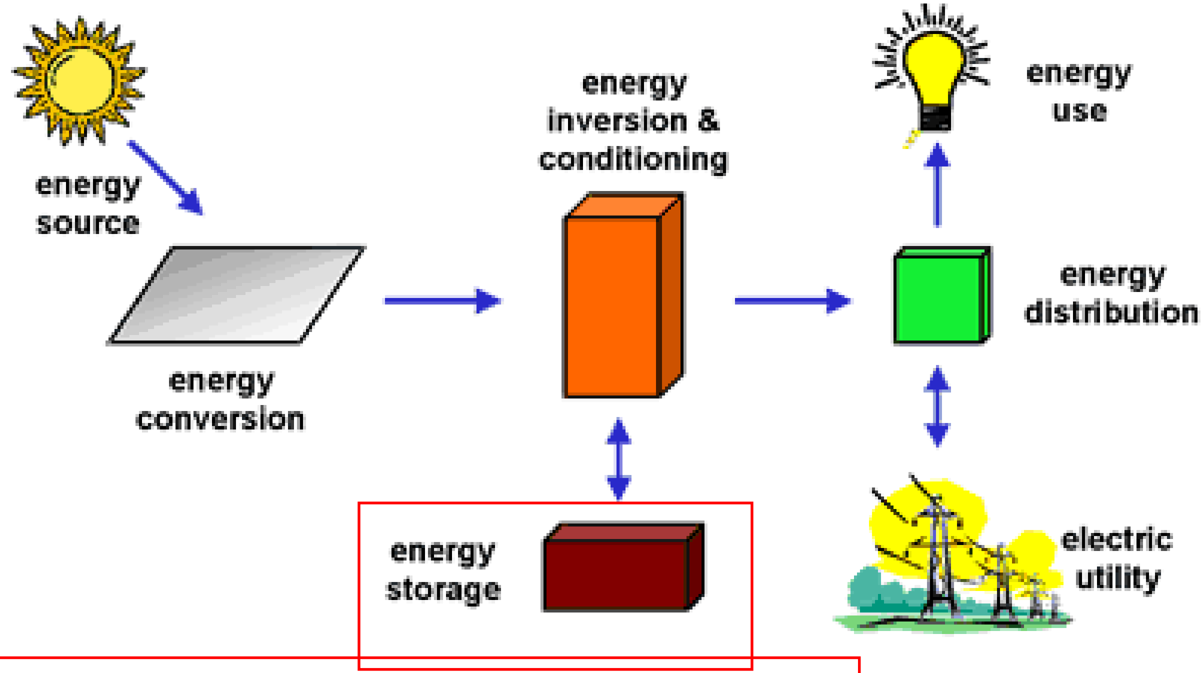


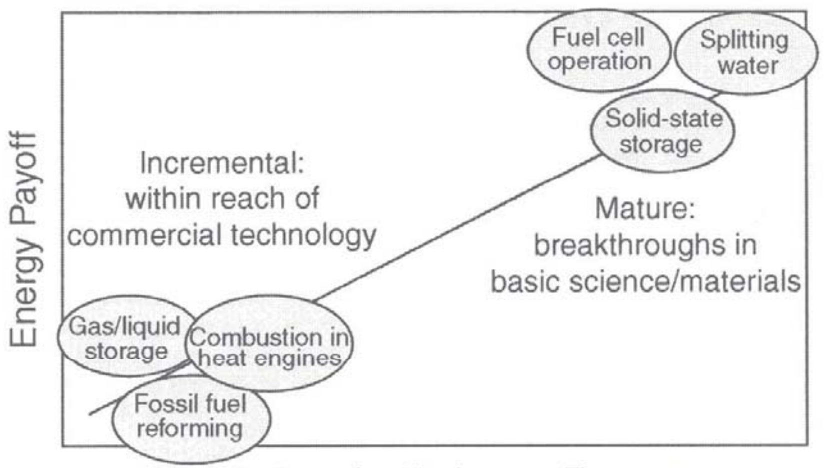
Clathrates



Zinkantimonide

Renewable Energy Management





Evolution of a Hydrogen Economy