Oxide thermoelectrics

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Thermoelectrics are solid state devices with two basic modes of operation. The first mode, based on the Peltier Effect, involves the application of current through the module, absorbing heat from one side of the device and emitting it from the other side. The generation of cold and hot faces of the plate makes Peltier devices ideal for heating and cooling applications. Conversely, the Seebeck Effect, second mode of operation, can be used for power generation purposes. When a temperature gradient is applied across a TE module an electric current is produced [1].

The efficiency of a thermoelectric material depends on two conditions. The first is the Carnot efficiency (sets the limiting value on the fraction of the heat which can be used), which for all heat engines cannot be exceed. The second condition depends on the thermoelectric properties, Seebeck coefficient (S), electrical resistivity (ρ) and thermal conductivity (κ). All these properties of material together are included in a dimensionless description of thermoelectric properties called Thermoelectric Figure of Merit (ZT). For small temperature difference this efficiency is given by $ZT = S^2T/ \rho\kappa$ [1].

Therefore the achievement of the highest possible thermoelectrical efficiency is a challenge owing to the conflicting combination of material traits that are required. Good thermoelectrics are therefore crystalline materials that manage to scatter phonons for reduced thermal conductivity without significantly disrupting the electrical conductivity. Thermoelectrics therefore require a rather unusual, so called a 'phonon-glass electron-crystal, (PGEC), type of material [2, 3].

Recently a new class of thermoelectric materials was introduced based on a metal oxide such as Na_2CoO_4, $CaMnO_3$, $(ZnO)(In_2O_3)$, ZnO and $CuAlO_2$. The listed oxide thermoelectric materials appear promising, since they are chemically stable at high temperatures and they have high oxidation resistance. They are also nontoxic [4]. Beside ZnO which is an outstandingly promising oxide n-type material as a high-temperature thermoelectric material above 973K, we shall also study p-type conductors Na_xCoO_2, $Ca_3Co_4O_9$ and their related systems, which exhibit thermoelectric anisotropy and fairly high thermoelectric performance due to the layered structure. We will study the synthesis of those thermoelectric materials and tailoring of their thermoelectric characteristics for the best thermoelectric efficiency via structure, microstructure and phase optimization, and with addition of various dopants. Finally, by constructing a new measuring system for thermoelectric characterization, we will be able to fully assess the thermoelectric properties of prepared materials in regard to their composition, structural and microstructural characteristics.

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