VACOTHERM

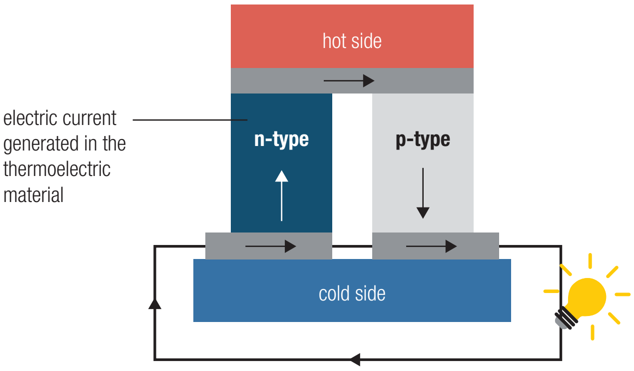
THERMOELECTRIC MATERIAL USED FOR DIRECT CONVERSION OF HEAT INTO ELECTRICITY

- ZT values approx. 0.9 @ 500 °C
- Hf-free intermetallic compounds, earth abundant raw materials
- Matching thermal expansion coefficients for low thermal stresses
- High temperature stability
- High mechanical strength

The recently developed thermoelectric materials VACOTHERM® are Hafnium (Hf-) free half-Heusler intermetallic compounds. There are two differently doped types of VACOTHERM: VACOTHERM n and VACOTHERM p are our n-type and p-type semiconducting thermoelectric materials. Both intermetallic compounds match perfectly in terms of thermal expansion coefficients, are stable at high temperatures, most efficient above 300 °C and are characterized by a high mechanical strength.

VACOTHERM materials are used in thermoelectric generators (TEG) for direct conversion of heat into electricity. Their working mechanism is based on the Seebeck-effect: when placed in a temperature gradient, the materials generate a useable electric voltage.

Today, thermoelectric power generation gains importance in the context of direct conversion of thermal energy into electrical energy. Applications are exhaust energy recovery in automotive or heavy duty vehicles, waste heat recovery in industrial applications or improving efficiency in combined heat and power plants. The typical operating principle of a TEG is shown in fig. 1. The main advantages of this direct energy conversion are that no mechanical or chemical processes and no moving parts, liquids or gases are needed. The devices are robust, compact and maintenance free.



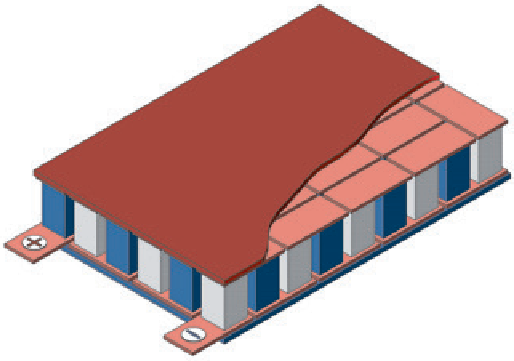


Fig. 1: Operating principle of thermoelectric generators (TEG)

The ability of a thermoelectric material to convert heat into electricity is expressed by its figure of merit ZT.

$$ZT = \frac{S^2\sigma}{\kappa} \text{ x } T$$

S	Seebeck coefficient
σ	electric conductivity
κ	thermal conductivity
T	temperature

In order to realize high ZT-values, the combination of a high Seebeck coefficient S with high electric conductivity σ and low thermal conductivity κ is necessary. This unique set of properties could be realized in our VACOTHERM materials. With ZT-values of 0.9 @ 500 °C VACOTHERM is tailored for optimum efficiency at higher temperatures, where conventional Bismuth-Telluride thermoelectric materials fail. This makes them ideal candidates for a broad variety of waste heat recovery applications. The typical figure of merit ZT for our VACOTHERM n and VACOTHERM p is shown in fig. 2.

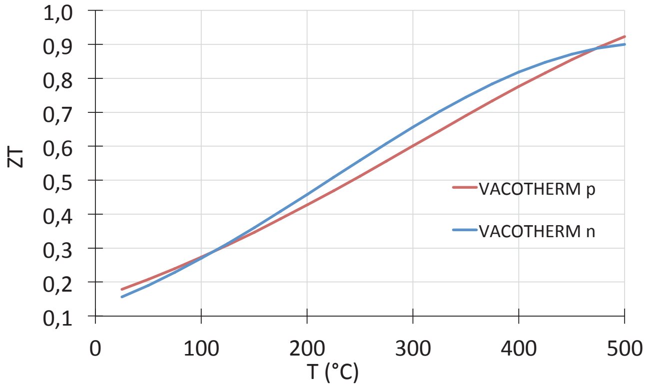


Fig. 2: Typical thermoelectric figure of merit ZT for VACOTHERM n and VACOTHERM p

MATERIAL PROPERTIES

PROPERTIES OF VACOTHERM n / p (typical values) @ room temperature

Property		Unit	VACOTHERM n	VACOTHERM p
Seebeck-coefficient	S	µV / K	-145	110
electric conductivity	σ	S / cm	1350	3500
thermal conductivity	κ	W / (m · K)	5.5	7.2
density	ρ	g / cm^3	7.4	8.1
heat capacity	c_p	J / (g · K)	0.31	0.29
linear expansion coefficient	α_L	1/K	9.1×10^{-6}	8.1×10^{-6}
flexural strength*	σ_f	MPa	200	200

* in three-point bending

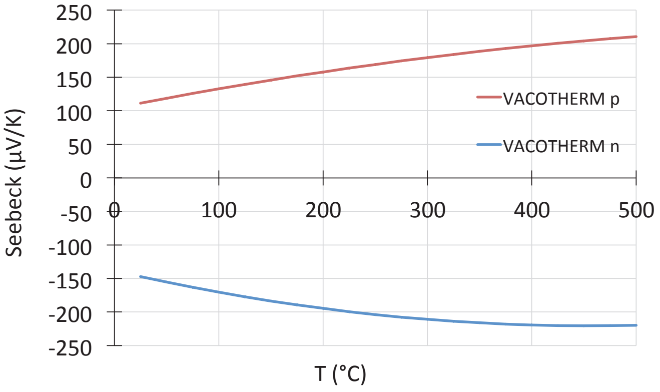


Fig. 3: Typical Seebeck-coefficients of VACOTHERM n and VACOTHERM p

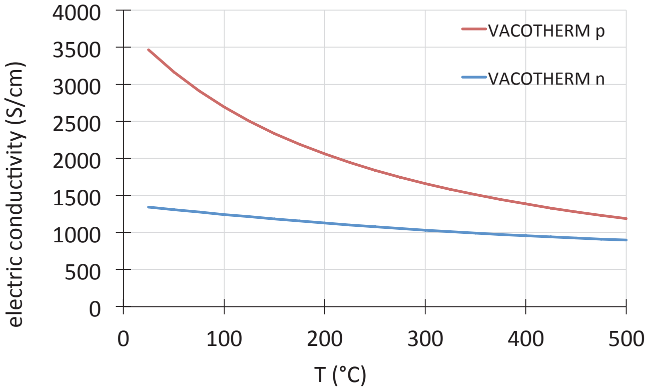


Fig. 4: Typical electric conductivity of VACOTHERM n and VACOTHERM p

Typical material properties such as Seebeck-coefficient, electric and thermal conductivity and linear thermal expansion coefficient of VACOTHERM n and VACOTHERM p are shown in fig. 3-6.

Excellent thermal stability and oxidation resistance of VACOTHERM has been confirmed by long-term temperature tests at 550 °C for 100 hours in air without detecting any degradation or change in material properties.

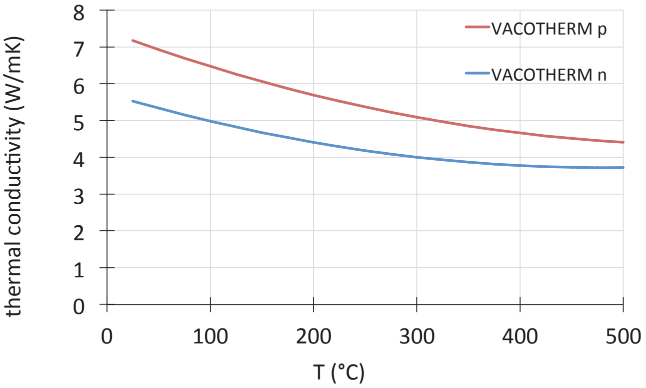


Fig. 5: Typical thermal conductivity of VACOTHERM n and VACOTHERM p

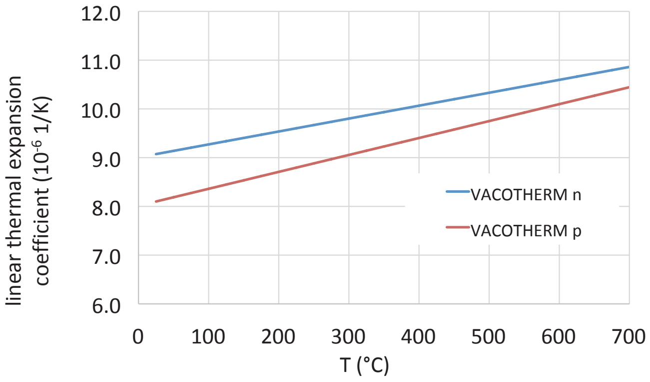


Fig. 6: Typical linear thermal expansion coefficient of VACOTHERM n and VACOTHERM p

COMPOSITION IN WEIGHT %

VACOTHERM n

Sn	Ni	Zr	Ti
49	25	12	14

VACOTHERM p

Sb	Fe	Nb	Ti	V
47	22	25	3	3

FORMS OF SUPPLY

Standard form of supply:	small blocks, typically 1 - 2 mm per dimension
Optional coating of contact surfaces:	nickel or gold available other coatings possible on request
Other shapes and formats:	custom-tailored geometries possible on request

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Published by VACUUMSCHMELZE GmbH & Co. KG, Hanau

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