

Method for producing a thermoelectric component and thermoelectric component

The present invention relates to a method for producing a thermoelectric component according to the preamble of patent claim 1. Furthermore, the present invention relates to a thermoelectric component.

The mode of operation of a thermoelectric component is based on the thermoelectric effect, which is also called Seebeck effect and Peltier effect, respectively. The field of application of the present invention is thus thermoelectrics. A thermoelectric component can be used on the one hand for generating energy as a thermoelectric generator and on the other hand for temperature control as a Peltier element. A third field of application for thermoelectric components are sensors, e.g. thermoelements and thermocolumns.

In a thermoelectric generator, voltage and thus electric current is generated by way of a temperature difference. Inversely, in a Peltier element, one side of the thermoelectric component is heated by applying voltage and due to the resulting flow of current and the other side of the thermoelectric component is cooled. When the thermoelectric component is used as a temperature sensor, a change in temperature is detected via a change in voltage at the output of the thermoelectric component.

Fig. 1 shows the basic structure of a thermoelectric component 1. In principle, such a thermoelectric component 1 is composed of pairs of thermoelectric legs with n-legs 2 and p-legs 3. These n- and p-legs 2, 3 are n- and p-conducting materials, as are also used in other fields of semiconductor technology. Due to an electrically conductive contact material 4 the n-legs 2 and the p-legs 3 are alternatingly contacted with one another. Thus the n- and p-legs 2, 3 are connected electrically in series and thermally in parallel. The pair of thermoelectric legs and the electrically conductive contact material 4 are provided between layers of an electrically insulating substrate 5.

As is schematically shown in Fig. 1, there is a temperature gradient from "hot" to cold" between an upper side of the thermoelectric component 1 and a lower side of the thermoelectric component 1. Due to this temperature gradient it is possible to use the thermoelectric component 1 as a thermoelectric generator so that voltage is applied between the outputs of the thermoelectric component. This is illustrated by the "minus" and the "plus" sign in Fig. 1

However, it is equally possible, with the same structure in Fig. 1, to generate a temperature gradient between the upper side and the lower side of the thermoelectric component 1 by applying an external voltage and with the current flowing in the circuit through the thermoelectric component. The thermoelectric component 1 is thus used as a Peltier element.

To contact the pairs of thermoelectric legs with the electrically conductive contact material 4, soldering methods or mechanical methods may e.g. be employed.

In the soldering process a soldering paste or a liquid solder is normally applied in a screen-printing method. Alternatively, a solder can be applied by way of foil-shaped parts. Further solder coatings are formed by means of vaporization, sputtering, plasma spraying or electroplating methods.

Contacting by means of soldering methods has the drawback that the softening point of the solder must be higher than the operating temperature of the thermoelectric component. If the softening point of the solder is below the operating temperature of the thermoelectric component, the field of application of the thermoelectric component is restricted because at elevated temperatures the contact connections may fuse and the component may thereby get destroyed. Solders for thermoelectric applications in the range between 300°C and 450°C are not available.

Moreover, at operating temperatures above 250°C the solders that can be used for thermoelectric components show further defects such as brittleness. As a rule, an additional electrical and thermal resistance that further reduces the efficiency of the thermoelectric component is inevitably created by the solder layer.

In mechanical bonding methods, e.g. sintering electrically conductive braiding into thermoelectric material or pressing electrical contacts against the thermoelectric material, the complicated manufacture of the thermoelectric components is disadvantageous. Moreover, mechanically pressed contacts show poor electrical and thermal properties, whereby the efficiency of such thermoelectric components is reduced.

Embodiments of the present invention seek to provide a method for producing a thermoelectric component by which legs can be contacted with the thermoelectrically conductive contact material at low costs and in a safe way, and also an efficient thermoelectric component.

According to an aspect of the present invention there is provided a method for producing a thermoelectric component with at least one pair of thermoelectric legs, including an n-leg and a p-leg, wherein both legs are welded to an electrically conductive contact material, wherein the n-leg and the p-leg of the pair of legs are welded in separate welding steps to the contact material.

A physicochemical reaction depending on the welding parameters and materials occurs in this process, wherein the contact material or a layer positioned thereon joins the leg material or a reaction layer positioned thereon.

Apart from the ease of automation of the whole method it is thereby possible to optimize welding methods, welding tools and welding parameters with respect to the respective leg properties and the electrically conductive contact material to be joined. Since the thermal load that arises during welding of the individual legs lasts for a short period of

time only, the thermoelectric properties of the leg materials do not change. To be more specific, material does not evaporate or oxidize.

Preferably, the welding parameters for welding the n-leg and the welding parameters for welding the p-leg are set to be independent of one another. It is thereby possible to select for each leg material to be welded or for each material pair of leg material and contact material to be welded the optimum parameter settings, such as flow of current and/or hold time and/or bias current and/or heating-up period and/or contact pressure for the welding process.

According to a preferred embodiment the legs are provided at one of their ends in longitudinal direction with contact surfaces that are brought into contact with the contact material, and the welding of the n-leg and/or the welding of the p-leg is performed on the contact surface and/or at the side of the contact surface of the respective leg. This creates a maximally possible contact surface between the electrically conductive contact material and the contact surfaces of the respective leg, resulting in a low contact resistance of the thermoelectric component.

According to a further preferred embodiment the contact material is pressed by at least one welding electrode onto the leg to be welded, either before and/or during the respective welding step. A separate fixation of the electrically conductive contact material is thus not needed.

Preferably, the n-leg and the p-leg of the pair of legs are welded by gap welding to the contact material.

Further preferably, the contact material is brought into contact with the corresponding leg and a gap of a gap electrode contacting the contact material is set in conformity with a width of the leg to be welded. This permits an exact energy input for forming the welded joint.

Likewise, it is possible that the contact material is brought into contact with the corresponding leg, and that a gap of a gap electrode contacting the contact material is set to be wider than a width of the leg to be welded.

Preferably, the contact material encloses an end of the leg to be welded at least partly in a radial direction of the leg, and the gap electrode contacts the contact material in a radial direction of the leg to be welded. It is thereby possible that the energy input for welding takes place from the side, wherein the gap electrode can be placed on or pressed against the contact material.

According to a further preferred embodiment the legs to be welded and/or the contact material are preheated prior to welding. This prevents stresses in the material caused by thermal shock.

According to a further preferred embodiment the thermoelectric component comprises a plurality of pairs of legs, wherein among a selection of pairs of legs first the n-legs and then the corresponding p-legs are welded to the contact material. It is equally possible that the thermoelectric component comprises a plurality of pairs of legs, wherein among a selection of pairs of legs first the p-legs and then the corresponding n-legs are welded to the contact material. With both options several n-legs and several p-legs, respectively, can thus be welded in parallel, whereby the time needed for producing the thermoelectric component is shortened.

It is particularly preferred when the thermoelectric component comprises a plurality of pairs of legs and all of the n-legs are simultaneously welded to the contact material. Likewise, it is particularly preferred when the thermoelectric component comprises a plurality of pairs of legs, and all of the p-legs are simultaneously welded to the contact material. The time needed for producing the thermoelectric component is thus minimized if first all of the n-legs and then all of the p-legs are welded, or vice versa.

Furthermore, it is possible that all of the n- and p-legs are welded separately, but simultaneously to the contact material.

Further preferred embodiments of the method according to the invention are outlined in the further dependent claims.

According to a second aspect of the invention there is provided a thermoelectric component, produced according to one method as defined in the first aspect, comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material.

According to an embodiment of the invention there is provided a thermoelectric component comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, the electrically conductive contact material being coated. This ensures a particularly reliable electrical connection between the legs and the contact material.

The above-mentioned embodiment is further provided by a thermoelectric component comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, the legs having different dimensions. Depending on its field of application, the thickness of the thermoelectric component can thus be varied, so that the said thermoelectric component can be used efficiently.

According to an embodiment of the invention there is provided a thermoelectric component comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, wherein the electrically conductive contact material encloses an end of the welded leg at least in part in radial direction thereof. The contact surface between the contact material and the leg is thereby increased and the contact resistance is reduced.

According to an embodiment of the invention there is provided a thermoelectric component comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, the electrically conductive contact material being welded in the longitudinal direction of the welded leg to a contact surface thereof. This thermoelectric component also composes a large-area contact surface between the contact material and the respective leg, whereby low contact resistance is achieved.

Preferably, the electrically conductive contact material is coated with an electrically conductive material.

According to a further preferred embodiment the thermoelectric component comprises a plurality of pairs of legs, which legs are connected via the contact material electrically in series and thermally in parallel. This yields compact thermoelectric components of high efficiency.

Preferably, the n- and p-legs of a pair of legs are electrically interconnected at one side of the thermoelectric component via the contact material, and the n-leg of the above-mentioned pair of legs is connected at the opposite side of the thermoelectric component to another neighboring p-leg and the p-leg of the above-mentioned pair of legs is electrically connected to another neighboring n-leg.

Preferably a mechanical stabilization is provided between neighboring legs. Such a thermoelectric component is very robust and can also be used in vibrating environments without failure of the welded joints.

According to a further preferred embodiment at least one of the legs is provided at one or both ends or on the faces with at least one additional layer as a diffusion barrier and/or adhesive layer and/or for reducing the transition resistance to the contact material. It is also possible that the contact material comprises at least one additional layer as the

diffusion barrier and/or adhesive layer and/or for reducing the transition resistance to the respective leg.

Preferably, the thermoelectric component is mechanically flexible. While solder connections tend to break relatively rapidly under bending stresses, welded joints are much more resistant, so that a flexible thermoelectric component can be adapted to different environments, e.g. to neighboring thermoconductors.

Further preferred embodiments of the thermoelectric component according to the invention are explained in the further dependent claims.

The present invention shall now be explained in more detail with reference to preferred embodiments in conjunction with the associated figures, of which:

- Fig. 1 is a schematic illustration showing a basic structure of a thermoelectric component for explaining the functional principle;
- Fig. 2 is a schematic illustration showing a pair of legs of a thermoelectric component;
- Fig. 3 is a schematic illustration showing a thermoelectric component arranged around a thermoconductor;
- Fig. 4 is a schematic illustration showing a thermoelectric component of a flat construction;
- Fig. 5 is a schematic illustration showing a thermoelectric component of a flat construction with a mechanical stabilization;
- Figs. 6-9 are schematic illustrations showing a method for producing a thermoelectric component; and

Figs. 10-12 show different gap welds for contacting p- and n-legs with electrically conductive contact material.

Beside Fig. 1, which has already been described in the introduction to the specification, Fig. 2 is a schematic illustration showing a preferred embodiment of a pair of legs of a thermoelectric component 1.

In the subsequent description like reference numerals are used for like features, and for reasons of a clear illustration reference numerals are not always indicated in the figures for all similar features, particularly for all legs of the various embodiments of thermoelectric components 1. Rather, only individual legs are provided by way of example with the respective reference numerals.

The thermoelectric component 1 in Fig. 2 comprises a pair of legs, consisting of an n-leg 2 and a p-leg 3. The n-leg 2 and the p-leg 3 are electroconductively contacted with electrically conductive contact material 4 by means of welds. In the upper area of Fig. 2, the two legs 2, 3 are interconnected by a strip of electrically conductive contact material 4. In the lower area of Fig. 2, each of the two legs 2, 3 is connected to a separate strip of electrically conductive contact material 4.

A voltage can already be tapped on the last-mentioned strip if the thermoelectric component 1 is a thermoelectric generator or a temperature sensor. As an alternative, contacting with a source of current can already be carried out at said places if the thermoelectric component 1 is used as a Peltier element.

According to a preferred embodiment the electrically conductive contact materials 4 in the lower area of Fig. 2 are however electrically conductively connected to further neighboring legs 2, 3. This means that in Fig. 2 the n-leg 2 is connected at its left side to a further p-leg (not shown) whereas the p-leg 3 at its right side is electroconductively

connected to a further n-leg (not shown). Apart from Fig. 1, such arrangements are also found in Figs. 3 to 5, which are described hereinafter.

Hence, the n- and p-legs 2, 3 of the pair of legs shown in Fig. 2 are electrically interconnected via the contact material 4 on the upper side of the thermoelectric component 1. At the opposite lower side of the thermoelectric component 1 the n-leg 2 of the illustrated pair of legs is preferably connected to another neighboring p-leg (not shown), and the p-leg 3 of the illustrated pair of legs is preferably connected to another neighboring n-leg (not shown). As a result, the individual legs 2, 3 are connected via the contact material 4 electrically in series and thermally in parallel. Preferably, the thermoelectric component 1 comprises a plurality of pairs of legs, of which legs 2, 3 are connected via the contact material electrically in series and thermally in parallel, and the respective legs 2, 3 can here be contacted with each other in different spatial directions.

In the illustrated embodiments, the shape of legs 2, 3 is substantially block-shaped, but other forms of the legs are also possible, e.g. rotation-symmetrical, particularly round, cross-sections of the legs. The dimensions of the legs 2, 3 can be varied at random.

Preferably, at least one of the legs 2, 3 is provided at one or both ends or on the faces with at least one additional layer. For instance, this may be a layer for reducing the transition resistance 9 and/or a diffusion barrier 10 and/or an adhesive layer 11. These layers may be applied in different sequences and thicknesses to the respective legs 2, 3 particularly on the contact surfaces thereof relative to the contact material 4. For instance, an electroplating method is suited for said application.

Preferably, the electrically conductive contact material 4 may be coated in addition or alternatively with one or more layers. These may be a separate metallization 7 and/or further diffusion barriers 6, 8. In the illustrated embodiment the electrically conductive contact material 4 comprises an interior diffusion barrier 8 relative to the respective n- and p-legs 2, 3 next to an additional metallization 7, and an exterior diffusion barrier 6 between the metallization 7 and the electrically conductive contact material 4 proper. A

separate adhesive layer is also possible, where all layers can be arranged in different sequences. Again an electroplating method is preferably suited for applying said layers to the contact material 4.

A mechanically stable and also an electrically and thermally highly conductive connection can be established by providing additional layers on the electrically conductive contact material 4 and/or the legs 2, 3. Moreover, these coats serve to reduce the thermal and electrical transition resistance and to eliminate other objectionable effects, such as e.g. thermal and mechanical strains. To be more specific, the thermal expansion coefficient can be adapted by matching the respective layers in their material composition. Moreover, on the electrically conductive contact material 4 it is also possible to provide an insulation layer for electrically insulating the areas around the leg contact points, particularly in the case of very thin thermoelectric components 1.

Furthermore, Fig. 2 shows an optional substrate 5 which electrically insulates the thermoelectric component 1 to the exterior. However, it is also possible that the thermoelectric component 1 is open to the outside, e.g. when an adjoining thermoconductor 12 itself is made of an electrically insulating material.

Preferably, the n- and p-legs 2, 3 comprise at least one of the following elements or a composition of the following elements: Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si and Ge. It is advantageous when the legs 2, 3 substantially have compositions consisting of elements of the fourth and sixth main group, particularly any desired combinations of [Pb, Sn, Ge] and [S, Se, Te], such as e.g. PbTe, PbSe, PbS, SnTe, GeTe and GeSe. Preferably, at least one of the legs 2, 3 comprises a chalcogenide-based material.

Likewise, it is possible that the n- and p-legs 2, 3 substantially comprise compositions consisting of elements of the fifth and sixth main group, particularly compositions of [Bi, Sb]₂ and [S, Se, Te]₃, such as Bi₂S₃, Bi₂Te₃, Bi₂Se₃, Sb₂S₃, Sb₂Se₃ and Sb₂Te₃.

Likewise, it is possible that the legs 2, 3 comprise SiGe-based materials, skutterudite-based materials, half-Heusler-based materials, oxide-based materials, antimony-based materials, clathrate-based materials or boron-based materials.

It is also advantageous when the n- and p-legs 2, 3 comprise materials of the carbon group, i.e. the fourth main group of the periodic system, also in composition, i.e. C, Si, Ge, Sn and Pb. Nanocomposites also seem to be of advantage to legs 2, 3.

The following elements or a composition of the following elements are preferred for the electrically conductive material 4: Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si and Ge. This is also true for the coatings of the contact material 4.

It is particularly advantageous when the contact material 4 comprises a strip or wire of Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si or Ge alone or in combination with one or several other elements.

Possible are also several strips or wires of contact material 4 that are placed one on top of the other or side by side. Likewise, it is possible that a layer applied to the contact material comprises one or more of the aforementioned elements. This may particularly be a reaction layer that reacts physico-chemically with the respective leg 2, 3 and/or a reaction layer positioned on said leg during welding.

Preferably, all of the n-legs 2 and p-legs 3 are welded to the corresponding strips or wires of electrically conductive contact material 4. However, it is also possible that the legs 2, 3 are only welded at one side of the thermoelectric component 1 to the strips or wires of electrically conductive contact material 4, e.g. on the upper side with respect to Fig. 2. At the opposite side the legs 2, 3 may also be connected by another joining method (solder method, mechanical joining method) to the respective strips or wires of the electrically conductive contact material 4.

Preferably, the n- and p-legs 2, 3 may have different dimensions so as to adapt the thermoelectric component 1 to different environments. It is also advantageous when the electrically conductive contact material 4 in the longitudinal direction L of the respective leg 2, 3 is fully welded to a contact surface, particularly face, thereof. Furthermore, it is advantageous when the electrically conductive contact material 4 encloses an end of the welded leg 2, 3 at least in part in the radial direction R thereof. The aforementioned embodiments may also be combined with one another in any desired way.

Fig. 3 is a schematic illustration showing a thermoelectric component 1 arranged around a thermoconductor 12. In contrast to the embodiment shown in Fig. 2, the embodiment of Fig. 3 is without any electrically insulating substrate 5 because the thermoconductor 12 itself is preferably electrically insulating. The thermoconductor 12 is e.g. tubular and preferably has a round cross-section. Preferably, the thermoelectric component 1 therefore has a curved, particularly annular or tubular shape.

It is particularly advantageous when the thermoelectric component 1 is mechanically flexible and can be adapted to the cross section of the thermoconductor 12. With the welds between the contact material 4 and the legs 2, 3 it is possible to adapt the flexible thermoelectric component 1 to different environments and installation situations because in contrast to conventional soldered joints the welded joints sustain substantially greater loads and are less prone to breakage.

Each of Figs. 4 and 5 shows thermoelectric components 1 of a flat construction. The contact surfaces of the legs 2, 3 are each provided in their longitudinal direction L with diffusion barriers 10. In contrast to Fig. 4 the embodiment in Fig. 5 has no continuous, electrically insulating outer substrate 5, but comprises sections of said substrate 5. Each of the sections of the substrate 5 covers the strips of the electrically conductive contact material 4, so that an electrical insulation to the outside is ensured.

It is thus possible to deform the thermoelectric component 1 so as to adapt it to geometrically difficult installation situations. For reinforcing purposes a mechanical

stabilization 13 is provided in the interior of the thermoelectric component 1, the stabilization enclosing the respective legs 2, 3 and separating neighboring legs from each other. This mechanical stabilization 13 can remain in the thermoelectric component 1, but can also be removed again after manufacture thereof. In the first-mentioned case it should not be electrically conductive and only show very poor thermal conduction; in the second case the thermal and electrical conductivity of the mechanical stabilization 13 plays no role.

When the mechanical stabilization 13 remains as a matrix material in the thermoelectric component 1, it serves not only stabilization, but also prevents e.g. contamination of or change in the chemical composition of the legs 2, 3. Preferably, ceramic materials, glasses, porcelain or plastic materials are used. Especially when elastically deformable plastic materials are used as the matrix material for the mechanical stabilization 13, it is possible to flexibly adapt the thermoelectric component 1 stabilized in this way to the installation situation.

Preferably, the contact material 4 has thicknesses between 1 μm and 1 mm and widths between 10 μm and 100 mm. To connect two legs 2, 3, one or several strips of the contact material 4 may be used side by side or one on top of the other.

Figs. 6 to 9 are schematic illustrations showing a preferred method for producing a thermoelectric component 1. These figures show the thermoelectric component 1 or parts of the thermoelectric component 1 in a three-dimensional view. The flat contact material 4 extends in Figs. 8 and 9 along the base areas of the thermoelectric component 1 to be produced, i.e. along its length and width. Longitudinal axes of the legs 2, 3 define the height of the thermoelectric component 1 to be produced, the legs 2, 3 extending in Fig. 6 in longitudinal direction L.

In Fig. 6, the n- and p-legs 2, 3 are already arranged, as desired, with a view to the later installation situation. It is here also possible to use legs 2, 3 with different leg lengths. As

for the composition of the legs and their form, reference is made to the preceding description.

Subsequently, the legs 2, 3 are preferably surrounded by a matrix material as mechanical stabilization 13, as has been described above.

Previously described, electrically conductive contact material 4 is each time welded for connection of two neighboring n- and p-legs 2, 3 on the top side and on the bottom side (not shown) to the said legs. n- and p-legs may be welded consecutively in time. It is also possible that all of the n- and p-legs 2, 3 are welded separately, but simultaneously to the contact material 4.

Preferably, the welding method used is resistance welding, such as gap welding, spot welding, projection welding or roll welding. Preferably, these welding methods are carried out in a protective gas atmosphere, either in an inert gas or in an active gas, to prevent contamination of the weld, particularly by oxides. Likewise, it is possible to carry out the welding method in vacuum.

Other welding methods, such as arc welding, gas shielded welding, laser beam welding, electron beam welding, plasma welding or hydrogen welding, are possible. Particularly advantageous is however gap welding, preferably narrow gap welding or inert-gas narrow-gap welding, which will still be discussed further below. MIG welding methods, either with inert gas or active gas, are advantageous. Tungsten inert-gas welding should particularly be mentioned here.

It is possible in all methods to preheat the legs 2, 3 to be welded and/or the contact material 4 prior to welding.

The welding operation accomplishes stable contacting with possible applications up to very high temperatures. Welding takes place by way of a short energy input into the contact material 4 and possibly into one or several materials positioned on top or

underneath and into the leg material and possibly into one or several materials positioned thereabove.

With the welding method almost all material combinations of contact material and leg material and of the materials positioned on top or underneath can be connected to one another. This accomplishes high adhesion, and very high-melting materials can be connected at the same time, so that contacting satisfies the respective thermal demands. Moreover, contacts established with this technique are distinguished by high mechanical stability.

Since it is possible to join almost any material combinations of contact material and leg material and the corresponding layered structures by welding, the thermal expansion coefficient can be easily adapted and diffusion can be easily prevented by means of diffusion barriers. Differences in height of the individual legs do not play a role here. The welding process can be easily automated owing to its simplicity and achieves high reproducibility.

In Fig. 9, the optional mechanical stabilization 13 is removed if necessary. Subsequently, the thermoelectric component 1 may e.g. be provided on its top and bottom side with the above-described outer substrate 5.

Figs. 10 to 12 depict different gap welds for contacting the n- and p-legs 2, 3 with the electrically conductive contact material 4. Reference numeral 14 designates a gap electrode, the two electrode tips of which are spaced apart by a gap BE. The width of gap BE is variably adjustable. Preferably, the n-leg 2 and the p-leg 3 have different leg widths B2 and B3.

In the embodiment illustrated in Fig. 10, the gap BE of the gap electrode 14 is set according to the width B2 of the n-leg 2. The gap electrode 14 contacts the contact material 4 positioned on legs 2, 3 and presses said material preferably onto the leg 2 and 3, respectively, to be welded. However, it is also possible that the contact material 4 is

pressed by other means already onto the respective leg 2, 3. The latter must particularly be borne in mind if contactless welding is carried out, for instance by means of laser beam welding or electron beam welding.

The contact surfaces or faces including legs 2, 3 at their ends in longitudinal direction L are brought into contact with the contact material and the respective leg is welded preferably across the whole contact surface of the said leg 2, 3.

The electrodes, preferably the electrode tips of the gap electrode 14, are pressed at a contact pressure between 0.001 N/mm^2 and 10000 N/mm^2 against the contact material 4 provided on the respective leg. For welding purposes current is flowing in the range of from $1 \mu\text{A/mm}^2$ to 10 kA/mm^2 and between 1ns and 10s between the two electrodes through the contact material 4 and the leg to be respectively welded.

After the n-leg 2 has been welded at the left side of Fig. 10 in a first welding step, gap BE of the gap electrode 14 is set to the width B3 of the p-leg 3 located at the right side and is positioned above said leg. As an alternative, it is also possible to change the position of the thermoelectric component 1 accordingly.

For the second subsequent welding step further welding parameters, such as current flow, hold time, biasing current, heating-up period and/or contact pressure are matched in a corresponding way to the smaller p-leg 3, which is made up of a different material. It is also possible to change the welding tool itself and to adapt the welding parameters accordingly. Thus, different welding parameters are set independently of one another preferably for welding n- and p-legs 2, 3 with different geometry and/or different composition.

In a further preferred embodiment in Fig. 11, gap BE of the gap electrode 14 contacting the contact material 4 is set to be wider than the width B2 or B3 of the leg to be respectively welded.

While in Figs. 10 and 11 the gap electrode 14 contacts the contact material 4 in longitudinal direction L of the leg 2, 3 to be welded, Fig. 12 shows a further embodiment in which the contact material encloses an end of the leg 2, 3 to be welded at least in part in a radial direction R of the leg 2, 3, i.e. in its width. The gap electrode 14 contacts the contact material 4 in radial direction R of the leg 2, 3 to be welded and acts on the contact material 4 with a force F in radial direction R.

To this end it is advantageous when the contact material 4 is pre-formed with corresponding recesses or hollows for the ends of legs 2, 3. However, it is also possible that these recesses are only formed by pressing a per se flat strip of contact material 4 onto the respective leg ends.

Independently of the selected welding method, it is advantageous when the thermoelectric component 1 comprises a plurality of pairs of legs so that among a selection of pairs of legs first the n-leg 2 and then the corresponding p-leg 3 is welded to the contact material 4, or vice versa. In case the thermoelectric component 1 comprises a plurality of pairs of legs, it is advantageous when all n-legs 2 or all p-legs 3 are welded to the contact material 4 at the same time. To be more specific, it is advantageous when all n-legs 2 of one side (top or bottom side of the thermoelectric component 1) or all p-legs 3 of one side are simultaneously welded to the contact material 4.

It is also possible that the contact material 4 is made up of several layers, preferably of different materials, that are connected, particularly welded, to each other and/or to the respective leg 2, 3. These multi-layered contact materials 4 preferably comprise foils, particularly coated foils. In this instance it is possible to connect or weld the multilayered contact material 4 in one or several welding steps to each other and/or to the corresponding leg 2, 3.

The previously described embodiments refer to a method for producing a thermoelectric component 1 with at least one pair of thermoelectric legs, including an n-leg 2 and a p-leg 3, both legs 2, 3 being welded to an electrically conductive contact material 4, the n-

leg 2 and the p-leg 3 of the pair of legs being welded in separate welding steps to the contact material 4, and to a thermoelectric component 1.

Patent Claims

1. A method for producing a thermoelectric component comprising at least one pair of thermoelectric legs, including an n-leg and a p-leg, both legs being welded to an electrically conductive contact material, **characterized in** that the n-leg and the p-leg of the pair of legs are welded in separate welding steps to the contact material.
2. The method according to claim 1, **characterized in** that welding parameters for welding the n-leg and welding parameters for welding the p-leg are set independently of one another.
3. The method according to claim 1 or 2, **characterized in** that at least at one of their ends in longitudinal direction the legs comprise contact surfaces which are brought into contact with the contact material, and welding of the n-leg and/or welding of the p-leg is performed on the contact surface and/or at the side of the contact surface of the respective leg.
4. The method according to claim 3, **characterized in** that welding of the n-leg and/or welding of the p-leg is performed over the whole contact surface of the respective leg.
5. The method according to at least one of claims 1 to 4, **characterized in** that the contact material consists of a plurality of layers, preferably of different materials, which are joined in one or more welding steps with each other and/or with the respective leg.
6. The method according to at least one of claims 1 to 5, **characterized in** that the contact material or a layer provided thereon reacts physico-chemically with the material of the p-leg and/or a reaction layer provided thereon and/or physico-

chemically with the material of the n-leg and/or a reaction layer provided thereon, and the reaction layer consists of at least one of the elements Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si or Ge alone or in combination with another element.

7. The method according to at least one of claims 1 to 6, **characterized in** that prior to and/or during the respective welding step the contact material is pressed onto the leg to be welded.
8. The method according to claim 7, **characterized in** that the contact material is pressed by at least one welding electrode onto the leg to be welded.
9. The method according to at least one of claims 1 to 8, **characterized in** that the n-leg and the p-leg of the pair of legs are welded by resistance welding separately to the contact material.
10. The method according to claim 9, **characterized in** that the n-leg and the p-leg of the pair of legs are welded by gap welding to the contact material.
11. The method according to claim 10, **characterized in** that the contact material is brought into contact with the corresponding leg, and a gap of a gap electrode contacting the contact material is set in conformity with a width of the leg to be welded.
12. The method according to claim 10, **characterized in** that the contact material is brought into contact with the corresponding leg, and a gap of a gap electrode contacting the contact material is set to be wider than a width of the leg to be welded.
13. The method according to claim 12, **characterized in** that the contact material encloses an end of the leg to be welded at least in part in a radial direction

of the leg, and the gap electrode contacts the contact material in radial direction of the leg to be welded.

14. The method according to claim 11 or 12, **characterized in** that the gap electrode contacts the contact material in longitudinal direction of the leg to be welded.
15. The method according to at least one of claims 1 to 14, **characterized in** that welding is performed under vacuum or in an inert gas atmosphere.
16. The method according to at least one of claims 1 to 8, **characterized in** that the n-leg and/or the p-leg of the pair of legs is/are welded to the contact material by inert gas welding, preferably by MIG welding, tungsten inert-gas welding, MAG welding, plasma welding or hydrogen welding.
17. The method according to at least one of claims 1 to 8, **characterized in** that the n-leg and/or the p-leg of the pair of legs is/are welded to the contact material by laser beam welding.
18. The method according to at least one of claims 1 to 17, **characterized in** that the legs to be welded and/or the contact material are preheated prior to welding.
19. The method according to at least one of claims 1 to 18, **characterized in** that the thermoelectric component comprises a plurality of pairs of legs, wherein among a selection of pairs of legs first the n-legs and then the corresponding p-legs are welded to the contact material.
20. The method according to at least one of claims 1 to 19, **characterized in** that the thermoelectric component comprises a plurality of pairs of legs, wherein among a

selection of pairs of legs first the p-legs and then the corresponding n-legs are welded to the contact material.

21. The method according to at least one of claims 1 to 20, **characterized in** that the thermoelectric component comprises a plurality of pairs of legs, and all of the n-legs are simultaneously welded to the contact material.
22. The method according to at least one of claims 1 to 21, **characterized in** that the thermoelectric component comprises a plurality of pairs of legs, and all of the p-legs are simultaneously welded to the contact material.
23. The method according to at least one of claims 1 to 22 **characterized in** that the n- and p-legs of a pair of legs are electrically interconnected via the contact material at one side of the thermoelectric component, and that at the opposite side of the thermoelectric component the n-leg of the aforementioned pair of legs is electrically connected to another neighboring p-leg and the p-leg of the aforementioned pair of legs is electrically connected to another neighboring n-leg.
24. The method according to claim 23, **characterized in** that all of the n-legs of one side are simultaneously welded to the contact material.
25. The method according to claim 23 or 24, **characterized in** that all of the p-legs of one side are simultaneously welded to the contact material.
26. The method according to any one of claims 1 to 24, **characterized in** that all of the n- and p-legs are welded separately, but simultaneously to the contact material.
27. A thermoelectric component, produced according to a method according to at least one of claims 1 to 26, comprising at least one pair of thermoelectric legs

which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material.

28. The thermoelectric component particularly according to claim 27, comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, **characterized in** that the electrically conductive contact material is coated.
29. The thermoelectric component, particularly according to claim 27 or 28, comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, **characterized in** that the legs have different dimensions.
30. The thermoelectric component, particularly according to at least one of claims 27 to 29, comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, **characterized in** that the electrically conductive contact material encloses an end of the welded leg at least partly in radial direction thereof.
31. The thermoelectric component, particularly according to at least one of claims 27 to 30, comprising at least one pair of thermoelectric legs which includes an n-leg and a p-leg and which is welded to at least one electrically conductive contact material, **characterized in** that the electrically conductive material is welded in longitudinal direction of the welded leg to a contact surface thereof.
32. The thermoelectric component according to at least one of claims 27 to 31, **characterized in** that the contact material consists of a plurality of layers, preferably of different materials, which are connected to each other and/or to the respective leg.

33. The thermoelectric component according to claim 32, **characterized in** that the contact material comprises a plurality of layers preferably of coated foils.
34. The thermoelectric component according to at least one of claims 27 to 33, **characterized in** that the electrically conductive contact material is coated with an electrically conductive material.
35. The thermoelectric component according to at least one of claims 27 to 34, **characterized in** that the contact material comprises a strip of at least one of the elements Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si or Ge alone or in combination with one or a plurality of other elements and/or with one of the elements Ta, W, Mo, Nb, Ti, Cr, Pd, V, Pt, Rh, Re, Cu, Ag, Ni, Fe, Co, Al, In, Sn, Pb, Te, Sb, Bi, Se, S, Au, Zn, Si or Ge alone or in combination with one or a plurality of other elements.
36. The thermoelectric component according to at least one of claims 27 to 35, **characterized in** that the individual legs are connected via the contact material electrically in series and thermally in parallel.
37. The thermoelectric component according to at least one of claims 27 to 36, **characterized in** that the thermoelectric component comprises a plurality of pairs of legs, the legs of which are connected via the contact material electrically in series and thermally in parallel.
38. The thermoelectric component according to at least one of claims 27 to 37, **characterized in** that the n- and p-legs of a pair of legs are electrically interconnected via the contact material at one side of the thermoelectric component, and that at the opposite side of the thermoelectric component the n-leg of the aforementioned pair of legs is electrically connected to another

neighboring p-leg and the p-leg of the aforementioned pair of legs is electrically connected to another neighboring n-leg.

39. The thermoelectric component according to claim 38, **characterized in** that the legs are welded at one side or at both sides of the thermoelectric component to the contact material.
40. The thermoelectric component according to at least one of claims 27 to 39, **characterized in** that a mechanical stabilization is inserted between neighboring legs.
41. The thermoelectric component according to at least one of claims 27 to 40, **characterized in** that at least one of the legs comprises a chalcogenide- based material.
42. The thermoelectric component according to at least one of claims 27 to 41, **characterized in** that on one or both ends or contact surfaces at least one of the legs comprises at least one additional layer as a diffusion barrier and/or adhesive layer and/or for reducing the transition resistance to the contact material.
43. The thermoelectric component according to at least one of claims 27 to 42, **characterized in** that the contact material comprises at least one additional layer as a diffusion barrier and/or an adhesive layer and/or for reducing the transition resistance to the respective leg.
44. The thermoelectric component according to at least one of claims 27 to 43, **characterized in** that the thermoelectric component is mechanically flexible.

45. The thermoelectric component according to at least one of claims 27 to 44,
characterized in that the thermoelectric component is a thermoelectric generator
or a Peltier element or a sensor element.