Abstract: A wasted heat harvesting device (1000) for harvesting electricity including switching means (1200) configured to convey a magnetic field from a first region to at least a second region when the temperature of the switching means (1200) crosses a predetermined temperature.
Active cooling for a concentrated photovoltaic cell

In recent years, the development of renewable energy has increased due to concern over the availability of fossil energy sources as well as environmental concerns. Among the different kinds of renewable energy sources, solar energy is the most abundant. Accordingly, there has been intensive research on how to collect solar energy and transform it into electricity. Among the different techniques proposed, photovoltaic (PV) cells are well known in the art and have been extensively developed in order to increase their efficiency and lower their cost.

In particular, concentrated photovoltaic (CPV) cells are known to be cheaper to manufacture than a standard photovoltaic type system providing the same amount of power. This is due to the fact that concentrated photovoltaic cells use lenses to focus the solar light on a PV surface which is smaller due to the light concentration. Accordingly, the area and material required is reduced.

At high concentration ratios of the solar light, for instance, more than 500 times, cooling of the photovoltaic cell is required. This is due to the fact that PV cells are less efficient at higher temperatures and due to the possibility of the PC cells being damaged by very high temperatures.

In order to cool down the PV cells, passive cooling, such as a heat dissipater becomes complicated and therefore costly. As an alternative, it is known to use an active cooling solution in which some medium, like water or oil is used for cooling down the cell. In this approach, the cooling medium is heated and either directly used, for instance as hot water, or used to run a generator for electricity production. In the latter case, the efficiency of the electricity-generation process is rather low.

More specifically, a typical CPV cell can be sized between 0.25cm² and 1cm². Assuming a concentration ratio of 500, it can be estimated that about 5 to 18 watts are wasted in heat. This is roughly on the same order of magnitude of the energy transformed into electricity by the CPV cell.

Accordingly, it would be an improvement in the art of concentrated photovoltaic cells if the generated heat could be transformed into electricity via a highly efficient process.
Such a problem is solved by the invention, as defined by the independent claims.

More specifically, the present invention may relate to a wasted heat-harvesting device for harvesting electricity including: switching means configured to convey a magnetic field from a first region to at least a second region when the temperature of the switching means crosses a predetermined temperature.

Thanks to such approach, a wasted heat harvesting device is capable of converting heat into electricity in an efficient manner.

In some embodiments, the wasted heat harvesting device can further include: magnetic means configured to generate the magnetic field; a magnetic flux conveyor configured to convey a magnetic flux generated by the switching of the switching means; and electricity generating means configured to generate electricity from the magnetic flux.

Thanks to such approach, a wasted heat harvesting device is capable of converting heat into electricity with a simple design.

In some embodiments, a first side of the magnetic flux conveyor can be connected to one pole of the magnetic means and the switching means can be placed between a second side of the magnetic flux conveyor and the other pole of the magnetic means.

Thanks to such approach, the magnetic field can generate a magnetic flux flowing through the magnetic flux conveyor.

In some embodiments, the switching means can be a magnetic alloy switch.

Thanks to such approach, the switch can allow or prevent passage of the magnetic field.

In some embodiments, the electricity generating means can include a coil wound around the magnetic flux conveyor.

Thanks to such approach, electricity can be generated from the magnetic flux.

In some embodiments, the magnetic flux conveyor can be any of iron type, ferromagnetic alloy, such as Fe or Fe-P or FeSi or Ni/Fe 45/55.

Thanks to such approach, the magnetic flux can be conveyed efficiently.
In some embodiments, the magnetic means can be any of SmCo$_5$, Sm$_2$Co$_{15}$, Nd$_2$Fe$_{14}$B or Ba ferritis.

Thanks to such approach, the magnetic field can be efficiently realized.

In some embodiments, the switching means can be made of Gd$_3$(Si$_x$Ge$_{1-x}$)$_4$.

Thanks to such approach, the switching of the magnetic flux can be realized in an efficient manner.

The present invention may further relate to a wasted heat harvesting system including: at least two wasted heat harvesting devices according to any of the previous embodiments, each of the at least two wasted heat harvesting devices including a device power output for outputting electricity generated by the electricity generating means.

Thanks to such approach, multiple wasted heat harvesting devices can operate in conjunction.

In some embodiments the at least two device power outputs can be connected in parallel or in series to each other.

Thanks to such approach, multiple wasted heat harvesting devices operating at the same frequency can operate in conjunction.

In some embodiments, the connection of the at least two device power outputs can be connected to an AC/DC converter and the output of the AC/DC converter can be connected to a power output of the wasted heat harvesting system.

Thanks to such approach, the power output of the wasted heat harvesting system can be connected to a second power output of a similar wasted heat harvesting system.

In some embodiments, the connection of the at least two device power outputs can be connected to an AC/AC converter and the output of the AC/AC converter can be connected to a power output of the wasted heat harvesting system.

Thanks to such approach, the power output of the wasted heat harvesting system can be connected to a second power output of a similar wasted heat harvesting system.

In some embodiments, each of the at least two device power outputs can be connected to an AC/DC converter.
Thanks to such approach, multiple wasted heat harvesting devices not operating at the same frequency can operate in conjunction.

In some embodiments, the output of the AC/DC converters can be connected in series or in parallel to each other and the resulting connection can be connected to a power output of the wasted heat harvesting system.

Thanks to such approach, multiple wasted heat harvesting devices not operating at the same frequency can operate in conjunction.

In some embodiments, each of the at least two device power outputs can be connected to an AC/AC converter.

Thanks to such approach, multiple wasted heat harvesting devices not operating at the same frequency can operate in conjunction.

In some embodiments, the output of the AC/AC converters can be connected in series or in parallel to each other and the resulting connection can be connected to a power output of the wasted heat harvesting system.

Thanks to such approach, multiple wasted heat harvesting devices not operating at the same frequency can operate in conjunction.

The present invention may further relate to a modular wasted heat harvesting system comprising at least two wasted heat harvesting systems according to any of the previous embodiments.

The present invention may further relate to a photovoltaic cell including a wasted heat harvesting device and/or a wasted heat harvesting system and/or a modular wasted heat harvesting system according to any of the previous embodiments.

Thanks to such approach, heat generated by sunlight on the photovoltaic cell can be efficiently converted into electricity.

The present invention may further relate to a solar module comprising a plurality of photovoltaic solar cells, in particular concentrated photovoltaic solar cells, further comprising at least one wasted heat harvesting device configured to transform heat into electricity configured and arranged such that at least one of the photovoltaic solar cells is furthermore cooled by the transformation of heat into electricity.
Thanks to such approach, the solar module can efficiently operate thanks to the cooling of the cells and the generated heat can additionally be converted into electricity.

The present invention may further relate to a method for realizing a wasted heat harvesting device including the steps of: a first deposition step of depositing a metal layer on a substrate; a second deposition step of depositing a magnetic alloy on the substrate; a third deposition step of depositing a ferromagnetic seed material on the substrate; a fourth deposition step of depositing a metal layer on the substrate; and a fifth deposition step of depositing a magnetic material on the substrate.

Thanks to such approach, it is possible to realize a wasted heat harvesting device with a reduced number of steps and with technology compatible with photovoltaic cells manufacturing.

The invention will be described in more detail by way of example hereinafter using advantageous embodiments and with reference to the drawings. The described embodiments are only possible configurations in which the individual features may however, as described above be implemented independently of each other or may be omitted. Equal elements illustrated in the drawings are provided with equal reference signals. Parts of the description related to equal elements illustrated in the different drawings may be left out. In the drawings:

Figure 1a is a schematic drawing of a wasted heat harvesting device according to an embodiment of the present invention;

Figure 1b is a schematic drawing of the operation of the wasted heat harvesting device of Figure 1a;

Figures 2 to 7 are schematic drawings of a method for realising a wasted heat harvesting device of Figure 1a;

Figures 8a and 8b are schematic drawings of wasted heat harvesting device according to further embodiments of the present invention;

Figure 9a is a schematically drawing of a wasted heat harvesting system in accordance with a further embodiment of the present invention.

Figures 9b, 10a, 10b and 11 are schematic drawings of modular wasted heat harvesting systems in accordance with further embodiments of the present invention.
As can be seen in Figure 1a, a wasted heat harvesting device 1000 in accordance with an embodiment of the present invention comprises a magnet 1100 including south pole 1101 and north pole 1102, a ferromagnet 1400, a switch 1200 and a coil 1300. The two end of the coil 1300 act as a power output 1500 of the wasted heat harvesting device.

As can be seen in Figure 1b, when the switch 1200 switches from the open position of Figure 1a to the closed position Figure 1b, a magnetic flux $\Phi$ 1600 is generated by the magnetic field of magnet 1500 being redirected through the ferromagnet 1400. The magnetic flux 1600 induces a current $I$ 1700 in coil 1300. The current 1700 can be collected at power output 1500 for instance, to power a load 1900 resulting in a voltage drop V 1800.

In other words, the magnetic field is conveyed from a first region outside the coil 1300 to a second region inside the coil 1300 by the switch 1200.

Symmetrically, when the switch moves from the closed position of Figure 1b to the open position of Figure 1a, an opposite magnetic flux is generated resulting in an opposite induced current. Accordingly, by the opening and closing of the switch 1200, an AC current is generated at the power output 1500.

More specifically, the switch 1200 is a magnetic switch alloy that switches on and off depending on its temperature. The wasted heat harvesting device is placed in thermal contact with a CPV cell. When the CPV cell is exposed to sunlight, its temperature will rise. As the temperature rises above a first predefined temperature, the switch 1200 closes. This causes the temperature to drop. As the temperature drops below a second predefined temperature, the switch opens. After a certain time, the CPV cell temperature will start rising again because of solar irradiation and the temperature will increase again, leading to a new cycle.

In this manner, the CPV cell can be cooled actively. That is, thermal energy is converted to electricity in order to cool the cell, instead of passively dissipating the thermal energy.

Although the above embodiment has been described with a first and a second predetermined temperature, so as to indicate a hysteresis of the magnetic switch alloy, the present invention is not limited to this. Alternatively, the magnetic switch alloy could have a substantially negligible hysteresis and the first and second predetermined temperature could substantially correspond to a single threshold temperature.
For instance, the material of the magnetic switch alloy could be Gd₅(Si₅Geₓ)₄. When using this material, the first and second predetermined switching temperatures can be set, for instance, between 40 and 80°C according to the composition of the switching alloy.

Although the embodiment has been described with reference to a coil 1300, and a ferromagnet 1400, the present invention is not limited to this. Alternatively, the present invention could be realized even without a ferromagnet, but only using a geometry that allows a magnetic field to be at least partially re-directed, or conveyed, from a first region to a second region, based on a change in temperature. The magnetic flux generated by such change can then be converted into electrical energy. The conversion to electrical energy can be done via the coil but also via any other means that allows a magnetic flux to be converted in electricity, such as a straight piece of conductor.

The material and dimensions of the switch 1200 are chosen based on the thermal mass of the CPV cell on which the wasted heat harvesting device 1000. More specifically, the thermal mass of the heat harvesting device 1000 is matched to the thermal mass of the CPV cell to be cooled. The term matching in this context means that, for instance, the heat harvesting device 1000 on the cell backside is e.g. a 1.5 mm wide ring and 200µm thick. In this case the physical mass of the ferromagnetic material is comparable, i.e. matched, to the mass of the cell.

As can be seen in figure 2, a process for realizing a wasted heat harvesting device 1000 includes a deposition step S1 of depositing a metal layer on a substrate 100, thereby obtaining intermediate wasted heat harvesting device 1001. The deposition of the metal layer results in a first and a second coil segment 1301 and 1302, respectively.

More specifically, figure 2 represents from top to bottom, a top view of substrate 100, a section view of substrate 100 along the line A-A', and three section views of substrate 100 along the lines B-B', C-C and D-D'.

As can be seen in the section view along line A-A', the deposited metal layer could have a thickness T1 in the range of 100 to 200µm with a preferred value of 150µm. The metal could be any of iron based material or any other material which enables high magnetic flux.

Moreover, in this particular example, the length of the first and second coil segments 1301 and 1302 along direction Y, on the top view, is longer than the length of those elements
along direction Y. However, the present invention is not limited to this. Alternatively, the dimensions of the first coil segment, and second coil segment could be different between each other as long as the chosen dimensions allow the realisation of a coil.

As can be seen in figure 3, the process for realizing a wasted heat harvesting device further includes a deposition step S2 of depositing a magnetic alloy on a substrate thereby obtaining intermediate wasted heat harvesting device. The deposition of the magnetic alloy results in switch 1201.

More specifically, figure 3 represents from top to bottom, a top view of substrate 100, a section view of substrate 100 along the line A-A', and three section views of substrate 100 along the lines B-B', C-C and D-D'.

As can be seen in the section view along line A-A', the deposited magnetic alloy layer could have a thickness $T_2$ in the range of 100 to 300 µm with a preferred value of 200 µm. The metal could be any of Gd$_3$(Si$_x$Ge$_{1-x}$)$_4$ as described above or any other thermo magnetic material with the capability to switch the magnetic performance at defined temperature.

As can be seen in figure 4, the process for realizing a wasted heat harvesting device further includes a deposition step S3 of depositing a ferromagnetic seed material on a substrate thereby obtaining intermediate wasted heat harvesting device 1003. This deposition of the ferromagnetic material results in ferromagnetic seed layer 1401.

More specifically, figure 4 represents from top to bottom, a top view of substrate 100, a section view of substrate 100 along the line A-A', and three section views of substrate 100 along the lines B-B', C-C and D-D'.

The purpose of the ferromagnetic layer 1401 is to realise a base for the subsequent quicker deposition of a ferromagnetic thick layer 1402.

As can be seen in the section view along line A-A', the deposited ferromagnetic layer could have a thickness $T_3$ in the range of 100 to 200 µm with a preferred value of 150 µm. The material could be any of iron type, ferromagnetic alloy, such as Fe or Fe-P or FeSi or Ni/Fe 45/55. The advantage of such material is that it has excellent ferromagnetic performance.
In the particular example of Figure 4, the position of the ferromagnetic seed layer 1401 in the present embodiment consists in an outer circle close the peripheral substrate 100, an inner circle and two connecting arms between the inner and outer circles. However, the present invention is not limited to this and more examples will be provided below. Generally speaking, the ferromagnetic material should be deposited so that is can be connected at least on one side to the subsequently deposited magnet and so that it can be connected on at least one side to the magnetic switch alloy. In this embodiment, as can be seen in the section taken along line A-A\, the ferromagnetic seed layer 1401 is deposited on a region overlapping first and second coil segments 1301 and 1302 but not in a region overlapping switch 1200.

As can be seen in figure 5, the process for realizing a wasted heat harvesting device 1000 further includes a deposition step S4 of depositing a ferromagnetic material on a substrate 100 thereby obtaining intermediate wasted heat harvesting device 1004. This deposition of the ferromagnetic material results in ferromagnetic thick layer 1402.

More specifically, figure 4 represents from top to bottom, a top view of substrate 100, a section view of substrate 100 along the line A-A', and three section views of substrate 100 along the lines B-B', C-C' and D-D'.

The ferromagnetic thick layer 1402 is deposited over ferromagnetic seed layer 1401. The combination of the two layers results in ferromagnet 1400.

As can be seen in the section view along line A-A', the deposited ferromagnetic layer could have a thickness T4 in the range of 100 to 200 \( \mu \text{m} \) with a preferred value of 150 \( \mu \text{m} \). The metal could be the same of the ferromagnetic seed layer 1401, or a different one. The advantage of using a different material is that a ferromagnetic seed could be chosen so as to secure good mechanical and thermal contact to the cell backside surface.

Although Figures 4 and 5 and two steps S3 and S4 have been defined in order to realise a ferromagnet 1400, the ferromagnet 1400 could be realised in a single deposition step or in more than two depositions steps. The advantage of using more than one deposition step is that seed layer deposition may secure a better mechanical and thermal contact compared to a single step process.

As can be seen in figure 6, a process for realizing a wasted heat harvesting device 1000 includes a deposition step S5 of depositing a metal layer on a substrate 100, thereby
obtaining intermediate wasted heat harvesting device 1005. The deposition of the metal layer results in a third coil segment 1303.

More specifically, figure 6 represents from top to bottom, a top view of substrate 100, a section view of substrate 100 along the line A-A’, and three section views of substrate 100 along the lines B-B’, C-C and D-D’.

As can be seen in the section view along line D-D’, the deposited metal layer could have a thickness T5 in the range of 100 to 200μm with a preferred value of 150μm. The metal could be the same one used for first and second coil segment 1301 and 1302.

Third coil segment 1303 is deposited so that it creates a connection between one end of first coil segment 1301 and an end of second coil segment 1302. In this manner, a coil structure 1300 wound around ferromagnet 1400 is achieved.

As can be seen in figure 7, the process for realizing a wasted heat harvesting device 1000, further includes a deposition step S6 of depositing a magnetic material on a substrate 100 thereby obtaining wasted heat harvesting device 1000. This deposition of the magnetic material results in magnet 1100. Alternatively or in addition, the magnet can be realized through deposition or assembly of a finished permanent magnet. The deposition may require an activation of the magnet through annealing and magnetization.

More specifically, figure 7 represents from top to bottom, a top view of substrate 100 and a section view of substrate 100 along the line F-F’.

As can be seen in the section view along line F-F’, the deposited magnetic layer could have a thickness T6 in the range of 100 to 300μm with a preferred value of 200μm. The magnetic material could be any of SmCo5, Sm2Co17, Nd2Fe14B or Ba ferritis. The advantage of such materials is that they are all very strong permanent magnet materials.

In the particular example of Figure 7, the position of the magnet 1100 in the present embodiment is between the outer circle of ferromagnetic material 1400 close the peripheral substrate 100 and the inner circle of ferromagnetic material 1400. However, the present invention is not limited to this and more examples will be provided below. Generally speaking, the magnet should be deposited so that it can be connected at least on one side to the ferromagnetic material 1400 and on the other side to the ferromagnetic material 1400 or to the switch 1200.
Although in the above examples the thicknesses T1, T2, T3, T4, T5 and T6 have been pictured as being different, the present invention is not limited by this graphical representation, which has only been employed so as to clarify the various thicknesses. More specifically, the thicknesses could all be the same, or some of them could be the same.

Although in the above examples the term deposition has been employed for the steps S1, S2, S3, S4, S5 and S6, this term is to be intended in the general meaning of realizing a layer. Accordingly, in order to deposit the described layers, a CVD, PVD, plasma deposition, nanoprinting, screen printing, or any other deposition technique could be used.

The deposition of any of the layers could be followed by one or more annealing steps.

Figures 8A and 8B represent alternative embodiments of wasted heat harvesting device 1106 and 1107. More generally, any physical implementation of the wasted heat harvesting device 1000 according to Figure 1a can be realized.

In general, a typical size of the wasted heat harvesting devices 1000, 1106 and 1107 is in the range of 5.5mm by 5.5mm. This is the typical cell size used in the terrestrial CPV cell industry.

Figure 9a illustrates a wasted heat harvesting system 2000 according to a further embodiment of the present invention. The wasted heat harvesting system 2000 could be attached to the backside of a CPV cell. In the case that the CPV cell is realized on a Germanium substrate, the wasted heat harvesting system 2000 could be realized or applied on the underside of the Germanium substrate before or after the realization of the CPV cell.

The wasted heat harvesting system 2000 includes a plurality of wasted heat harvesting devices 1000. Each wasted heat harvesting device 1000 includes at least magnet 1100, ferromagnetic material 1400, switch 1200 and coil 1300. The power output 1500 of the coil 1300 of each of the wasted heat harvesting devices 1000 produces AC current. Accordingly, when a plurality of wasted heat harvesting devices 1000 is to be connected together on a wasted heat harvesting system 2000, different options are available.

For instance, the multiple power outputs 1500 could all be connected to each other in series, in parallel or in groups of parallel and series connections. In the following, four embodiments of the present invention will be described in which the connections of the
multiple power outputs 1500 within a wasted heat harvesting system 2000 are described in conjunction with the connections of multiple power outputs 2500 of a plurality of wasted heat harvesting systems 2000.

Figure 9b illustrates a modular wasted heat harvesting system 3000 composed by two wasted heat harvesting systems 2000, each having a power output 2500. Each of the two wasted heat harvesting systems 2000 includes a plurality of wasted heat harvesting devices 1000, each having a power output 1500.

In figure 9b the multiple power outputs 1500 are connected in parallel to each other and this parallel connection is input into AC/DC converter 2100. In this manner, a wasted heat harvesting system 2000 would output a DC current on the power output 2500. In this case, it is assumed that the different wasted heat harvesting devices 1000 of the wasted heat harvesting system 2000 are operating with the same frequency. This might be the case if the wasted heat harvesting devices are, for instance, in close proximity to each other.

Additionally, a second wasted heat harvesting system 2000 is realised in the same manner as described above. The two power outputs 2500 of the two wasted heat harvesting systems 2000 are connected to each other in parallel so as to realise a modular wasted heat harvesting system 3000. This may be used for in the case where the two wasted heat harvesting systems 2000 are placed in different regions having different temperatures, which would cause the operation of the plurality of wasted heat harvesting devices in each of the wasted heat harvesting system 2000 to be not in phase with the remaining wasted heat harvesting devices.

Although the outputs 1500 of the multiple wasted heat harvesting devices 1000 of each of the two wasted heat harvesting systems 2000 are illustrated as being connected in parallel to each other, they might be connected in series instead.

Similarly, although the outputs 2500 of the two wasted heat harvesting systems 2000 are illustrated as being connected in parallel to each other, they might be connected in series instead.

In figure 10a the multiple power outputs 1500 are connected in parallel to each other and this parallel connection is input into AC/AC converter 2200. In this manner, a wasted heat harvesting system 2000 would output a AC current on the power output 2500. In this case,
it is assumed that the different wasted heat harvesting devices 1000 of the wasted heat harvesting system 2000 are operating with the same frequency. This might be the case if the wasted heat harvesting devices are, for instance, in close proximity to each other.

Additionally, a second wasted heat harvesting system 2000 is realised in the same manner as described above. The two power outputs 2500 of the two wasted heat harvesting systems 2000 are connected to each other in parallel so as to realise a modular wasted heat harvesting system 3000. This may be used for in the case where the two wasted heat harvesting systems 2000 are placed in different regions having different temperatures, which would cause the operation of the plurality of wasted heat harvesting devices in each of the wasted heat harvesting system 2000 to be not in phase with the remaining wasted heat harvesting devices. In this case, if the frequency of operation of the two wasted heat harvesting systems 2000 is not the same, the frequency of the AC current being output at power outputs 2500 can be aligned, via a connection 301 1 between the AC/AC converters 2200. In this manner, the operation of the wasted heat harvesting systems 2000 can be phased, so as to provide a stable output 3500 of modular wasted heat harvesting systems 3000.

In figure 10b each of the multiple power outputs 1500 is connected to an AC/DC converter 2101. In this manner, a wasted heat harvesting system 2000 would output a DC current on the power output 2500. In this case, it is assumed that the different wasted heat harvesting devices 1000 of the wasted heat harvesting system 2000 are not operating with the same frequency.

In figure 11 each of the multiple power outputs 1500 is connected to an AC/AC converter 2201. In this manner, a wasted heat harvesting system 2000 would output an AC current on the power output 2500. In this case, it is assumed that the different wasted heat harvesting devices 1000 of the wasted heat harvesting system 2000 are not operating with the same frequency. In order to guarantee an efficient combination of the multiple AC currents being generated, a phase information is shared among the plurality of AC/AC converters via connection 3031.

Any combination of the wasted heat harvesting device 1000, wasted heat harvesting system 2000, and modular wasted heat harvesting system 3000, can be mounted on the back surface of a CPV cell, or, more generally, a PV cell. For instance, it could be mounted directly on the cell. Alternatively, or in addition, it could be mounted onto a heat-sink.
Still alternatively, or in addition, any combination of the wasted heat harvesting device 1000, wasted heat harvesting system 2000, and modular wasted heat harvesting system 3000, could be realized directly on the back of the PV or CPV cell.

Although the present invention has been described with reference to the cooling of a concentrated photovoltaic cell, the present invention is not limited to this and could be used for cooling of any semiconductor substrate.

Still in addition, the present invention could be realised on a thin film, either semiconductor, metallic or plastic or any other material and could be employed as an active cooling capable of generating current through the wasted heat in an application other than semiconductors, for instance, for powering engine management systems, or any surfaces exposed to the sun, like black painted surface, or motor engines, for instance in cars, etc.

While the above was described with respect to one or more various embodiments, a person skilled in the art will appreciate the features described herein with respect to one or more embodiments can be combined together without departing from the scope of the present invention as defined by the claims.
CLAIMS

1. A wasted heat harvesting device (1000) for harvesting electricity including:
switching means (1200) configured to convey a magnetic field from a first region to
at least a second region when the temperature of the switching means crosses a
predetermined temperature.

2. The wasted heat harvesting device according to claim 1 further including:
magnetic means (1100) configured to generate the magnetic field;
a magnetic flux conveyor (1400) configured to convey a magnetic flux generated
by the switching of the switching means; and
electricity generating means (1300) configured to generate electricity from the
magnetic flux.

3. The wasted heat harvesting device according to claim 1 or 2 wherein
a first side of the magnetic flux conveyor (1400) is connected to one pole of the
magnetic means (1100) and the switching means (1200) is placed between a
second side of the magnetic flux conveyor (1400) and the other pole of the
magnetic means (1100).

4. The wasted heat harvesting device according to any of the previous claims
wherein
the switching means (1200) is a magnetic alloy switch.

5. The wasted heat harvesting device according any of the previous claims wherein
the electricity generating means (1300) includes a coil (1300) wound around the
magnetic flux conveyor (1400).

6. The wasted heat harvesting device according any of the previous claims wherein
the magnetic flux conveyor (1400) is any of iron type, ferromagnetic alloy, such as
Fe or Fe-P or FeSi or Ni/Fe 4.5/55.

7. The wasted heat harvesting device according any of the previous claims wherein
the magnetic means (1100) is any of SmCo₅, Sm₂Co₁₅, Nd₂Fe₁₄B or Ba ferrits.

8. The wasted heat harvesting device according any of the previous claims wherein
the switching means (1100) is made of Gd₅(SiₓGe₇₋ₓ)₄.
9. A wasted heat harvesting system (2000) including:
   at least two wasted heat harvesting devices (1000) according to any of the
   previous claims, each of the at least two wasted heat harvesting devices (1000)
   including a device power output (1500) for outputting electricity generated by the
electricity generating means.

10. The wasted heat harvesting system according to claim 9 wherein
   the at least two device power outputs (1500) are connected in parallel or in series
to each other.

11. The wasted heat harvesting system according to claim 10 wherein
   the connection of the at least two device power outputs (1500) is connected to an
   AC/DC converter (2100) and the output of the AC/DC converter (2100) is
   connected to a power output (2500) of the wasted heat harvesting system.

12. The wasted heat harvesting system according to claim 10 wherein
   the connection of the at least two device power outputs (1500) is connected to an
   AC/AC converter (2200) and the output of the AC/AC converter (2200) is
   connected to a power output (2500) of the wasted heat harvesting system.

13. The wasted heat harvesting system according to claim 9 wherein
   each of the at least two device power outputs (1500) is connected to an AC/DC
   converter (2101).

14. The wasted heat harvesting system according to claim 13 wherein
   the output of the AC/DC converters (2101) are connected in series or in parallel to
   each other and the resulting connection is connected to a power output (2500) of
   the wasted heat harvesting system.

15. The wasted heat harvesting system according to claim 9 wherein
   each of the at least two device power outputs (1500) is connected to an AC/AC
   converter (2201).

16. The wasted heat harvesting system according to claim 15 wherein
   the output of the AC/AC converters (2201) are connected in series or in parallel to
   each other and the resulting connection is connected to a power output (2500) of
   the wasted heat harvesting system.
17. A modular wasted heat harvesting system comprising at least two wasted heat harvesting systems (2000) according to any of claims 9 to 16.

18. A photovoltaic cell including a wasted heat harvesting device (1000) and/or a wasted heat harvesting system (2000) and/or a modular wasted heat harvesting system (3000) according to any of the previous claims.

19. A solar module comprising a plurality of photovoltaic solar cells, in particular concentrated photovoltaic solar cells, further comprising at least one wasted heat harvesting device configured to transform heat into electricity configured and arranged such that at least one of the photovoltaic solar cells is furthermore cooled by the transformation of heat into electricity.

20. A method for realizing a wasted heat harvesting device including the steps of:
   a first deposition step (S1) of depositing a metal layer on a substrate (100);
   a second deposition step (S2) of depositing a magnetic alloy on the substrate;
   a third deposition step (S3) of depositing a ferromagnetic seed material on the substrate;
   a fourth deposition step (S5) of depositing a metal layer on the substrate; and
   a fifth deposition step (S6) of depositing a magnetic material on the substrate.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

*INV.* H01L37/04 H01L31/052 H01L31/058

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>WO 2008/116792 AI (ABB RESEARCH LTD [CH] ; RUSSBERG GUNNAR [SE] ; DAHLGREN MI KAEL [SE] ; THO) 2 October 2008 (2008-10-02) page 2, line 18 - page 3, line 2 page 5, line 15 - page 9, line 8; figures 1, 2</td>
<td>1-3,5-7. 9-17</td>
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</table>

* Further documents are listed in the continuation of Box C.

**X** See patent family annex.

* Special categories of cited documents:

  - "X" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent but published on or after the international filing date
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  - "O" document referring to an oral disclosure, use, exhibition or other means
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**Date of the actual completion of the international search**

18 September 2012

**Date of mailing of the international search report**

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Steiner, Markus
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