EXTRACTION OF ENERGY FROM HEAT SOURCES BY THERMOELECTRIC EFFECT USING STEP-UP TRANSFORMERS

by

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Dedication :

"To my loving parents and to my beloved wife."

Declaration:

I hereby declare this submission is my own work and that, to the best of my knowledge and behalf, it contains no material previously published or written by another person no materials, which to substantial extent, has been accepted for the award of any other academic qualification of a university of any other institute of higher learning except where acknowledgement is made in the text.

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Abstract:

While a transformer in operation, throughout its entire life cycle dissipates energy, in forms of heat, vibration, & radiation which in fact is not so far conserved or collected. Studies show this waste heat of transformers out of above waste energies, is more prominent to extract than others.

The aim of this study is to search for a method to extract this waste heat energy, from step up (high capacity) transformers, using thermoelectric principles. The thermoelectric couple was used as the basic element of extraction of heat and converts it to electrical energy and stored it for further use. Use of thermopile, thermo module, nano film conductors, quantum dot applications were also considered in enhancing the extraction amount & extraction efficiency.

Through its theatrical modelling using single couple of BiTe – TE, it is found that about 2% efficiency could be reached. Through modular design, nano films there exists a max limit of 7% with the current technology.

With the current experiments and studies of quantum dot / thin films technology, the improvement of quality of material and methods of construction of module, no sooner may reach to a better ground. Although the extracted energy is very minimal it is very free to extract without any operational cost.

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CONTENTS

List of Figures:

Nomenclature / Notations

A	Sample cross sectional area
A	Cross-sectional area; total area; resonant scattering intensity
A	Coefficient of T^2 term of electrical resistivity of a kondo lattice system
a	Coefficient of - T^2 term of electrical resistivity of a kondo impurity system
$\dot{A}$	Angstrom unit
$\dot{A}$	Dimensionless seebeck tensor
A^1	Material parameter
$A_n A_p$	Cross –sectional area of the n – and p-legs, respectively
C_v	Specific heat at constant volume
C_v	Specific heat
D	Carrier's diffusion constant
D	Bandwidth
D	Sample density
d	Thermal diffusivity (d) and the specific heat (C_v) of the sample
d/dt	= ‖/‖t + vgrad full substantial time derivative
dS	Entropy change
e	Dimensionless electric field
I	Electrical current
I	Electrical current
I	Current in multistage generation
I	Strength of the intra – site exchange interaction
I_B	Bragg intensity

I_i	Thermodynamic flow
I_o	Ioffe criterion
$I_{ep}I_{pe}I_{pp}$	Electron – phnon, phonon – electron, and phonon – phonon collision intergrals
I_B	Bragg intensity
I_b	Phonon mean –free path
I_r	Current ratio
j	Exchange interaction
J	Electrical current density
J	electrical current density
ΔT	Temperature gradient
T	absolute temperature in Kelvin
T	Absolute temperature
t	Modulus of temperature gradient
T_O	temperature of the sample
T_o	Characteristic temperature ($\propto T_k$) of model
T_o	Magnetic ordering temperature
e	Electrical charge of an electron
E	electric field
E	Energy of a charge carries
E	Energy of a charge carries electric field
E_A	Activation Energy
E_b	Potential Barrier Height
E_f	Electronic energy of the Final state of a phonon assisted hop
E_i	Electronic energy of the initial state of a phonon assisted hop

E_f	Fermi Energy
E_g	Energy band gap
v	velocity of charged particle
v	mass transport rate
p, u	Drift velocities of electrons and phonons
$\propto$	Thermoelectric Power
$\propto$	Seebeck coefficient or thermo power
$\propto$	Seebeck coefficient or thermoelectric expansion coefficient, coefficient of T^2 term of electrical resistivity of a kondo impurity system
$\propto$	Seeback coefficient fusion with phonons
ϵ	Charge carrier energy, energy
ϵ	Emissivity $(0 \leq \epsilon \leq 1)$
ϵ_b	Potential barrier height
ϵ_1	Deformation potential
η	Reduced energy of charge carried, generation efficiency; reduced Fermi energy, reduced barrier height

AMBIENT TEMPERATURE: Temperature of the air or environment surrounding a thermoelectric cooling system; sometimes called room temperature.

ASPECT RATIO: The numerical ratio of the length (height) to cross-sectional area of a thermoelectric element. An element's L/A aspect ratio are inversely proportional to its optimum current.

BISMUTH-ANTIMONY: A thermoelectric semiconductor material that exhibits optimum performance characteristics at relatively low temperatures.

BISMUTH TELLURIDE: A thermoelectric semiconductor material that exhibits optimum performance in a "room temperature" range. An alloy of bismuth telluride most often is used for thermoelectric cooling applications.

BTU: British Thermal Unit: The amount of thermal energy required to raise one pound of water by one degree Celsius at a standard temperature of 15°C.

CALORIMETER: A scientific apparatus used to measure the evolution or absorption of heat. Thermoelectric modules, when used in a calorimeter, may exhibit much higher sensitivity than conventional thermopiles.

CASCADE MODULE (MULTI-STAGE MODULE): A thermoelectric module configuration whereby one module is stacked on top of another so as to be thermally in series. This arrangement makes it possible to reach lower temperatures than can be achieved with a single-stage module.

CFM: Cubic Feet per Minute: The volgenerallyu metric flow rate of a gas, typically air, expressed in the English system of units. For thermoelectric applications, this refers to the amount of air passing through the fins of a forced convection heat sink.

CLOSED-LOOP TEMPERATURE CONTROLLER: A temperature controlling device having some type of temperature sensor (thermocouple, thermistor, RTD, etc.) that will transmit or "feed back" temperature data to the controller. Based on the returned information, the controller will automatically adjust its output to maintain the desired temperature.

COEFFICIENT OF PERFORMANCE (COP): A measure of the efficiency of a thermoelectric module, device or system. Mathematically, COP is the total heat transferred through the thermoelectric device divided by the electric input power. COP sometimes is stated as COPR (Coefficient of Performance as a Refrigerator) or as COPH (Coefficient of Performance as a Heater).

COLD SIDE OF A THERMOELECTRIC MODULE: The side of a module that normally is placed in contact with the object being cooled. When the positive and negative module leads are connected to the respective positive and negative terminals of a DC power source, heat will be absorbed by the module's cold side. Typically, the leads of a TE module are attached to the hot side.

CONDUCTION (THERMAL): The transfer of heat within a material caused by a temperature difference through the material. The actual material may be either a solid, liquid or gas (or a combination) where heat will flow by means of direct contact from a high temperature region to a lower temperature region.

CONVECTION (THERMAL): The transfer of heat by means of air (gas) movement over a surface. Convection actually is a combined heat transfer process that involves elements of conduction, mixing action, and energy storage.

COUPLE: A pair of thermoelectric elements consisting of one N-type and one P-type connected electrically in series and thermally in parallel. Because the input voltage to a single couple is quite low, a number of couples normally are joined together to form a "module."

DEGREES KELVIN: Absolute temperature scale where absolute zero (0K) represents the point where all molecular kinetic energy of a mass is zero. When calculating the temperature dependent properties of semiconductor materials, temperature values must be expressed in degrees Kelvin. On the Celsius scale, 0°C equals 273.15K; in respect to quantity, one Kelvin degree equals one Celsius degree. Note that the (°) symbol normally is not used when denoting degrees Kelvin.

DELTA-T: The temperature difference between the cold and hot sides of a thermoelectric module. Delta T may also be expressed as "DT" or "DT."

DENSITY: The mass of a material per unit volume; often expressed as pounds per cubic foot or grams per cubic centimetre.

DICE: A general term for blocks of the thermoelectric semiconductor material or "elements" prepared for use in a thermoelectric module.

DIE: An individual block of thermoelectric semiconductor material used in the fabrication of a module. A die may also be called an "element," "leg," or "thermo element."

EFFICIENCY: For thermoelectric coolers, mathematical efficiency is the heat pumped by a module divided by the electrical input power; for thermoelectric generators, efficiency is the electrical output power from the module divided by the heat input. To convert to percent, multiply by 100. See definition of Coefficient of Performance.

ELEMENT: An individual block of thermoelectric semiconductor material. See definition of DIE.

EMISSIVITY: The ratio of the energy emitted by a given object to the energy emitted by a black-body at the same temperature. Emissivity is dependent upon an object's material and surface finish.

THERMOELECTRIC GENERATOR: A device that directly converts energy into electrical energy based on the Seebeck Effect. Bismuth telluride-based thermoelectric generators have very low efficiencies (generally not exceeding two or three percent) but may provide useful electrical power in certain applications.

THERMOELECTRIC HEAT PUMP: Another name for a thermoelectric module or thermoelectric cooler. The term Heat Pump has been used by some specifically to denote the use of a thermoelectric module in the heating mode, but this usage is uncommon.

THERMOELEMENT: Another name for a thermoelectric element or die.

THERMOPILE: When a thermoelectric module is used in a calorimeter application it is frequently called a thermopile. Some have used the word thermopile as a synonym for thermoelectric module regardless of application, but such use is unusual.

THOMSON EFFECT: The phenomena whereby a reversible evolution or absorption of heat occurs at opposite ends of a conductor having a thermal gradient when an electrical current passes through the conductor.