JNCASR scientist to develop new materials for converting waste heat to electrical energy

Kanishka Biswas, scientist from Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru will use the Swarnajayanti fellowship he has received from the Department of Science and Technology to design and synthesize new materials that can recover energy wasted in the form of heat and covert that into electricity.

Such materials which have low thermal conductivity and high thermoelectric materials performance will pave the way for devices which can be used in waste heat recovery in automobiles, space missions, thermal, chemical, steel, nuclear power plants and oil refiners and can also be coupled with new renewable technologies such as solar-thermoelectric and heat recovery in Li-batteries.

Research shows that nearly 65% of all utilized energy gets irreversibly dissipated as waste heat. As the world probes for sustainable ways to meet its every growing energy demand, Dr Biswas's research can play a significant role in saving this huge loss of waste heat.

Dr Biswas will be working to find Lead (Pb) free inorganic solids, which will possess ultra-low thermal conductivity and high thermoelectric performance. Such materials are expected to save wastage of energy in the form of heat, be nearly maintenance free and environmental friendly and also can be used in waste heat to electricity generation.

Efficient thermoelectric materials are required to save wastage of heat. To what extent a thermoelectric material can convert the waste heat to useful electrical energy can be quantified by a metric called the figure of merit. Figure of merit depends on properties of the material like electrical conductivity, Seebeck coefficient and thermal conductivity as well as temperature.

The challenge in developing efficient thermo electric materials is to fit three seemingly different material properties into one single inorganic solid: high electrical conductivity of metals, high Seebeck coefficient (the magnitude of electrical voltage generated from a given temperature gradient) of semiconductors and low thermal conductivity of glasses. Conflicting interdependency among the Seebeck coefficient, electrical conductivity and electrical thermal conductivity leave the only choice of tuning of the lattice thermal conductivity independently to enhance the figure of merit.

Thus to develop an efficient thermoelectric material Dr Biswas has to tweak its properties effectively. Lattice vibration technically called phonons carries significant amount of heat in a material that contributes directly to the lattice thermal conductivity. While most traditional approaches (such as phonon scattering by extrinsic solid solution point defects and nano/meso-structuring) have proven to effectively reduce lattice thermal conductivity, these approaches are detrimental to the electrical mobility. Difficulty in juggling thermal conductivity and thermoelectric performance has limited the figure of merit is limited to 2 for decades. Thus, crystalline solids with *intrinsically* low lattice thermal conductivity are practically desirable as they offer phonon (heat) blocking but electron/hole transmitting medium.

In this Swarnjayanti Fellowship, Dr. Biswas has proposed to design new inorganic solids that will possess intrinsically ultra-low lattice thermal conductivity and high thermoelectric performance by only tailoring the intrinsic parameter such as chemical bonding, lone pair, anharmonicity, rattling dynamics, selective soft vibrations and liquid like cation flow. Introducing these concepts will reduce the thermal conductivity significantly but the carrier mobility will be retained, which is significantly novel and posses new fundamental approach that involves rich chemistry.

Dr. Biswas proposes to achieve high figure of merit of in the range 2.5 to 3 with experimental device efficiency around 15% by employing several new concepts and discovery of new thermoelectric materials with ultra-low lattice thermal conductivity which is desired for mass-market power generation applications.

Thermoelectric materials designed by tweaking such properties can directly and reversibly convert waste heat into electricity and will play a significant role in the future energy management.

The research can lead to a transformative sustainable energy source. Besides, thermoelectric energy conversion does not involve any moving parts and any toxic gas emission; thereby the materials he plans with intrinsically low thermal conductive metal chalcogenides for thermoelectric energy conversion will be nearly maintenance free and environmental friendly renewable energy conversion avenue, which have high significance and novelty.