16th STS-AIChE
Southwest Process Technology Conference

Synthesis of novel non centrosymmetric material for waste heat energy harvesting

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Sept 22-23, 2025, University of Houston

16th STS-AIChE Southwest Process Technology Conference

- PhD (Chemical Engineering) University of Colorado Boulder
- M. Tech (Chemical Engineering) IIT Kharagpur
- B. Tech (Chemical Engineering) West Bengal University of Technology
- Postdoctoral Fellow, University of Arkansas
- Postdoctoral Researcher, Prairie View A&M University (current)

Research areas:

Design, synthesis, characterizations of colloidal nanoparticles, quantum dots, polymeric membrane synthesis, nanocellulose, solid state synthesis. Application areas include catalysis, energy harvesting , anti bacterial and other biomedical applications

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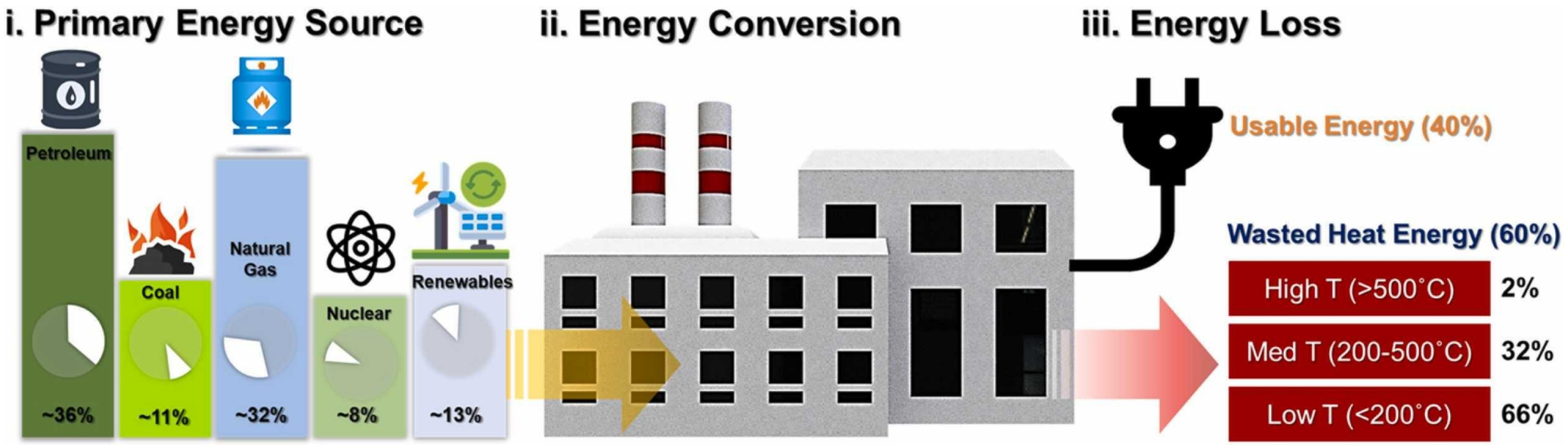
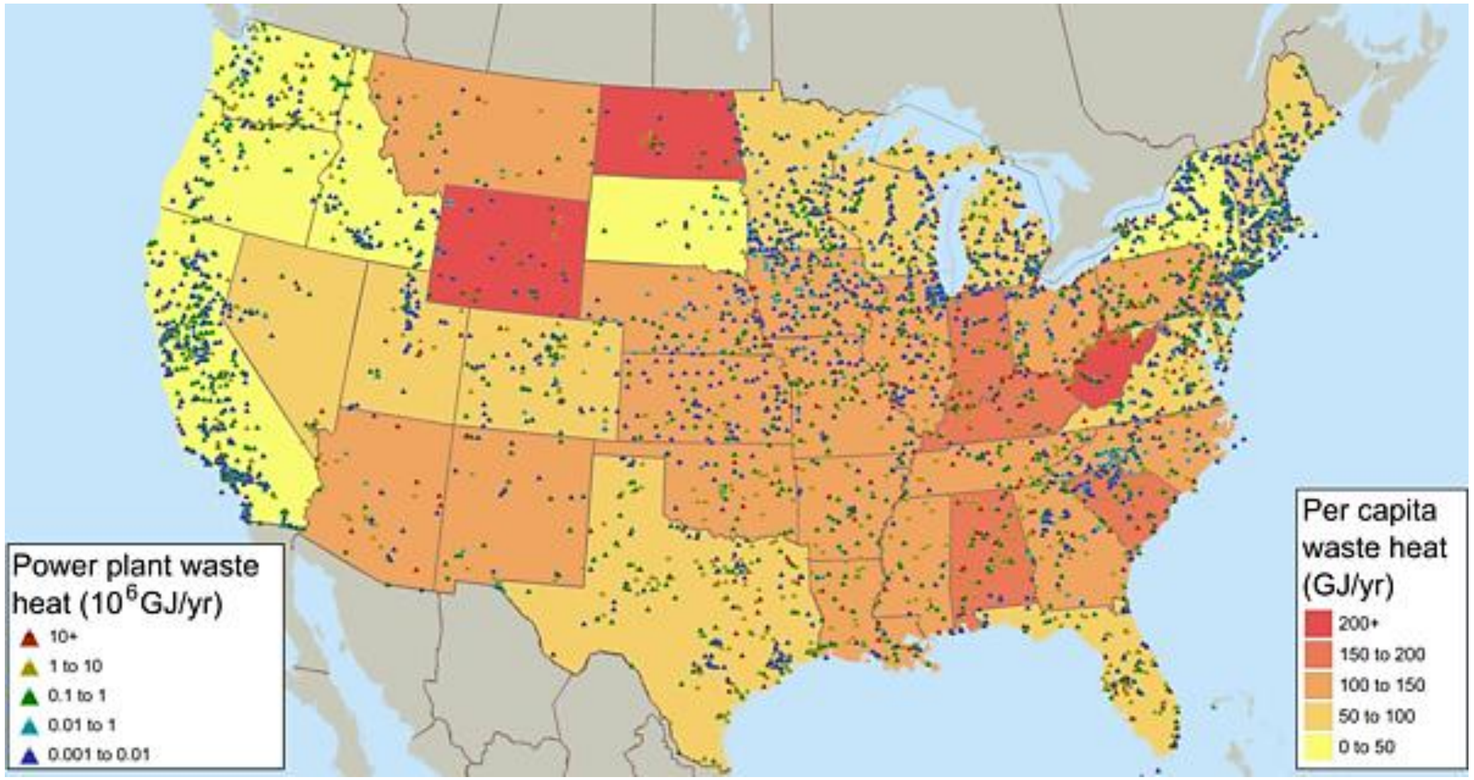
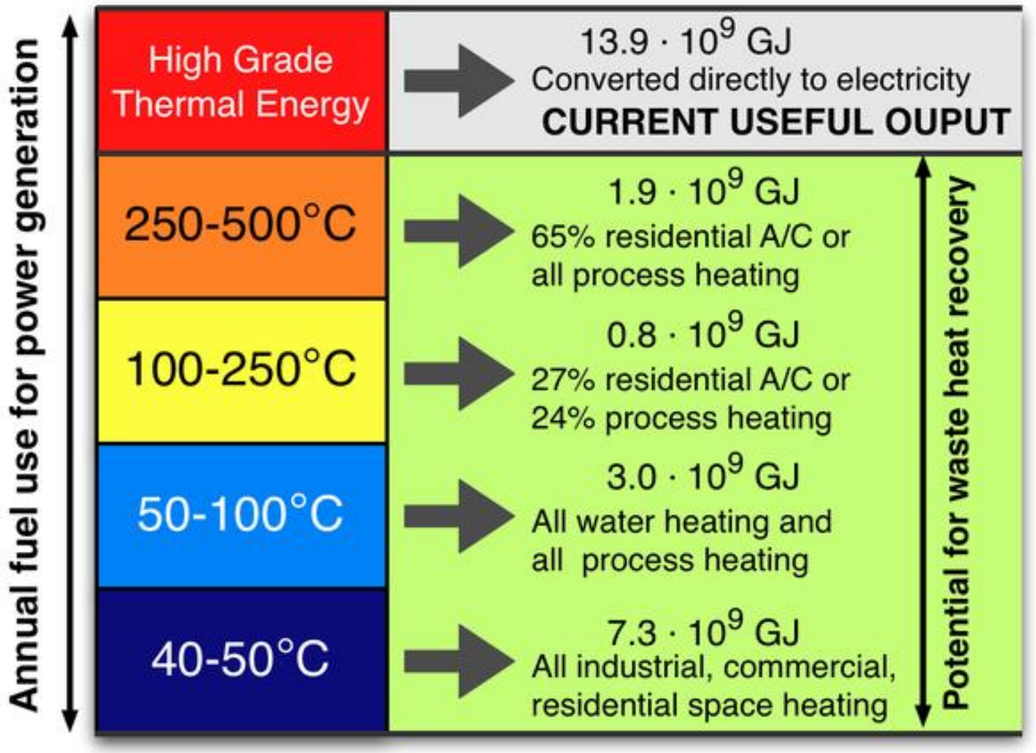


Nano Energy 114 (2023) 108596

43 * 10^9 GJ/year of waste heat energy

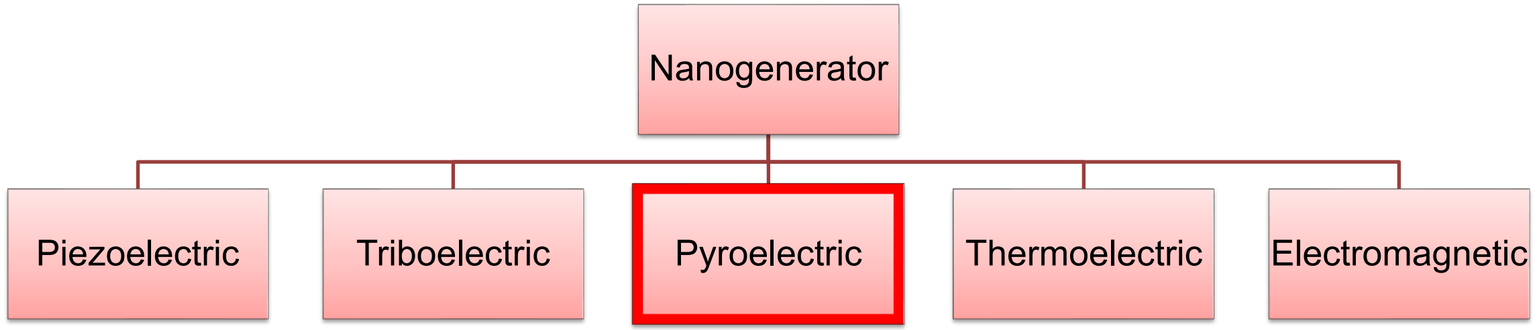


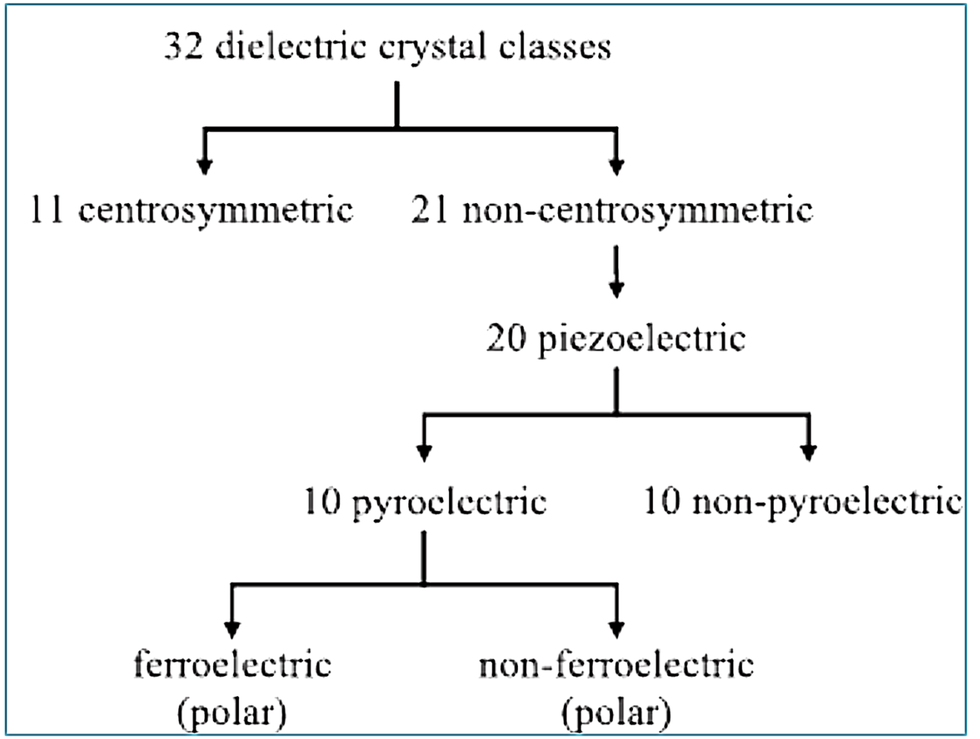


https://sites.psu.edu/mtfe/us-waste-heat-resources/

Nanogenerator

- It is a technology that uses nanomaterials for generating electricity
- This technology converts mechanical ,thermal energy or other external stimuli as produced by small scale physical change into electricity
- Energy produced by this nanogenerator will be few nanowatts to several milliwatts
- Based on mechanism they can be classified into 5 categories





Pyroelectric nanogenerator

- Converts the external thermal energy (temporal temperature change) into electrical energy by using nanostructured pyroelectric materials.

$I_p = Ap_c dT/dt$ (in linear range)

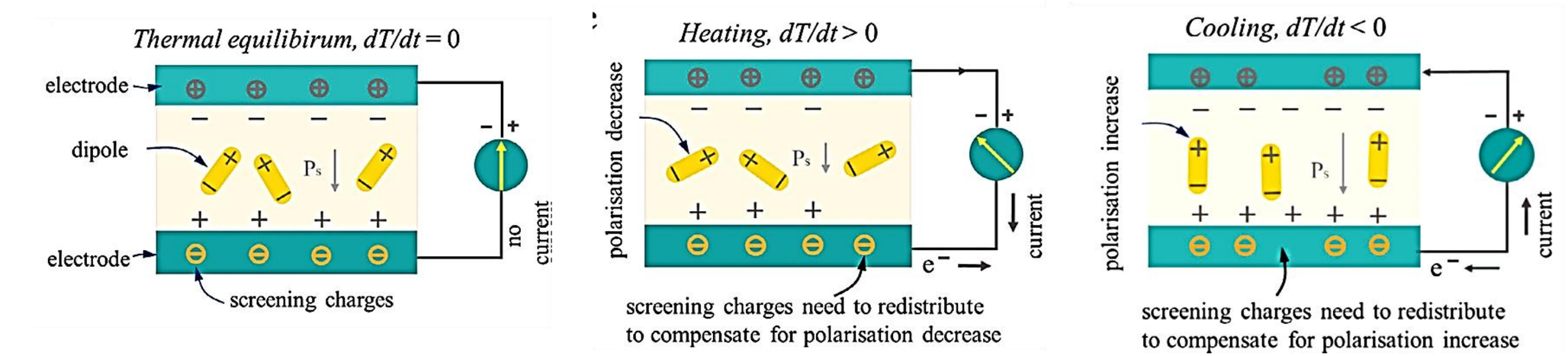
- The material must have spontaneous polarization (dipole moment per unit volume in absence of electric field), which occurs due to non symmetric crystal structure with unique polar axis

$F = p_C^2/(\rho c_p)^2 \epsilon_0 \epsilon_r$

- When heated, the crystal structure changes, and a reduction in spontaneous polarization takes place and they exhibit potential difference at both ends of materials

$k^2 = p_C^2 T_H / \rho c_p \epsilon_0 \epsilon_r$ **(dimensionless)**

- When cooled the reverse effect takes place which again results in potential difference



Adv. Funct. Mater. 2024, 34, 2312245

Some current focused materials

- Perovskite materials e.g., Lithium Tantalate ($LiTaO_3$) at nanoscale
- Doping of the parent material for enhanced properties
- Nanocomposites (e.g. carbon based)
- Making plasmonic-pyroelectric hybrids

Synthesis

Hydrothermal synthesis

(product is achievable in dispersed colloidal state and in dried powder from)

Solid State Synthesis

(polycrystalline powder form. The sizes are considerably larger than in hydrothermal synthesis)

Hydrothermal Synthesis

Precursors are dissolved by stirring

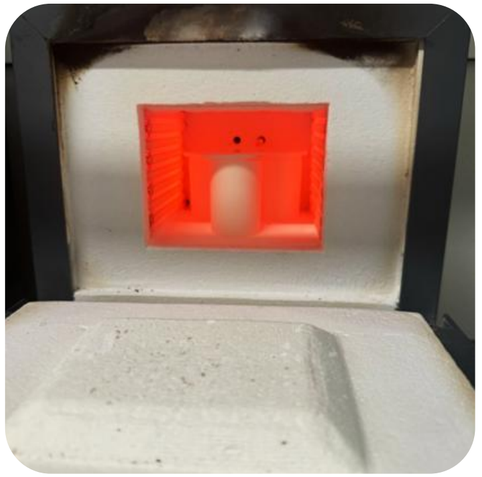
The reaction mixture transferred to the Teflon chamber of autoclave

The autoclave is put inside oven for desired temperature and time

The final product, which is washed by centrifugation and can be redispersed or stored as powder

Solid State Synthesis

Thorough mixing of the precursor using mortar pestle

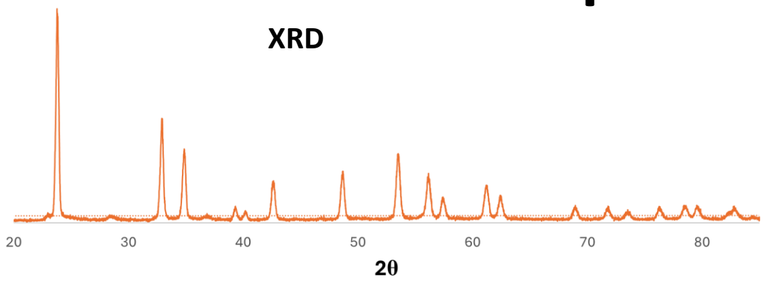


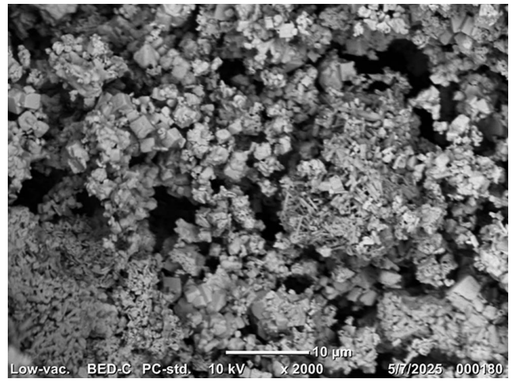
Putting the mixture in alumina crucible inside furnace set at desired temperature , reaction time and heating rate

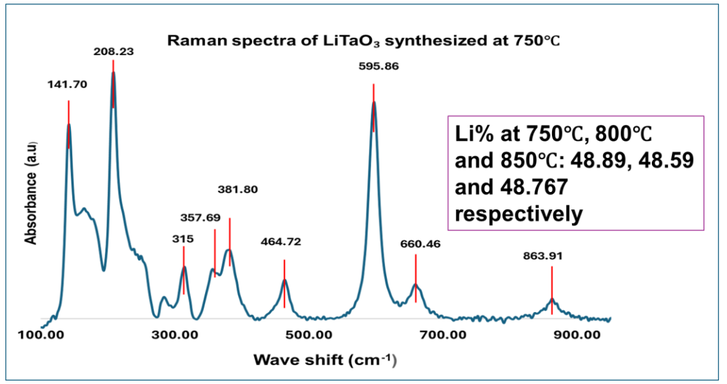
Allow the product to cool down and take out and grind thoroughly

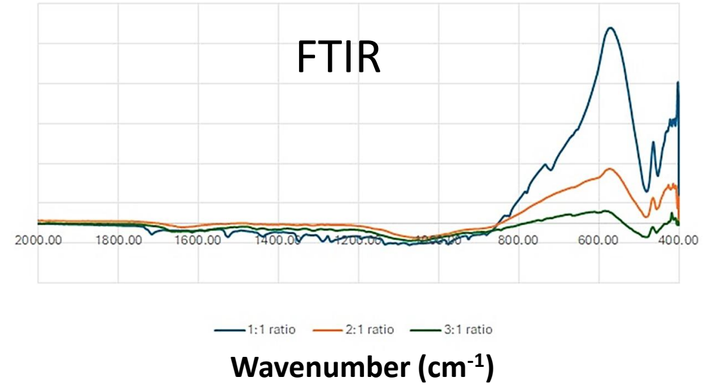
Characterization techniques

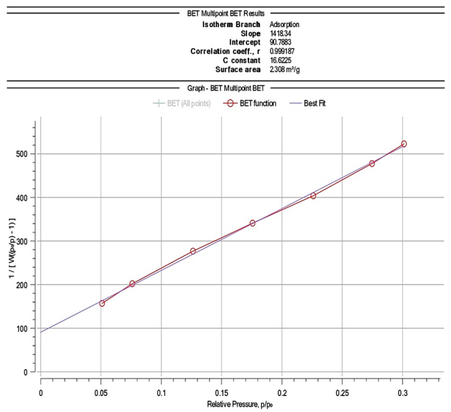
- X Ray Diffraction
- UV-Vis Spectroscopy
- Fourier Transform Infrared Spectroscopy
- Raman Spectroscopy
- Scanning Electron Microscopy
- Transmission Electron Microscopy
- BET











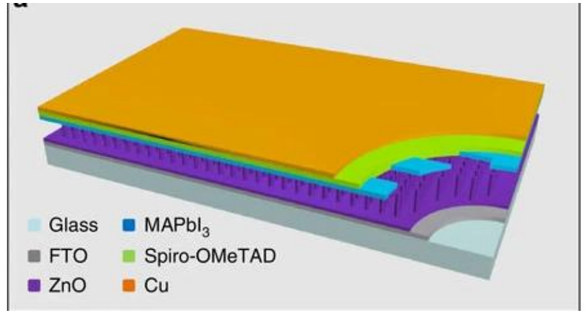
Near Future Plans

- To optimize the reaction parameters to maximize the yield and scaling up the production
- To customize the morphology/composition of the products depending on applications
- To design the materials to maximize pyroelectric conversion efficiency
- To explore new prospective application areas for pyroelectric material that will be economically feasible and profitable
- To expand the synthesis procedures (preferably in colloidal state)
- Focus on green synthesis, minimizing use of toxic precursors/chemicals

Acknowledgements

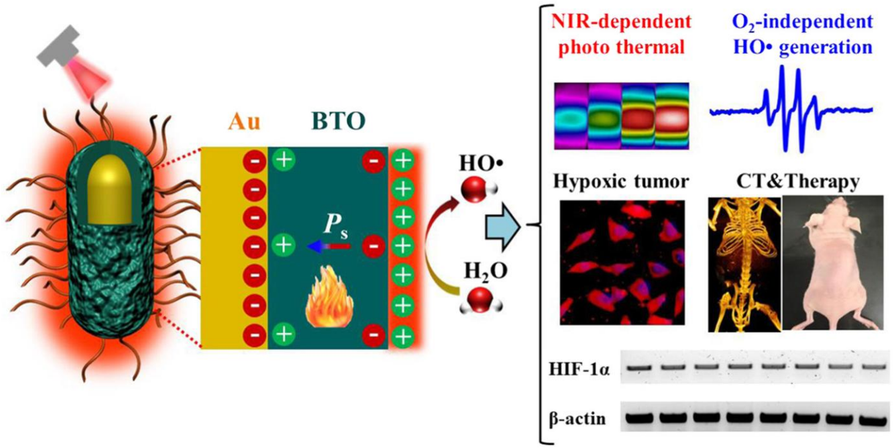
U S Department of Energy under award DE SC 0024534 for Basic Energy Sciences Reaching a New Energy Sciences Workforce (BES RENEW).

Application prospects of pyroelectric nanomaterials synthesized in colloidal state



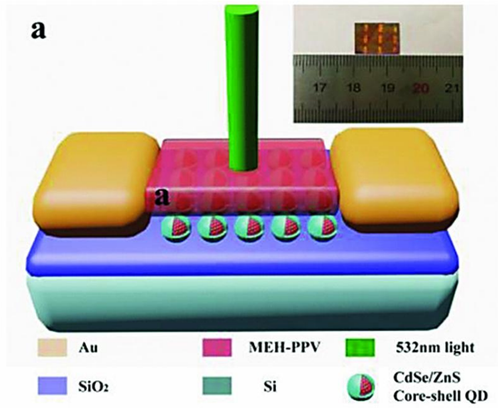
ultrafast ultraviolet nano sensing

Nat Commun 6, 8401 (2015)



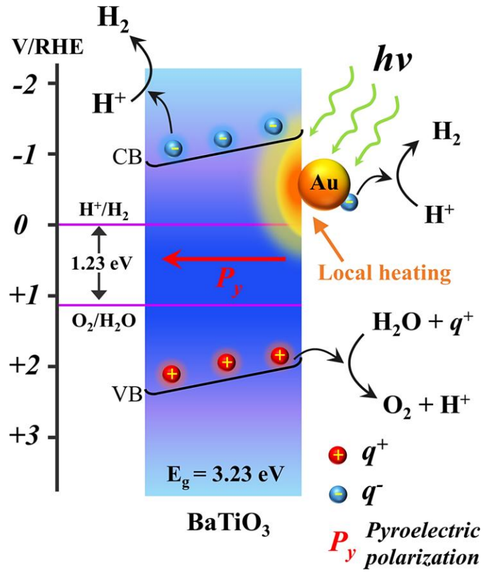
Temperature-mediated reactive oxygen species for hypoxic tumor therapy

Nano Today 38 (2021) 101110



Photodetectors Based On Photoinduced-Pyroelectric Effect

Adv. Optical Mater. 2018, 6, 1800639



pyro-catalytic hydrogen production enabled by plasmonic local heating

Nature Communications | (2022) 13:6144

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