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3D printing of 2D (two dimensional materials) for robust electronics

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Name of Project: Printing of 2D (Two Dimensional) Materials for Robust Electronics

Sanction Letter No & Date:FA2386-19-1-4039, Proposal-19IOA039,Dt.02-05-2019

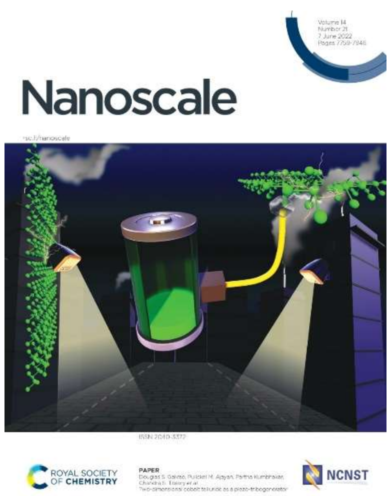
Duration of the Project:3years

Principal Investigator of the above Project: Prof. Chandra Sekhar Tiwary,

Department of Metallurgical and Materials Engineering, IIT Kharagpur

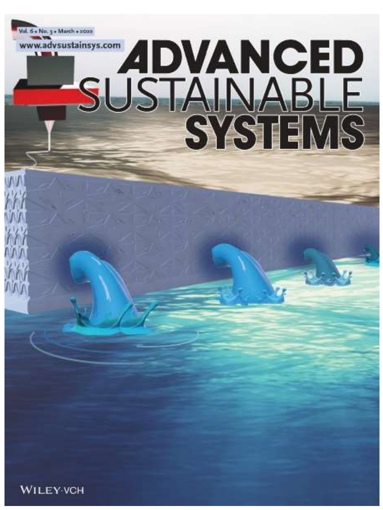
Highlight of the project

Followings are the results from project which were highlighted as cover-page in different journals



Atomically thin Cobalt telluride was used in electronics gazettes, to collect energy from waste heat. Waste heat and small mechanical pressures are used by buildings covered in cobalt telluride to create energy and light the city. We describe how 2D cobalt telluride's combination piezoelectric and triboelectric capabilities can be used to produce energy from waste heat in this article ($CoTe_2$). A five-fold increase in energy conversion efficiency was achieved by the piezo-triboelectric nanogenerator, which generated an open-circuit voltage of ~5V when subjected to a 1 N force. With a maximum voltage of about 10 V, a quick response time, and high responsiveness, the 2D piezo-tribogenerator has exceptional qualities.

Nanoscale, 2022,14, 7788-7797, https://doi.org/10.1039/D2NR00132B

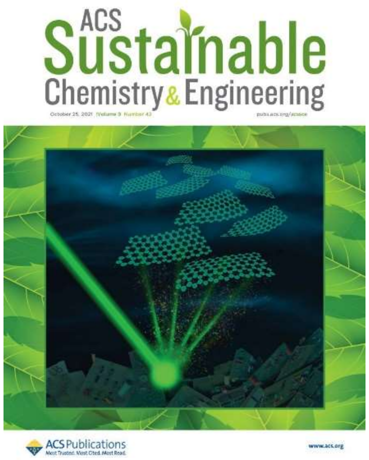


Compared to conventional treatment methods, 3D printed materials with configurable surface area, thickness, and roughness improve the removal effectiveness of heavy metals, oil, and organic matter from water.

Advanced Sustainable Systems, 2022, https://doi.org/10.1002/adsu.202100282

In this study, we gather and organise data on a broad range of 2D tellurides. The review seeks to give a general understanding of the materials' synthesis techniques, characteristics, and uses. We list numerous binary tellurides and talk about the fascinating characteristics that arise when a third element is added. Our investigation includes the optical, electrical, photo-electrochemical, magnetic, and quantum aspects of these 2D layered materials. Finally, we discuss future directions for this study as well as issues that must be resolved in order to fully realise the potential of 2D tellurides in a wide range of applications.

Materials Today, 2021, 402-426, https://doi.org/10.1016/j.mattod.2021.08.008

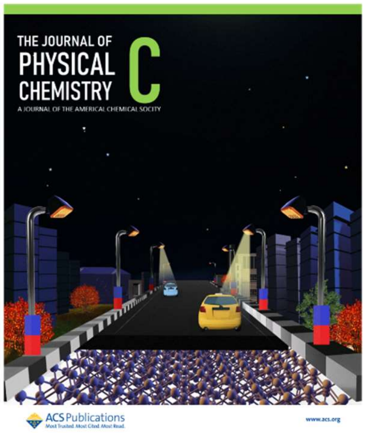


We present the pulsed laser ablation of electronic trash in deionized water for the manufacture of high-quality functional graphene from one of the main parts of e-waste, the polymeric component. Systematic modelling identifies the ideal laser parameters for the maximum yield of ~40% and good-quality graphene. For highly conductive electronics contacts that will be useful for upcoming robust electronics applications, high-quality synthetic graphene has also been used.

ACS Sustainable Chem. Eng. 2021, 14090–14100, doi.org/10.1021/acssuschemeng.1c03817

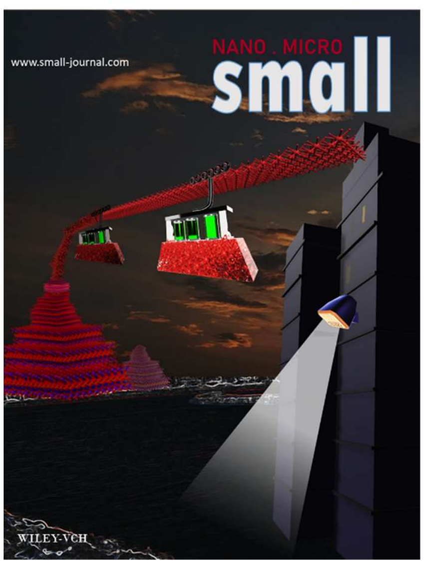
Topologically engineered 3D printed architectures with superior mechanical strength. Gyroids, Menger cubes, and origami/kirigami-based constructions are a few examples of quite unusual structures that have developed from advanced geometrical concepts. In other cases, innovation has resulted from emulating nature in bio-inspired materials (e.g. honeycomb structures, nacre, fish scales etc.). Using computer-aided design models, additive manufacturing has made it possible to easily fabricate complicated geometrical and bio-inspired architectures. These structures' mechanical qualities, including as strength, stiffness, and toughness, have been improved through the use of simulations and tests. In this paper, we give an overview of topologically designed materials with ideal mechanical properties that are also easily printable via additive manufacturing.

Materials Today, 2021, 72-94, https://doi.org/10.1016/j.mattod.2021.03.014



Energy Harvesting from Atomically Thin Co_2Te_3. The liquid-phase exfoliation technique is used to successfully exfoliate 2D Co_2Te_3 from the bulk crystal Co_2Te_3 as it was manufactured. It is discovered that the exfoliated Co_2Te_3 is a weakly ferromagnetic semiconductor material. With an output voltage of about 3.6 V, 2D Co_2Te_3 is also employed as a nanogenerator employing the flexoelectric effect. The ability to harvest energy was also studied at room temperature under various magnetic fields. Our density functional theory calculations confirm the magneto-crystalline anisotropy of this 2D monolayer system, and provide a microscopic insight into origin of the electric response under a magnetic field. Such electric response in atomically-thin material is particularly desirable for applications in nanoscale devices.

J. Phys. Chem. C 2022, https://doi.org/10.1021/acs.jpcc.2c02102



In this study, liquid-phase exfoliation from the naturally common mineral biotite is used to demonstrate the synthesis and characterisation of the ultrathin metal oxide known as biotene. The flexoelectric property of atomically thin biotene is utilised for energy harvesting by repeated bending. Surface charges cause a rise in the effective flexoelectric response, leading to voltage increases of up to 8 V and a high mechano-sensitivity of 0.79 V N^{-1} for normal force. Simulations using the density functional theory (DFT) serve to confirm this flexoelectric response. The magnetic field and thermal heating respond more strongly to the atomically thin biotene. A variety of potential two-dimensional (2D) oxide materials for energy production and energy harvesting applications are predicted by the synthesis of the metal-oxide two-dimensional (2D) biotene.

Small 2022, 2201667, https://doi.org/10.1002/smll.202201667

The key objectives of the projects :

I. Synthesis of high-quality large scale 2D materials
II. Preparation of 2D materials-based gel/liquid for printing
III. Engineering 3D printer for printing of 2D materials
IV. Printing high surface area, strong, robust architecture of 2D materials using 3D printer
V. Post processing of the interconnected architecture
VI. Building understanding and know-how using materials simulation

Deliverables

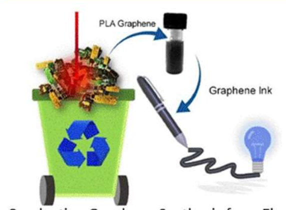
The project deliverables are divided into three sections. A. Synthesis of large scale 2D materials and their ink; B. Engineering 3D printer and optimize topology to make architectures with high strength, low density and high surface area; C. Decorating the 3D printed structures with 2D materials D. Printing using the 2D materials

We have optimized the process for synthesis of high quality and large scale 2D materials, nanoparticles. Simulation based optimum concentration of mixture for printing different components has been done in the project. The 3D printer is developed/modified for 3D printing of 2D materials.

We have produce well characterize 2D with metal and oxide nanoparticle. The liquid gel of chemically interconnected hybrid with required viscosity for 3D printing is produce. 3D printing of the 3D architecture using 2D materials gel. Mechanical and physical testing of the architecture. Testing of the 3D architecture for pollutant adsorption.

The results of the project are divided in subsequent sections and publication is cited as well

Preparation of ink for 3D printing template



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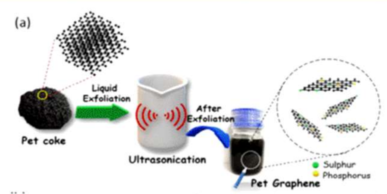

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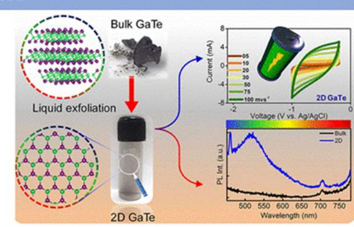

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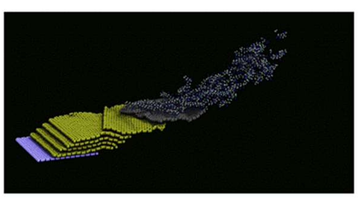

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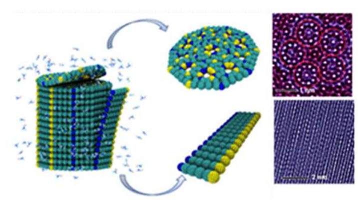

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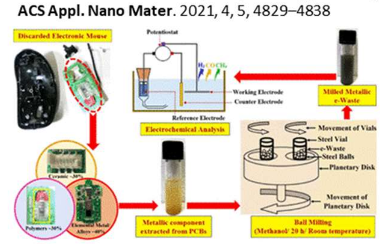

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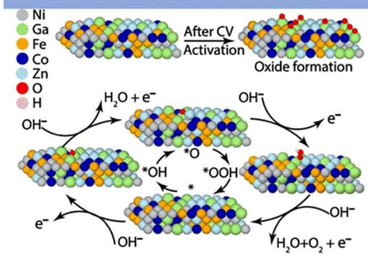

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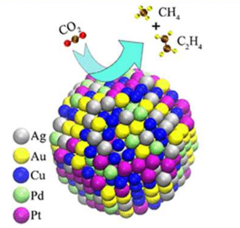

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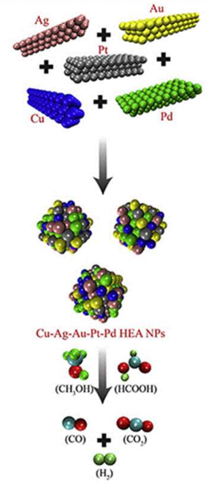

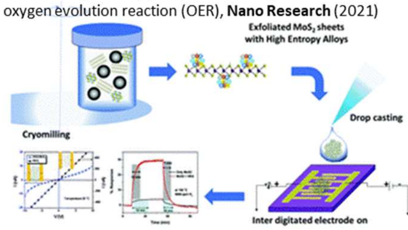

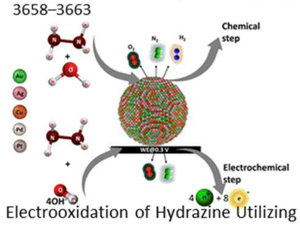

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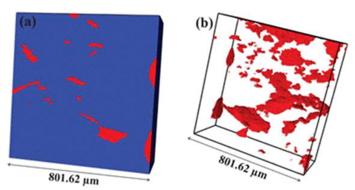

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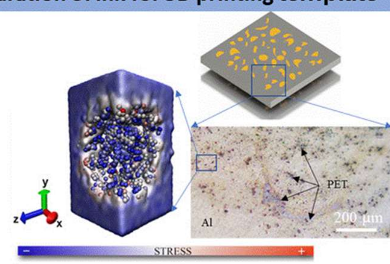

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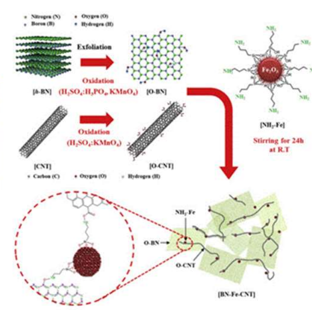

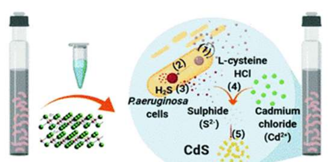

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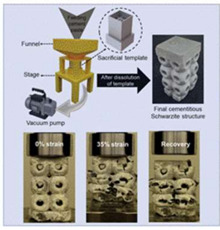

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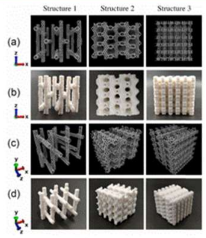

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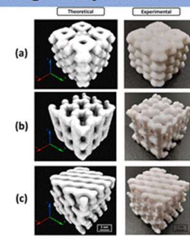

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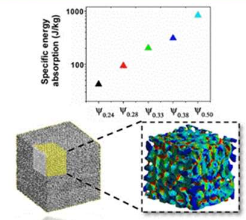

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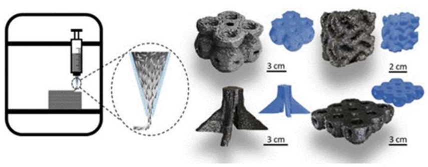

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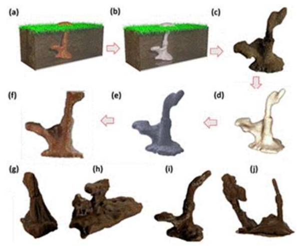

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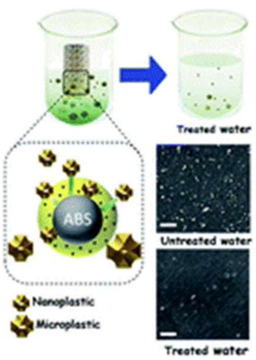

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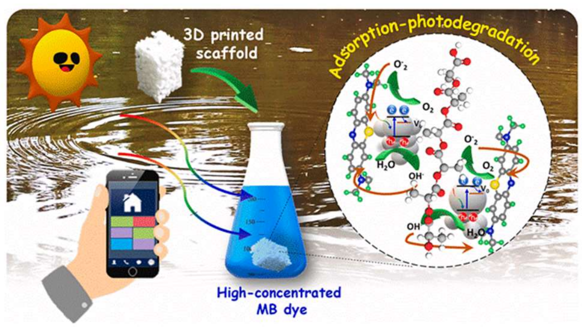

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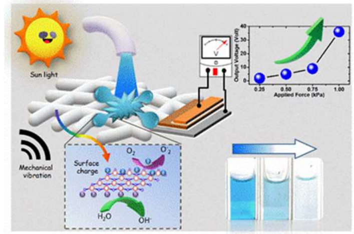

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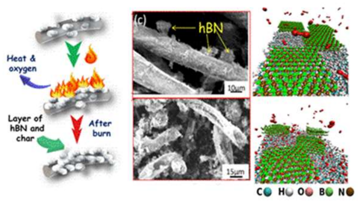

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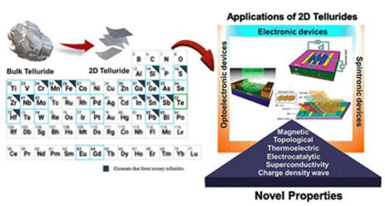

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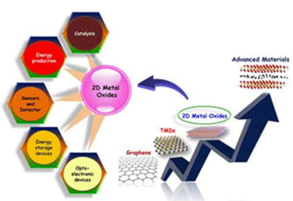

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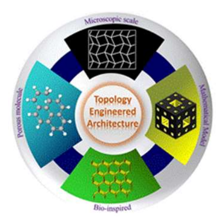

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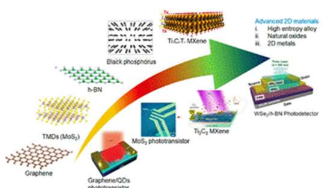

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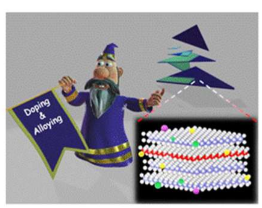

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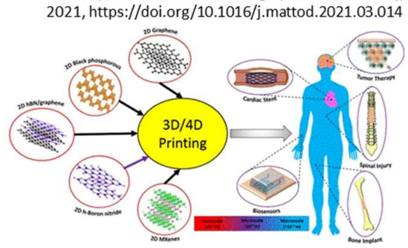

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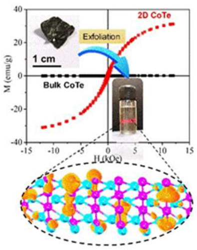

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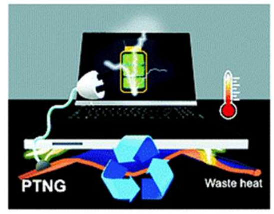

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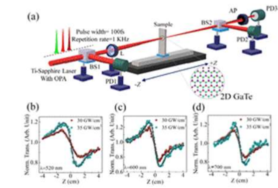

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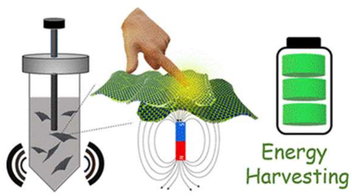

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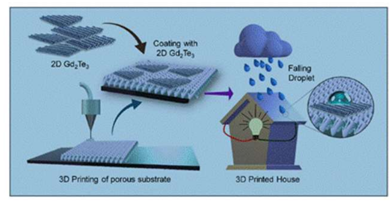

Publications:

List of publications

[1] S.D. Negedu, A. Karstev, M. Palit, P. Pandey, F.E. Olu, A.K. Roy, G.P. Das, P.M. Ajayan, P. Kumbhakar, C.S. Tiwary, Energy Harvesting from Atomically Thin Co 2 Te 3, J. Phys. Chem. C. (2022). https://doi.org/10.1021/acs.jpcc.2c02102.

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[9] S.D. Negedu, R. Tromer, C.C. Gowda, C.F. Woellner, F.E. Olu, A.K. Roy, P. Pandey, D.S. Galvao, P.M. Ajayan, P. Kumbhakar, C.S. Tiwary, Two-dimensional cobalt telluride as a piezo-tribogenerator, Nanoscale. 14 (2022) 7788–7797. https://doi.org/10.1039/D2NR00132B.

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Lab facilities developed using project

Student trained during the project

Meeting organized through the project

Several online meetings were organized with AFRL team.

Two Meetings at IITKGP were organized