Hydroprocessing of plastic/biomass waste in the presence of hydrogen is an efficient way of producing fuel-grade hydrocarbons. However, using hydrogen gas requires extreme reaction pressure and temperature conditions, which in turn not only increases the process cost drastically but also poses safety ambiguities. Hence, the sustainable strategy is to use safe liquid hydrogen carriers, such as methanol, ethanol, or butanol by means of in-situ hydrogen generation and utilization for plastic/biomass waste valorization. Concurrently, facile workup procedures should be developed for separating the byproducts generated from the hydrogen carriers to make the process practically feasible.

SP HeteroCat Lab:

The "SP HeteroCat Lab" at the Department of Chemistry, IITH, aims to design and develop sustainable heterogeneous catalytic methods for plastic/biomass waste conversion and diverse nitrogenous chemical synthesis. Our current work is focused on the catalytic recycling/valorization of two types of plastic waste: PET to value-added monomers and polyolefin plastic to fuels (petrol, diesel, or jet fuel) and porous carbon materials. The conversion of lignin, a waste product from 2G ethanol and pulp/paper industries, to fuels, chemicals, and functional carbon materials is another key focus of our research. The third research topic is to develop facile catalytic C-N coupling strategies for biomass-based N-heterocycles (drug motifs) using safe hydrogen carriers. The key to efficient and selective plastic/biomass waste valorization is to develop new heterogeneous catalytic materials with structural uniformity and the optimal amount of specific active sites. Thus, we strive for a deeper understanding of the catalysts at the nanoscale range that can provide us with valuable insights for the rational design of novel bifunctional nanostructured metal-based catalysts with optimum catalytic active sites (mainly acid-redox properties) for plastic/biomass waste conversion and diverse nitrogenous chemicals.

The success of any research group primarily depends on the research scholars. The SP HeteroCat group is fortunate to have enthusiastic, dedicated, and motivated research scholars, and their commitment and perseverance to work on challenging problems stimulate the group research endeavours at IITH. We aim to continue our commitment to excellence, innovation, and the pursuit of knowledge in the field of Heterogeneous Catalysis, with the ultimate goal of developing industrially relevant processes for plastic/biomass waste conversion towards a sustainable society.

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Catalytic dye degradation by hydrogel-silver nanoparticle nanohybrids

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Water pollution has emerged as a critical global issue, driven by the industrialization of sectors like paints, food, leather, printing, and textiles that extensively use dyes[1]. These industries generate over 7×105 tons and nearly 10,000 varieties of dyes and pigments, with more than 10,000 tons consumed annually1. Approximately 10–15% of these dyes are discharged untreated into water bodies, posing a significant threat[2,3]. The release of vast amounts of untreated dyes into the aquatic environment is a considerable concern, given their high toxicity and carcinogenicity to microbial populations and mammals[4,5]. It is imperative to treat wastewater effectively to eliminate these hazardous dyes before entering aquatic ecosystems.

Several approaches have been utilized for dye degradation, encompassing chemical[6], biological[7], photo-catalysis[8], and catalytic reduction using metal nanoparticles (NPs)[9]. However, using bare metal NPs has some drawbacks compared to stabilized counterparts. The elevated surface energy of naked metal NPs prompts agglomeration, resulting in a notable decline in catalytic activity. Furthermore, these nanoparticles are not easily recyclable through a straightforward centrifugation process. Both challenges can be mitigated by immobilizing metal NPs onto a solid support. Different supporting materials, including dendrimers[10], polymeric microgels[11,12], bulk hydrogels[13], and inorganic substances like reduced graphene oxide[14], are employed for this purpose.

The incorporation of silver nanoparticles (AgNPs) into gels represents an innovative approach to catalyze the degradation of dyes for wastewater treatment. This hybrid system combines the catalytic properties of ANPs with the structural support of a gel matrix. The gel provides a stable and immobilized environment for the silver nanoparticles, ensuring prolonged catalytic activity. When exposed to dye-contaminated water, the gel-encapsulated Ag NPs efficiently initiate degradation processes, breaking down dye molecules. This strategy not only enhances the catalytic efficiency of AgNPs but also facilitates easy separation of the catalyst from treated water. The synergy between silver nanoparticles and gel matrices presents a promising avenue for effective and practical dye degradation in wastewater remediation.

To achieve this goal, we have been working on synthesizing AgNPs in a bioinspired supramolecular gel (Figure-1). The gel here played a dual role as a reducing and capping agent, facilitating the green synthesis of AgNPs by reducing AgNO3. The nanohybrid hydrogels were utilized for the catalytic degradation of dyes (Figure-2). Figure-1 Photographs of gel and silver nanoparticles incorporated gel.

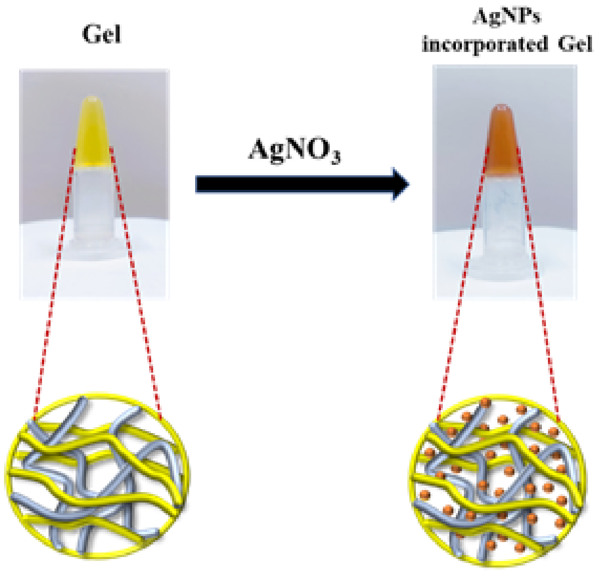
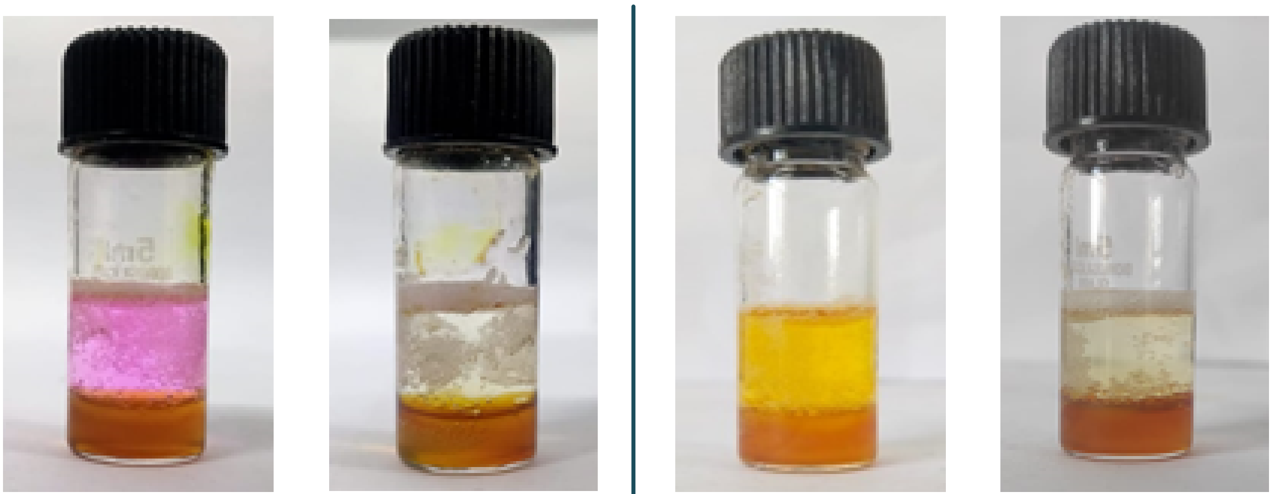


Figure-1: Photographs of gel and silver nanoparticles incorporated gel



Rhodamine B dye Before degradation

Rhodamine B dye After catalytic degradation by AgNPs

Methyl Orange dye Before degradation

Methyl Orange dye After catalytic degradation by AgNPs

Figure-2: Photographs of catalytic degradation of dyes by hybrid gel incorporated with silver nanoparticles.

In the upcoming stages, we plan to incorporate gold or silver nanoparticles along with graphene oxide in the gel. Subsequently, we aim to perform catalytic reduction of dyes using this hybrid gel. We will also endeavour to catalyze organic reactions with this advanced formulation.

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