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Review

Metal-Organic Frameworks: Synthesis, Adsorption, and Catalytic Applications

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ABSTRACT

Metal-organic frameworks (MOFs) are a class of crystals materials with pores that self-organize into a spatially organized network structure. They are made up of metal-containing nodes joined by an organic ligand network. MOFs offer three primary benefits The framework's adsorption areas and metal ion transportation are made better by their very porous framework and very high specific surface area. (2) The functional characteristics of the sites of adsorption can be changed by regulating the interaction between them and the metal ions. (3) MOFs may be generated on a wide scale because to their comparatively straightforward preparation method, and they maintain their stability under challenging circumstances. The current structural forms of MOFs (powder and membrane-like structures) and their production techniques, including mechanochemical, primary, and secondary growth processes, are initially outlined in this review article. Recent advancements in the enrichment of different metal ions, adsorption, analytical identification, and other catalytic uses of MOFs are then highlighted. A comprehensive description of the polymerization by radicals of methyl methacrylate (MMA) using microwave assisting agents and MOFs as catalysts is also given. The catalyst conditions, such as the number of MOFs-907, co-initiators and organic solvents, and polymerization time, should be carefully considered in this process. Future research directions and technological issues pertaining to MOFs materials that need to be resolved are also covered. A thorough grasp of metal-organic frameworks is the goal of this review. Because of its large porosity and active metal sites, MOFs are excellent for sophisticated adsorption and catalytic processes.

Introduction

In addition to being prevalent in nature, metal ions constitute vital trace substances for human health and survival. For example, iron ions take part in oxygen transport in the human body, ions of copper are engaged in the expression of genes and enzyme reactions [1], and ions of zinc are linked in human growth, development, and metabolism [2] while iron ions are associated with the transportation of oxygen in the human body [1]. Because of their widespread distribution, various forms, insolubility, poisonous consequences, and other characteristics, heavy metal ion pollution has become a global issue. Heavy metal ions, such as Pb, Cd, Hg, As, and Cr, are found in soil, air, and water in a range of numerous forms. The

digestive, immunological, neurological, and reproductive systems are all permanently harmed by these ions once they enter the human body through direct contact or the food chain [3].

Therefore, it is necessary to detect metal ions in food and the environment analytically and to use enrichment-based adsorption. The traditional techniques for eliminating metal ions over the past 10 years have included chemical precipitation, ion exchange, membrane filtering, and adsorption [4]. Adsorption is widely recognized as one of the finest techniques for finding and eliminating metal ions since it may eliminate many compounds concurrently as well as requires less experimental conditions. Conventional absorbent materials, such as carbon materials, zeolites, graphene, molecularly imprinted polymers, porous silicone materials, etc., still have certain disadvantages, nevertheless, such difficult framework modification, poor control, and restricted synthesis conditions. These issues continue to limit the utilization of these materials [3] The spatially network framework of conventional metal-organic frameworks (MOFs), which are crystalline porous compounds in which the ligands act as a bridge, is created spontaneously by the combination of inorganic metal-containing nodes and organic ligands [5]. Because of the specific coordination structural unit between the metal ion and the organic ligand, they are preferred to mesoporous materials with only organic ligands, such as covalent organic frameworks (COFs) and porous organic cages (POCs) [6]. This new type of porous material is intriguing due to its huge specific surface area, customizable microporosity, low framework density, and numerous applications. Among its numerous uses are ion adsorption, drug delivery, gas storage, and chemical separation [7] . The term "MOFs" was originally used in 2005 by Yaghi's research team. MOFs have a lot of potential as metal ion adsorbents because of their well-organized porous structure and adjustable physical and chemical characteristics, and their practical uses are very promising [8].

MOFs have three main advantages as adsorbents:

(1) Because of their very porous structure and extremely high specific surface area, adsorption sites and metal ions can be readily distributed throughout the framework. (2) Functional control is the ability to regulate the interaction between the metal ions and adsorption sites. Furthermore, MOFs may be generated on a massive scale due to their straightforward synthesis procedure, and they exhibit exceptional stability even in complicated settings [9]. The extraordinarily large surface area of porous membranes a highly desirable characteristic for the adsorption process is a significant benefit of adsorption by these membranes over traditional powder materials. Currently, the surface area of different porous membranes ranges from 1000 to 10,000 square meters per gram, which is significantly larger than the surface areas of zeolite and carbon [10]. The quick development of membrane-based technology for adsorption is dependent on the establishment and design of novel substrate materials. Despite being successfully used in organic dehydration and material adsorption, developed inorganic membrane materials like zeolite and ceramic membranes have limitations such weak membrane structure and low mechanical strength [11]. Because of this, composite membranes made of polymers and porous materials have been created. Nevertheless, regardless of the membrane's improved mechanical properties, the compatibility of the fillers as well as the polymeric material decreases its thermal and chemical resilience [12]. The idea of MOFs films/membranes was put forth by Caro's research team in 2005, and since then, membrane scientists have studied it extensively. Substrate-MOF-based composite based membrane materials have a higher affinity than conventional nanostructured porous materials. They do not create non-selective voids that are typical, and can preferentially separate or adsorb molecules with many different molecular weights by varying their dimensions of pore size [13]. major research has been carried out on MOF-5, HKUST-1, IRMOF, ZIF, and MIL membranes, and recent years have seen an important improvement in membrane-based MOF adsorption and separating technologies d [14]. Evolution of MOFs is depicted in Figure 1. From two-dimensional in nature (2D) to three-dimensional (3D) and even multiple-dimensional morphology, including permanently open-pore designs, the topological framework of MOFs membranes has expanded [15].

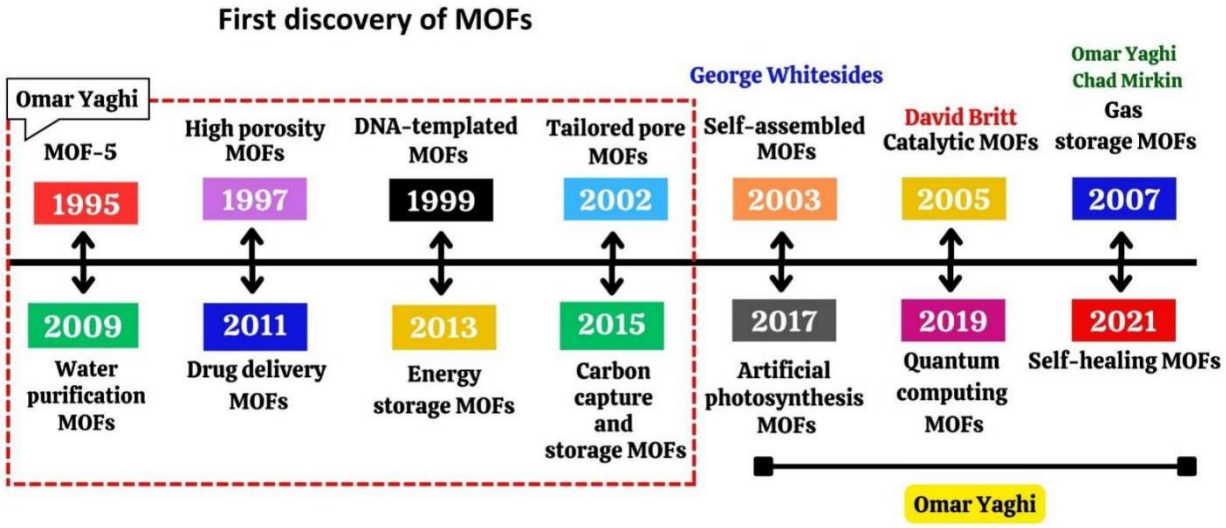


Fig 1: Historical background of MOFs

MOF membranes are incredibly versatile and modular. The trend of research articles published over the past ten years on MOFs in the area of conventional ion adsorption is shown in Figure 2. Numerous studies have demonstrated the exceptional adsorption properties of MOFs for environmental pollution, agricultural protection, and analytical testing [16]. A great deal of the research on metal ion adsorption, which is still in its early phases, has focused on the development of synthetic methods for MOFs and their use as adsorbents for the enrichment of heavy metal ions [17]. The present structural forms of MOFs materials (powder and membrane-like structures) and their preparation techniques, including mechanochemical, primary, and secondary growth processes, are first summarized in this review. The development of MOFs in adsorption, analytical detection, and other catalytic applications based on the enrichment of different kinds of metal ions is then highlighted. Lastly, a detailed discussion of the microwave synthesis process for methyl methacrylate radical polymerization is provided. Simultaneously, future research paths are considered and the technical obstacles associated with MOFs materials that must be overcome are highlighted. This review offers thorough and specific information regarding MOFs.

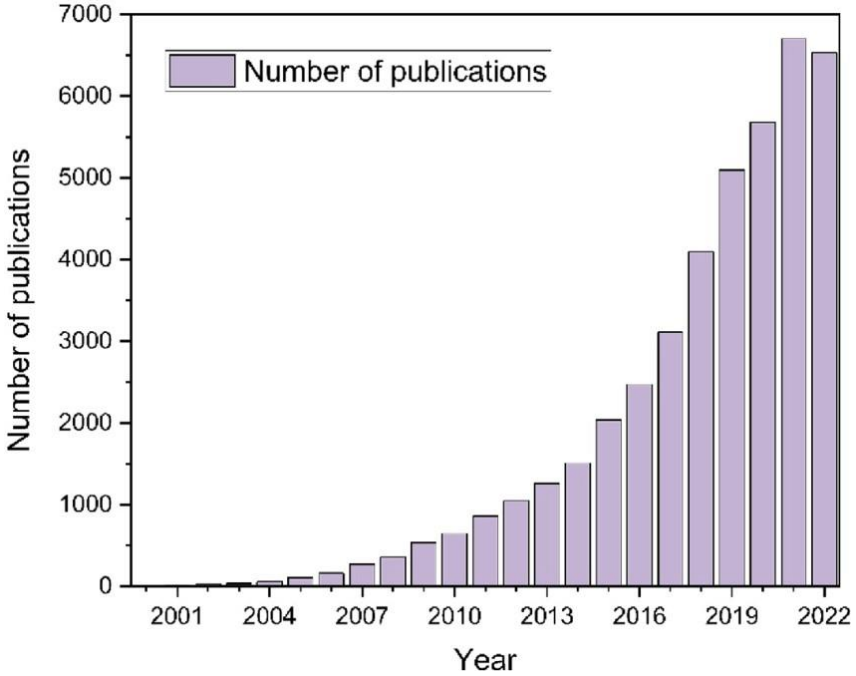


Fig 2: Growth trend of published articles on MOFs for metal ion adsorption is Adapted from Ref. [22] with permission of Journal of materials chemistry. A, Materials for energy and sustainability Copyright 2018.

1. MOF Synthesis:

Using aqueous and/or solvents made of organic matter as carrier materials, either hydrothermal or solvent heating techniques are typically used to create MOFs materials. The reaction temperature ranges from 37 to 200 degrees Celsius, and the reaction takes from hours to days [5]. MOFs powders and MOFs membranes are both of the main fields into which MOFs materials can be divided based on their physical and structural features. As a result, innovative synthesis methods have also been developed [18]. Powder-based MOFs materials have been successfully developed and manufactured using conventional synthetic methods including the hydro thermal method and the solvo thermal approach. Other synthesis methods, such as solvent-free methods like mechanochemical methods, have also improved significantly [19]. In addition to lowering the number of solvents used, solvent-free synthesis techniques also lower contamination and impurities in the crystals, making them highly promising from an economic and environmental standpoint [17]. When synthesizing pure MOFs membranes and MOF-based composite components, the stability of MOFs materials must be considered alongside the problem of dense polycrystalline layer formation on carriers [7]. While the number of research articles on in-situ and secondary growth methods has also increased in recent years, research based on interfacial synthesis and liquid phase epitaxy developed substantially, as shown in Figure 3. Naturally, the many states of MOFs have a direct or indirect impact on the physical and chemical properties of the materials themselves, such as mechanical strength, porous structure, and hydrophobicity [20]. Therefore, alternative synthesis methods are needed to create powder and membrane-based metal organic frame works.

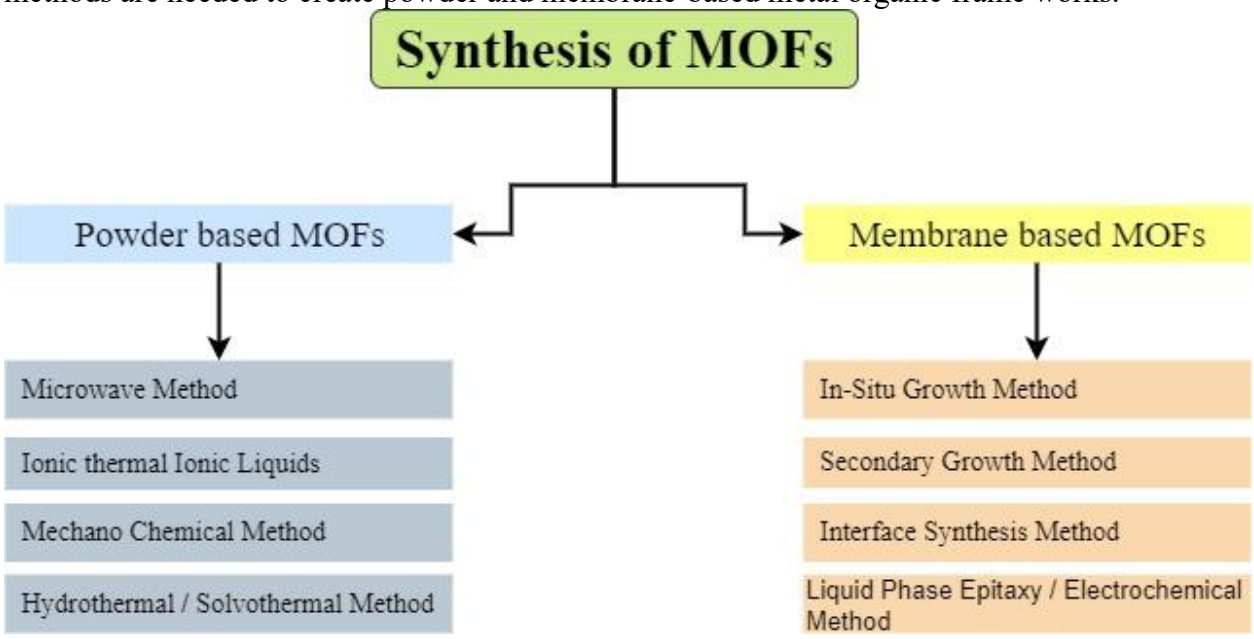


Fig 3: Different Synthetic metal organic frameworks approaches

1.1. Method for Making Powdered-Based MOFs

Two essential elements functional sites and organic ligands have a major impact on the design and production of MOFs powder materials. The choice of suitable organic ligands affects the structure and functional characteristics of metal organic frameworks [21]. The topological structure of MOFs is typically formed by the functional monomers that make up MOFs, and their structural benefits are crucial in attaining their spatial variety. As seen in Figure 4, common topological configurations are categorized into several network topologies, including squares, triangles, and lozenges. The type of donor atom,

coordination mode, stiffness or flexibility, functional groups, substituents, and geometric structure of the organic ligands all have a major impact on the structure of metal organic frame works [22]. MOFs with functional properties can be modified to provide the necessary stability, selectivity, and variety in addition to providing unique air structures [23]. To enable actual and gradual change of powdered-based MOFs, approaches for carefully adjusting the size, shape, and stability of the pores as well as introducing several functional groups inside the pores have been devised [16]. These precise management is necessary for the materials to function better and more efficiently. Therefore, we enthusiastically endorse the design approach that makes use of the architectural space structure, commonly referred to as the Secondary Building Unit (SBU), as the basic foundation. This method works well for preparing various MOFs for various uses, in addition to being appropriate for the synthesis of a particular MOF [24]. Additionally, by selecting a separation material that matches the desired material in terms of preferential selectivity and has the proper pore size, shape, and functional features, the separation of ions can be effectively controlled.

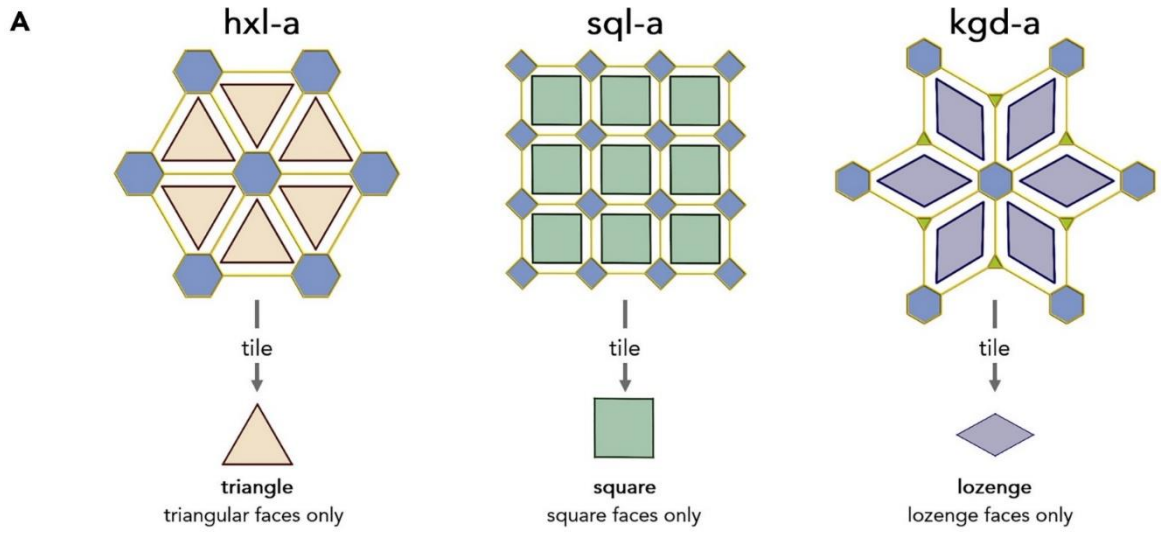


Fig: 4. (A) Common topologies of MOFs. (A) 2D hxl, sql and kgd topologies and their respective triangle, square and lozenge faces (windows for porous structures) is reproduced from Ref. [47] with permission from Communication Chemistry, Copyright 2018.

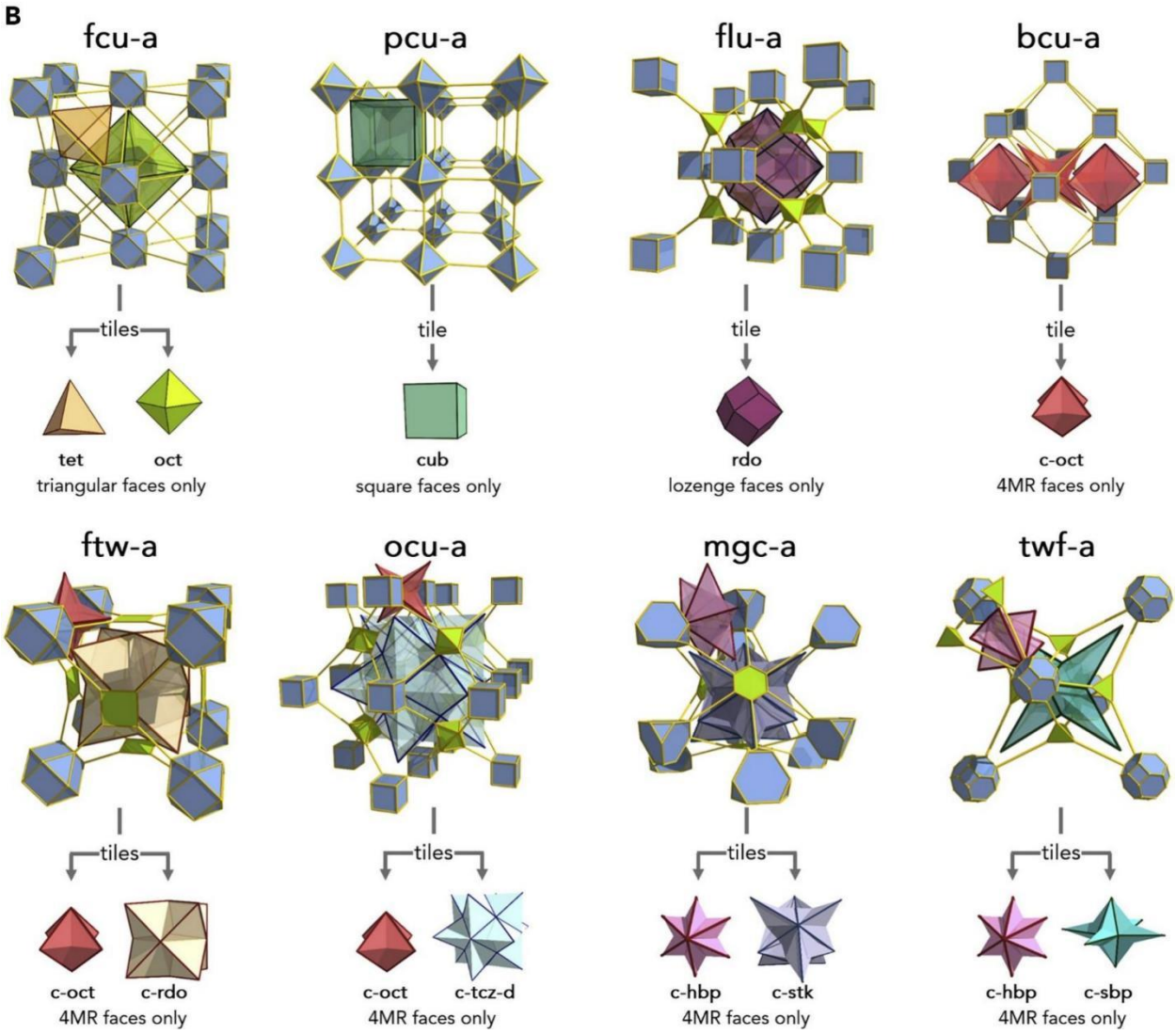


Fig 4:(B) 3D flu, pcu, flu, bcu, ftw, ocu, mgc and twf topologies and their respective tiles with triangle (fuc), square (pcu). Lozenge (flu) and a planer lozenege (bcu, ftw, ocu, mgc and twf) faces is reproduced from Ref. [47] with permission from Communication Chemistry, Copyright 2018.

1.2. Solvothermal /Hydrothermal approach

One common technique for creating the powder forms of porous materials is hydrothermal/solvothermal synthesis. Autoclave heat treatment in water or organic solvents can drastically change the hydrophilicity of the solvent and the polarity of metal salts and chemical ligands [25]. In addition to the fundamental reaction conditions such as the reaction volume, concentration, temperature, and duration a careful selection of chemical regulation is essential for hydrothermal and solvothermal processes [26]. Various kinds and amounts of modifiers may have different effects on crystallite size, in that the number of nucleation sites is a function of the competition that occurs with respect to metal-binding sites. Due to the rapid growth in this field, a number of pore-shaped composite components with stable chemical properties

and consistent design features have recently been developed by choosing chemical regulators with different characteristics [27]. The most important solvents utilized in the synthesis of MOF involve a variety of proton donors with high and high degree of polarity, including ethanol, water, methanol, acetic acid, dimethyl sulfoxide, a *N,N*-dimethylformamide, acetonitrile, and acetone [28]. The hydrothermal/solvothermal approach was used in the early work of MOFs, but the use of organic solvents is expensive and results in excessive loss, the anions (such as nitrates and chlorides) have too many danger concerns, and other major issues arise [20]. The MOF nanostructures with unprecedent characteristics have fabricated disclosing a Zn-based catalyst as [Zn(H N-BDC) (4-bpdh)]·3DMF at Tarbiat Modares Univesity (TMU) through a salt Zn(NO) ·6HO with 2,4-hexadiene applying hydrothermal method. The successful synthesis of this catalyst was confirmed by the use of TGA, XRD, FTIR, Elemental microanal., ICP, BET and OES measurements. Through Michael addition of annular benzimidamid hydrochloride to the (3E,5E)-3,5-bis-(benzylidene)-4-piperidone reactive class with reusability and retrievability over successive 5 runs without appreciable change in efficiency, the produced catalytic agent TMU-16-NH functions as a prospective competitor to create a new type of pharmaceutically relevant 2,4-diphenylpyrido[4,3-d]pyrimidine scaffolds. Furthermore, such methodology is accompanied by the excellent results such as the broad substrate range, mild reaction conditions, fast reaction time and product yield [29]. The more flexible proline-functionalized piller layered MOF [Zn (2,6-ndc) (bpb-NHPro)] was integrated into the framework through solvothermal reaction between the Zn (NO) and 5-bis(4-pyridyl) benzene (bpb-NHPro), 2,6-naphthalenedicarboxylic acid (H ndc) in N,N-di-Et formamide (DEF) and 1-L-Pyrrolidine-2-carboxamide-2. The aldol addition reaction of 4-nitrobenzaldehyde and cyclopentanone was selected as model reaction to evaluate the progress of which showed the opposite diastereoselectivity, favouring the syn-adduct; obtained by the homogeneous catalysis with a high achievement of 98% yield and diaster eomeric excess, till 98:2 (syn:anti) [30]. A novel Zr-MOF catalyst has designed by solvothermal process and modified by using pyridine carboxaldehyde embedded with Cerium tested by BET, ICO, TGA, FE-SEM, EDX, FAR-IR and FTIR analysis for catalyst structure. For a variety of reasons, including maintaining all three Lewis acids as activation functions with Langmuir surface area of 501.63 m^2/g, pore size of 2.27 nm, and pore volume of 0.28 cm^3/g at ambient temperature, the results demonstrated 90% high efficiency and retrievability in deviantization of polyhydro quinoline in series of Michael addition and Knoevenagel condensation approaches of synthesized Ui O-66-Pyca-Ce (III) catalyst [31]. By coagulation of Cd ions in solvothermal process with two squaramide based ligands two different MOFs Cd(L1)(DMF) and Cd(L2) (dpe) have synthesized and tested by PXRD, single crystal XRD, TGA and IR for elemental analysis. The outcomes show sq-Cd-NOF-1 features an entirely new 3D structure along 1D narrow apertures while sq-Cd-MOF-2 has a novel ring-ring linking chain-base two

layered as 2D MOF structure with higher porosity, offering potential applications in heterogenous catalysis after derivatization by Micheal addition reactions [32].

1.3. Ionic Thermal Approach (Ionic liquid method)

Ionic fluids (ILs) are a novel family of eco-friendly solvents with several uses. Ionothermal synthesis is the process of directing the synthesis of solid structures using ILs as templates and solvents. Despite its obvious disadvantages, such as relatively harsh reaction conditions, high process energy consumption, and large consumption of organic solvents, the ionothermal synthesis method can largely avoid the competition between the solvent/template and the framework in the solvothermal preparation process. Additionally, ILs are still regarded as one of the best solvents for successfully preparing MOFs and may be recycled and reused [33]. Ionothermal synthesis was recently used to create five unique classic Keggin-type PMOFs. The resulting material (MIMA) has a unique mechanically interlocked molecular structure and is constructed from two-dimensional interpenetrating polyrotaxane layers with a characteristic ring-like form. Furthermore, a novel two-dimensional three-layer interpenetrating polyrotaxane host-guest network is shown. As a result, it would be a novel strategy for high-stability entangled two-dimensional hierarchical PMOF systems [34] .

1.4. Mechanochemical Approach

The mechanochemical approach involves uniformly stressing the material while simultaneously subjecting it to physical deformation and chemical reactions caused by mechanical stress, such as vibrating, rotating, and grinding [35] Initially, the frame material is destroyed by mechanical force, resulting in a fine powder that increases the material's degrees of crystalline structure and specific surface region [36]. Second, the particles coagulate due to the Van der Waals force. Finally, the material begins to crystallize, and a mechanical amplification reaction starts inside it as a result of particle agglomeration. The most attractive feature of the mechanochemical technique is that the material can be produced by grinding alone, eliminating the need for initiators, catalysts, or heat reactions [37]. However, there is still more research and discussion to be done on the produced nano-powders' homogeneity, dispersibility, high energy consumption, aggregation, and purity. According to a recent paper, airflow impingement (AFI) offers a novel alternative to conventional mechanochemical synthesis. For the first time, an innovative airflow impingement method was developed as a replacement to the conventional method for the mechanochemical synthesis of MOFs. The most important advantage of using the airflow impingement method technique is that MOFs can be synthesized without a solvent, in contrast to MOFs produced using

the conventional solvothermal process. MOFs also have good area of the surface and a typical pore size. Solvent-free conditions have emerged as a major trend in MOF synthesis due to the growing volume of research. According to Brekalo and colleagues, basic zinc carbonate is an adequate precursor used for the solvent-free mechanically induced synthesis of ZIF. The procedure can be quantitatively and continuously monitored by measuring the pressure changes in the grinding vessel during the process due to the atmospheric carbon dioxide released from the precursor, a substance which permits the large-scale, low-loss synthesis of ZIF-8 by adding excess ligands to prevent by-products [28]. Some malononitrile, aldehyde and acidic C-H compounds were employed in malononitrile-based multicomponent reactions on restorable nanocomposites loaded with Fe_3O_4 nanoparticles on MOF using an ecofriendly reactive approach by tandem Knoevenagel-Michael cyclocondensation approach [38].

1.5. Microwave Method

In the microwave approach, electromagnetic energy reacts with mobile charges in the solution, such as conventional polar solvents, ions of metal, and deprotonated organic ligands [39]. In order to fast create MOFs crystal powder from the beginning mixture, Seyedpour and colleagues (2019) employed microwave waves in the range of 423 to 493 K. The energy of radiation from microwaves aided in the MOFs' rapid growth. The reaction duration and concentration of the precursor have a major influence on the yield and crystallinity of the final product.

1.5.1. Microwave synthesis of Metal organic frameworks:

Three milliliters of DMF are used to dissolve the linear 2,6-naphthalene dicarboxylic acid (H_2NDC) and 1,3,5-triyl-tris (benzoic acid) (H_3BTB) linkers. DMF is added to the mixture of (H_3BTB) and (H_2NDC) after being combined with acetic acid that contains iron III nitrate monohydrate. This mixture is put down in a flask and then heated at 120 centigrade for 24h. When this time passes then Orange cubical shape crystals were obtained and accumulated by decantation. DMF is used to wash the resulting product to eliminate beginning reagents. MOF is soaked in dried acetone for 72 hours. After emptying at 90°C for 24 hours, a hundred milligrams energized sample (twenty one percent yield of Fe $(NO_3)_2$ was collected [40].

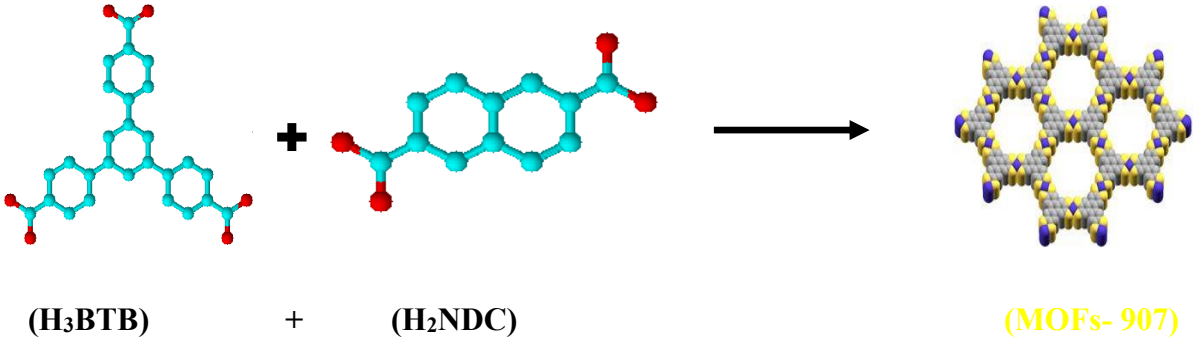


Fig 5: Microwave synthesis of MOFs is reproduced from Ref. [40] with permission from Elsevier, Copyright 2015.

1.6. Membrane based synthesis of Metal organic frameworks

Although full and flawless membranes are usually the aim of transmembrane-based MOF synthesis, the adsorption performance of composite membrane materials is usually influenced by the size, shape, and interactions of the ions with the membrane-based components. The substrate surface directly affects the nucleation and growth of MOFs membranes during the synthesis of membrane materials. In this case, it is challenging to create a uniform and dense MOFs membrane on the carrier's surface due to the lack of functional groups on the ligand to covalently bond with the substrate's surface hydroxyl group [41]. It is essential to use specific matrix synthesis or modification approaches to improve the heterogeneity nucleation locations in order to produce the optimum composite membrane structure [34]. A special kind of reagent Co-MOF-PDA-TA (MP-TA) have prepared using Tetra aniline and Dopamine in Micheal addition process that are compatible with waterborne epoxy, showed better passive film on the steel surface by characterization tools such as SEM, XRD and FTIR spectroscopy. The redox reaction between TA (reduced) and EB (oxidized) or LEB even by the involvement of 2 electrons that lead to generation of a passivation of coating, makes a great breakthrough to the potential application of MP-TA as a multirole additive [42].

1.7. The In-situ growth Approach

The in-situ growth approach entails submerging the substrate directly in a growth solution composed of ions of metal and a bonding agents in order to maintain the diffusion properties of the metal ions and connecting molecules [43]. The substrate is frequently changed with functional groups that interact with the metal ions in order to enhance the MOFs layer's ability to bind with the substrate. The MOFs layer is then formed by combining the bonding agent with the substrate. For instance, Wu and his collaborators created ZIF-8 membranes by treating pencil rods with IL in situ; these membranes were subsequently functionalized using PEG-NH_2 [44]. It can be seen that the ZIF-8/PEG-NH2 membrane had an increased

adsorption ability than the pristine ZIF-8 membranes while maintaining excellent stability and reusability. Yang and colleagues reported the rapid in-situ synthesis of Zn/Co-ZIF crystals on the fabric to produce a strong and dense MOFs membrane at room temperature [36] as shown in figure 6. When sodium carboxymethyl cellulose was added to the solution, the molecular sieve imidazole salt structure (Zn/Co-ZIF) crystals clung to each other on the surface because of the chemical impact of their surface, which stopped the solution phase crystals from clumping together. CMCMOF/cloth showed excellent selectivity and a good adsorption capacity (862.44 mg g^{1}) for Pb2þ.The CMC-MOF/cloth composites membrane can quickly absorb lead (Pb2þ) on filter devices, has strong removal efficiency, and may be reused in several regeneration cycles. Zhu and his team successfully produced a dopamine-modified MOFs composite membrane (prGO@cHKUST1) by employing the in-situ growth technique to generate a cubic structure with remarkable morphology and distinctive properties using Mg/Al layered double hydroxide as a modifier. Graphene oxide's (GO) interlayer spacing can be changed to fit in HKUST-1, increasing the membrane's hydrophilicity and flow [45]. Furthermore, the GO layer stacking can be altered by the intercalation effect of the MOFs and the reduction effect of polydopamine (PDA), leading to a large number of ambiguous pores and more active sites on the membrane's surface. In contrast to the prGO membrane and the original GO membrane, a modified membrane's permeation flux was ten and five times higher,respectively.

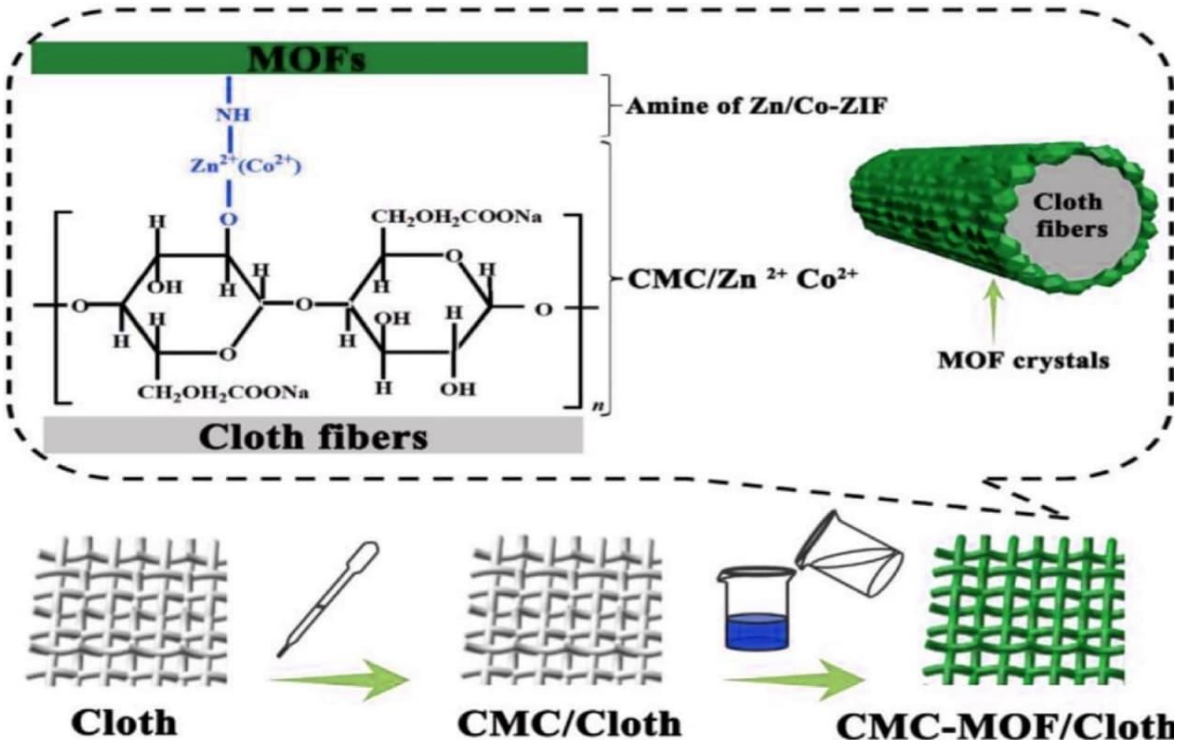


Fig:6. Schematic diagram of preparation of CMC/cloth and CMC-MOF/cloth composite membranes is reproduced from Ref. [43] with permission from American Chemical Society, Copyright 2018.

1.8. 2ndary growth Approach

Another name for the seed growth technique is the 2ndry growth approach. To create the MOFs layer, a seed layer is usually applied to the substrate, which is subsequently heated by a solvent in the mother liquor [46]. Seed layers can be generated using MOFs precursor and substrate in addition to being physically absorbed. Using the secondary growth approach, Yuan and his colleagues were able to create a complete MOFs (ZIF-300) on an Al_2O_3 base. As seen in Figure. 7 [47]. They then extracted heavy metal ions from waste water using the ZIF-300 film. With a water permeability of 39.2 L m^{-2} h^{-1} and a copper sulfate retention rate of 99.21%, the generated ZIF-300 film proved stable. One of the popular in-situ growth and 2ndry growth approaches can be used to produce almost all MOF films. However, these approaches have a number of drawbacks. Membrane formation is typically complicated by modification or seeding, a process which increases the availability of heterogeneous nucleation places onto the substrate's surface [40]. Additionally, MOFs crystals will precipitate in the solution as lumps due to the precursor's composition of metal ions and a connecting agent, wasting raw materials. Furthermore, the scaling up strategy is difficult [48].

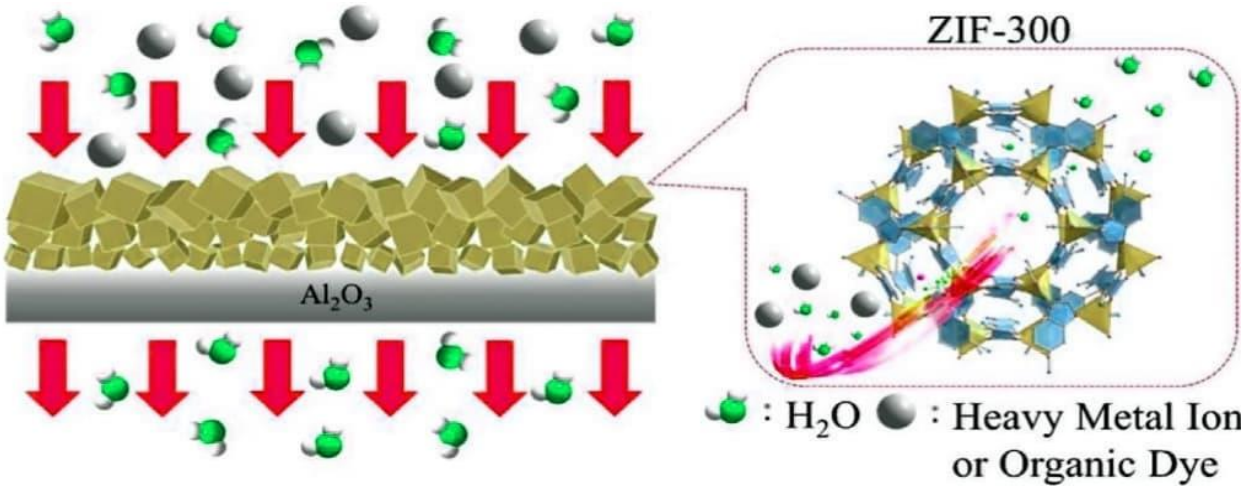


Fig 7: Schematic diagram of the process of removing heavy metal ions from water by the ZIF-300 membrane is reproduced from Ref. [47] with permission from Communication Chemistry, Copyright 2018.

1.9. Method of Interface synthesis

The two incompatible solvents, or the two solvents on either side of the substrate, are used to dissolve the ions of metal and the bonding agent used in the synthesis of the interface. During the formation of the MOFs membrane, the resulting molecules diffuse at the interface and in the opposite direction, and crystallization only occurs at the liquid-liquid interaction. It is advantageous to fill up the gaps, which are

principally formed at the defects, with the MOFs precursor at higher diffusion rates than the filled-up gaps, which are formed at the already formed MOFs, resulting in uniformly increased thickness of the membrane. In order to enhance the performance of an interfacial polymerized thin film nanocomposite (TFC) membrane, Li et al. added MOFs [49]. Zn2þ was added to the polymer solution during the synthesis to increase the permeability of the standard TFC membrane since the acids generated during the interfacial polymerization process will affect the membrane formation [43]. The MIL-101(Cr) MOF has been fabricated with terminal phosphate group MOF-supported nucleotides, which is irreversible binding of the ATP molecules, using XRD and DFT and NMR analysis showed Cr clusters at the ATP location interface with the terminal phosphate group in the Diels-Alder reaction, and in the Micheal addition reaction, had been shown Cr cluster sites that can serve as a new material for the Cu(II) occupancy systems as potential enantioselective heterogeneous agents. Although the straightforwardness of the concept of combining porous components into TFC membranes, all of the data demonstrated that TFC composite membranes outperformed ordinary membranes. This made it possible to successfully build continuous ZIF-8 films on microporous nylon with moderate separation performance. The interface synthesis method can minimize crystallization in the bulk solution and recover the reactants, producing a thin membrane with consistent thickness because the metal salt solution and the cross-linking agent solution are kept apart. Additionally, modular composite membranes can be directly designed using this highly scalable method. However, this approach has considerable limitations because only a few typical MOFs membranes, like ZIF-8 and ZIF-7 membranes, have been manufactured using it [50].

1.10. Liquid phase epitaxy Approach

In the liquid phase epitaxy approach, numerous metal ion and binder solutions are dissolved and then mixed together [40]. As shown in Fig. 8, Wang and colleagues [51] described a novel technique for producing MOF membranes using liquid phase epitaxy (LPE). Ten different MOF films can be rolled and loaded at the same time using their technology. Ten different MOF membranes can be rolled and loaded at the same time. Increased mechanical durability was a result of ultra-high molecular weight polyethylene interlaced MOF particles. The organic dyes exhibited a retention rate of up to 99% in cross-flow filtering mode with a water flux of 125.7Lh^{1}. Rapid solute adsorption happens through the porous MOFs, and rapid water penetration happens through the microscale channels between the MOF particles. High-performance surface adsorbers for essential separation processes can be produced using this approach. The liquid phase epitaxy approach produces MOFs with a discontinuous crystallization process, and the thickness of the MOFs layer may be accurately controlled by the number of cycles. The liquid phase epitaxy method is a

gentle, straightforward, and controllable preparation cycle. However, when producing the MOFs membrane, obtaining a continuous MOFs layer is difficult.

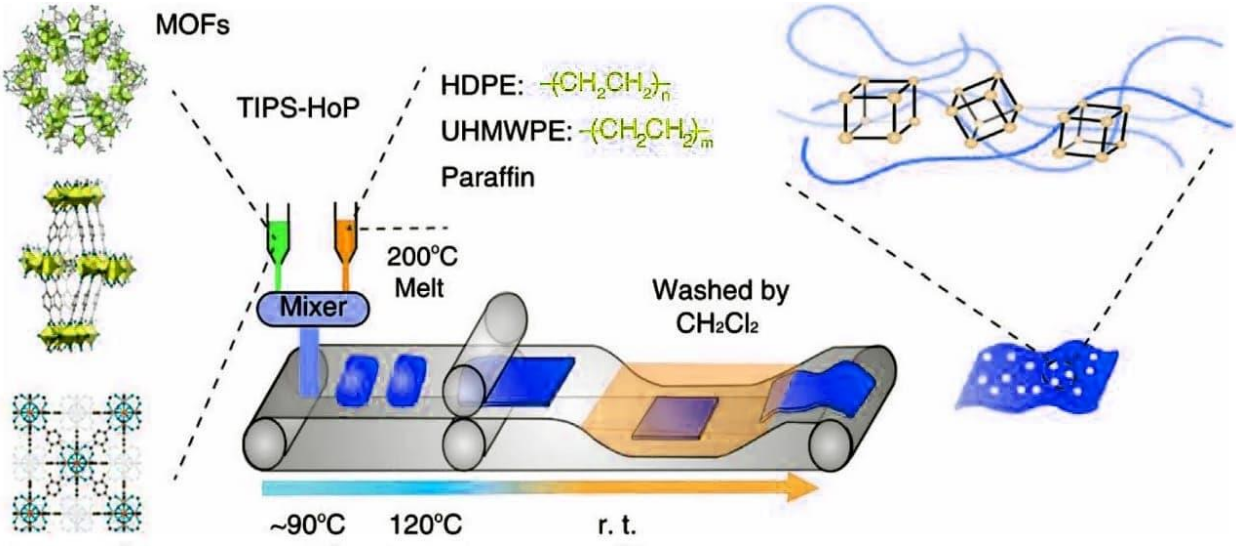


Fig. 8. Schematic diagram of the preparation process of MOF-PE-MMMs is reproduced from Ref. [40] with permission from Elsevier, Copyright 2015.

1.11. Electrochemical synthesis method

Electrode deposition is also known as electrochemical synthesis. The synthesis process is as follows. MOFs nucleate on the electrode surface at a critical concentration of the metal ions, and layered structures thereafter nucleate, grow, and form on the surface of the electrode. Ultimately, more electrochemical growth of the MOFs covers the exposed surfaces of the electrodes, resulting in a dense MOFs layer. The first report of the anodic deposition of MOFs thin membranes was published in 2005. The anodic dissolution of the metal anodes created the ions of metal, which then interacted with the organic ligands in the electrolyte to form MOFs on the anode. Anodic deposition comes in two varieties: low-temperature deposition and high-temperature deposition. Neutral ligands such as azoles and carboxylic acids must be deprotonated in-situ for MOFs based on anionic ligands. When hydroxide anions are deposited on the cathode, in-situ deprotonation of the ligand occurs, as shown in Figure 9. A MOFs membrane may form on the surface of cathode when metal ions are present in the solution [51].

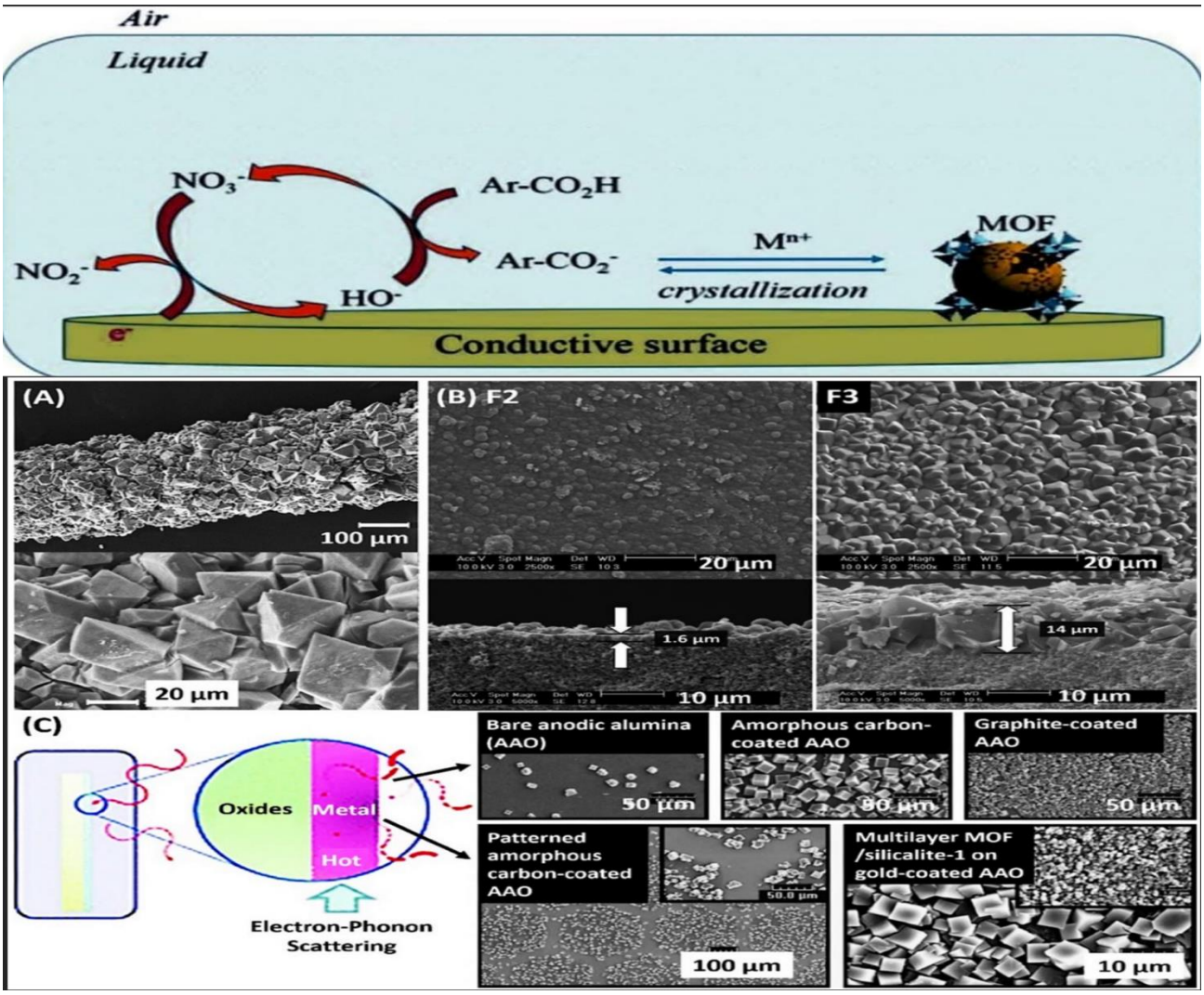


Fig. 9. Research on the cathode deposition mechanism of MOFs is reproduced from Ref. [51] with permission from Elsevier, Copyright 2018.

2. Catalytical Properties of MOFs:

They discover that the Phillips catalyst is part of a large dependence on polyethylene in the community and that they have been involved in research efforts aimed at developing catalysts that are homogeneous for the polymerization of ethylene; the catalysts they are developing are based on Cr. Ziegler–Natta catalysts are also emerging as a hot spot, with titanium and zirconium as focus points [10]. Metallocene and Ziegler Natta catalysts work for the polymerization of ethylene [11]. Ghobakhloo *et al* in 2022 have designed a novel Cu (II)-supported nano catalyst with stable and reusability without appreciable loss of activity in cyclized addition reactions that include Knoevenagel condensation–Michael. Aza-Micheal addition CuBTC reusable and retainable crystallinity MOF a substitute of amines responded in 2 to 24 h

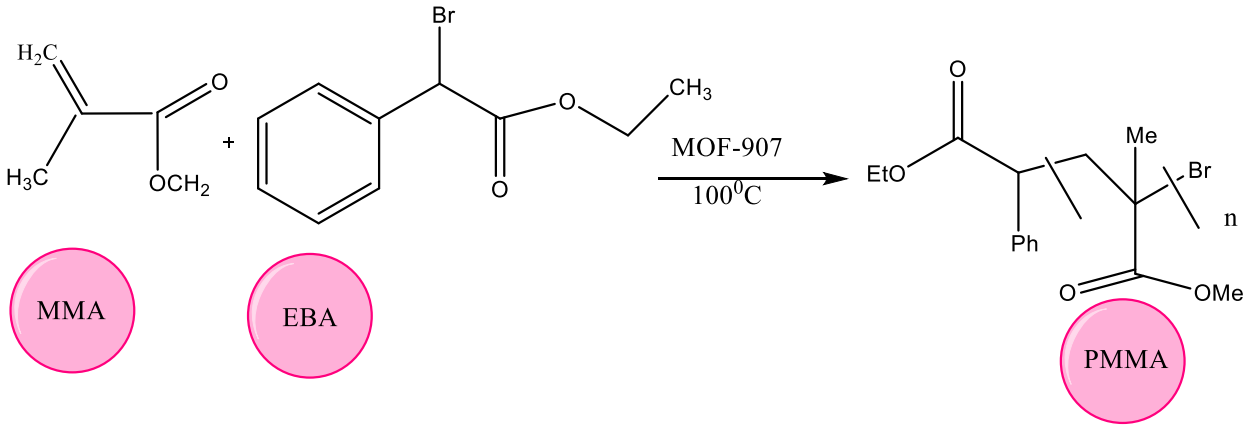
over 4 runs with no loss of the catalytic activity provided more promising result with aliphatic amines up to 98% yield [52]. The majority of the others played important roles in the polymerization of associated dienes such 1,3-butadiene or in the synthesis of isotactic polypropylene [53], and mostly originated from the transition metals that are in the first row. Although, several current studies have exhibited the adsorption activity of MOFs for unsaturated hydrocarbons a team of researchers reported a catalyzed disulfide addition reaction of Ni-MOF-74 for gaseous acetylene with superb selectivity in catalysis mechanism with prime advantage of recycling and easier separation possibility monitoring with FT-IR, XRD, EDX and SEM approaches [54]. There are numerous polymerization reactions that take place in the condensed phase (liquid or solid) substrates, and other coordination polymerization reactions that are implying gas-phase substrates [12]. These include radical-based processes, such as RAFT (reversible addition-fragmentation chain), ATRP (light-induced atom transfers radical polymerization), and ROP (ring-opening polymerization) [55]. These processes add co-polymerization and broaden the substrate's scope to include cyclic esters, acrylamides, and monomeric methacrylates. These radical-type reactions typically involve photoactive organic compounds and redox-sensitive transition metallic elements like Fe, Cu, or Ti. There are many publications on polymerization catalysts and many developments have taken place but it is a challenging task to preserve all of them. Guironnetand co-workers in the recent past tried it in their thorough analysis of recent trends in polymerization catalysis [56]. MOFs are thought to have high porosity and metal sites. Microwave-assisted radical polymerization of methylmeth acrylate is catalyzed by MOFs. The number of MOFs-907, co-initiators, organic solvents, and polymerization time are examples of catalysis-related parameters that need to be taken into consideration [5].

2.1. Methmethyl Acrylates

Polymethyl methacrylate is used in the dental industry. The low weight materials with high stability are PMMA [10]. The benefits of polymerization are extended with any advances in MOF-based catalysis for polymerization of methylmeth acrylate. For the methyl methacrylates ’polymerization, different methods of polymerizations are used like Atomic Radical Polymerization, Photopolymerization and Microwave assisted radical polymerization [11]. The most important method of polymerization is microwave assisted radical polymerization [12]. Methylmeth acrylate gets polymerized in the presence of catalyst MOFs-907.The polymerized product of PMMA is dependent on the concentration of Catalyst, initiator concentration as well as concentration of solvent DMF. If the Concentration of DMF is less, high yield product will be obtained [57, 58].

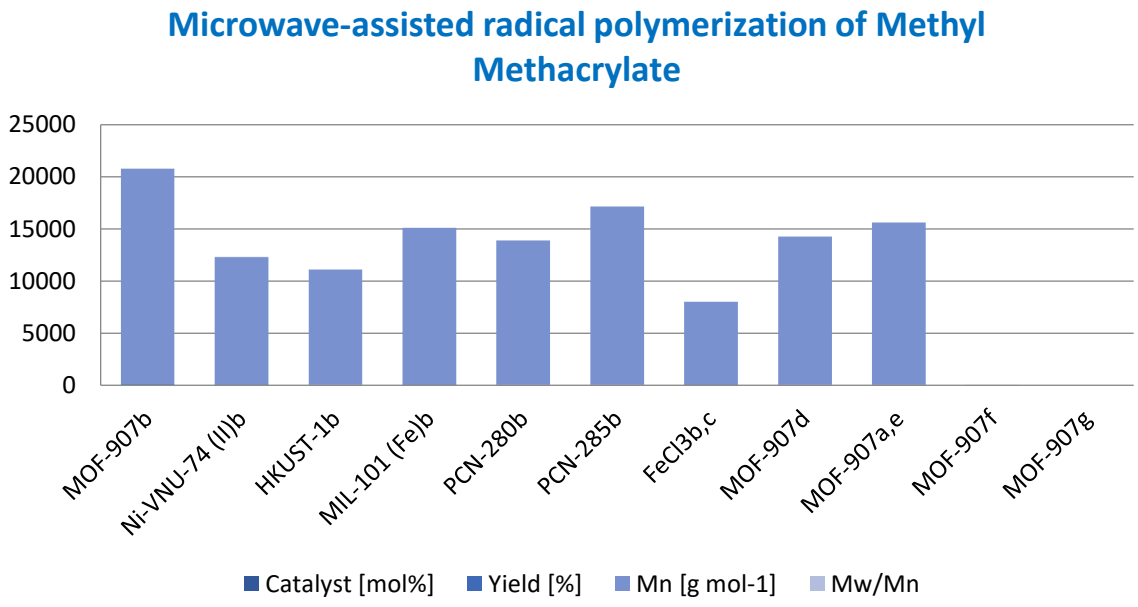
2.2. Microwave assisted Radical Polymerization of MMA

Activated MOF (3mg) is charged in a flask (10ml) which is also charged with few amounts of DMF, MMA, ethyl α-bromoisobutyrate (EBiB) / ethyl α-bromophenylacetate (EBPA) followed by closing the flask with microwave cap. Before being placed in the microwave system, the mixture in the flask was agitated for 30 minutes at 25 degrees Celsius. The polymerization reaction's synthesis conditions were established in a closed system at 100 °C for 30 minutes with 200 W of electricity.Following this procedure, the polymerization system is prepared. MOF builds up once the reaction is finished and is repeatedly soaked in dichloromethane. PMMA, the reaction's product, crystallizes out in a methanol solution. At room temperature, the PMMA should ideally dry. Conditions including reactant concentration, temperature, power, and reaction time will be examined for their effects [59].



Scheme No. 1: Microwave assisted Radical Polymerization of MMA

In the past, the researchers have used two types of co-initiators – ethyl alpha –Bromophenyl Acetate (EBPA) and ethyl alpha-Bromoisobutyrate (EBiB). By using EBiB, 68% of PMMA is synthesized while by using EBPA, only 43% PMMA product is synthesized.Thus, it can be concluded that EBiB is the most crucial initiator among all initiators which can yield maximum amount of PMMA. DMF is a solvent for use in the monolithic formulation process. It produces a high-yield product with less. Compared to Ni-Vu-74(II) or HKUST-1 types of Ni, Cu based MOFs, Fe-based MOFs have significantly stronger Lewis acid active sites.



Graph 1: Microwave assisted radical polymerization of Methyl Methaacrylate.

3. Applications of Metal organic frameworks

The functionality of MOFs (metal-organic frameworks) is critical to explore their structural along with chemical diversity for large number of potential applications [60]. Metal-based catalytic reagents, however, have an irreplaceable role in the chemical industry particularly in synthesis [61].

3.1. In the removal and adsorption of metal ions

Food processing, industrial progress, and materials science all depend on the Determination and analysis of ions of metals [10]. The porous materials' unique pore structure and superior adsorption qualities make them useful for metal ion removal and adsorption as well as inspection and identification [11]. This part will focus on the utilizing permeable composite components in order to evaluate a few typical metal ions of various metal ion kinds, including radioactive metal ions, d,f blocks, and alkaline earth metals. The alkali and alkaline metal ions Na, K, Ca, Mg, and Li are the most typical. The modification of a porous composite material to detect alkali metal ions is one of the main areas of research [12]. Because of the alkaline earth metals' large ion diameter, minimal density, and strong valence bond, the number of the coordination and bond effect with the donor, such as the carboxylic acid group, increase with increasing ion diameter [55]. For the production of stable alkaline earth MOFs, this is beneficial. In addition, alkaline earth metal ions have little toxicity and are very biocompatible. They may also successfully stop secondary

pollution brought on by heavy ions made up of metals by acting as fluorescent probes in biological systems [5]. A phosphate MOFs alginic acid hydrogel that uses brown algae to adsorb Liþ and Mg2þ was proposed by Park and coworkers. Adsorption properties analysis indicated that the main functional groups responsible for the adsorption of Liþ and Mg2þ were carboxylic acid and phosphonate groups. This led to the development of an effective ion recovery technology and a novel selective adsorption method for the separation and identification of magnesium and lithium ions [62].

3.2. Metal organic frameworks use in heavy metal ions

Metal ions can seriously harm many of the human body's organs because of their poisonous effects. Heavy metal ions can be adsorbed, removed, and analyzed using the MOF material, which is a composite MOF material with a specific pore structure and good adsorption properties [15, 63].

3.2.1. Ion of a divalent heavy metal

The most common metal ions are bivalent ions of heavy metals, such as Cu^{+2}, Pb^{+2}, Cd^{+2}, Hg^{+2}, and Ni^{+2}, which are necessary for extensive metal ion detection research [10]. Cu^{+2} ions pollution is mostly caused by the steel sector, metal processing, smelting and mining of copper-zinc ores, and the production of technology [11]. Ui O-66 MA is a dual amenable sensor to detect Cu (II) and H_2S in the aquatic systems with high selectivity and sensitivity undergo Micheal addition turn on fluorescent behavior with respective detections limits of 2.6 nM and 3.3 nM indicating development of multirole MOF sensor on routed in combinatorial principles [64]. The other MOFs (UiO-66-EDA) have also been synthesized using the Michael addition reaction as a Zr-based ethylenediamine multirole reagent for the adsorption of ions of heavy metal Cd^{+2}, Cu^{+2}, and Pb^{+2} from water. The maximum removal capacities of these MOFs were 217.39 milligram per gram, 208.33 milli gram per gram, and 243.90 milli gram per gram, respectively, due to electron sharing, electrostatic forces, and covalent forces between the metallic ions and the MOF (UiO-66-EDA) with different functional groups on its surface. Additionally, the stability of the produced UiO-66-EDA MOF in this exothermic and spontaneous in nature adsorption investigation was demonstrated by thermodynamic parameters that were monitored, such as ΔS (standard entropy changes), ΔH (standard enthalpy changes), and free energy changes (ΔG) [65]. Copper ion pollution in the atmosphere is mostly caused by the smoke and dust that smelting produces. Numerous recent studies have examined the acknowledgment and absorption of Cu^{2+} ions by ordinary porous materials [66]. For example, ZIF-8 nanoparticles were prepared on a large scale and grown in-situ on ZIF-8/PAN-NF membranes made of electrospun polyacrylonitrile (PAN) nanofiber Cu2þ showed good dynamical

absorption and standard filtering performance compared with the ZIF8/PAN nanofiller, according to Peng and coworkers. Copper was eliminated at a rate of 29.2% during the adsorption phase and 34.1% over four minutes [67]. The development of a thin ZIF-8 modified zeolite imidazole in salt (ZIF-8) forward osmosis film was also reported by Qiu and colleagues [68] on a crosslinked matrix of 1,3,5-benzenetricarboxylic acid chloride (TMC) and polyethyleneimine (PEI). The improved PDA layer made it possible for the nanofiller and the selective layer to have a good affinity. Compared to the original thin membrane composite membrane, ZIF-8@PDA demonstrated excellent water selectivity and higher water flux. Additionally, the altered membrane demonstrated a high rejection rate for heavy metal ions (Cu2 þ, Ni2þ, and Pb2þ). The human body's typical lead (Pb^{2+}) concentration is 0.1 mg L^{1}. Anemia and harm to the nervous system might result from exceeding this standard due to excessive Pb2þ in the water. Active steps to discharge lead should be taken after the blood lead level exceeds the standard [69].

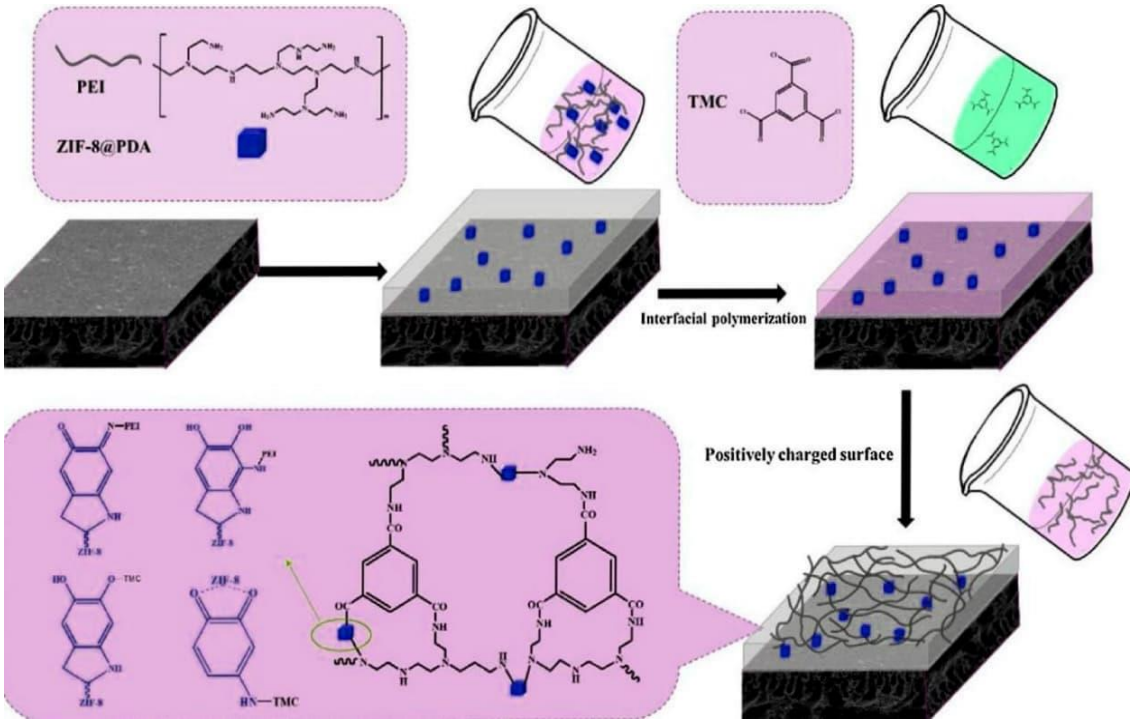


Figure 10. Schematic diagram of the preparation of ZIF-8@PDA modified TFN membrane is reproduced from Ref. [53] with permission from Elsevier, Copyright 2019.

3.3. Using Metal organic frameworks to radioactive ions

Numerous radioactive materials are unavoidably discharged into the environment as a result of the heavy use of coal, oil, and other fossil fuels [10]. Radionuclides such as uranium ,europium and strontium ions not only have a long half-life, high atmospheric mobility, water stability, and non-degradability

characteristics, but they also have extremely high toxicity and adverse effects that lead to a number of illnesses [11]. Thus, it is extremely important that the radioactive wastewater is properly treated prior to discharge into the environment. to detect and identify radioactive ions [12], It is essential to use materials with pores as solid adsorbents through chemical control. Uranium is a commonly used radioactive metal element and a fuel used for nuclear reactions. It is one of the most hazardous metal elements due to its high toxicity and poor degradability. the researchers Liu and colleagues synthesized MOFs with the azo functional group using the solvothermal method, and they tested uranium batch adsorption using MOFs and thermodynamics. The findings showed that the MOF's adsorption capability for uranium (U) ions in waste water was 312.32 mg/g, indicating that it is a suitable uranium adsorbent [59]. Using the same 3D framework, Song and colleagues conducted a series of studies on uranyl adsorption on iso network MOFs. The various adsorption processes were shown in studies using the Freundlich and Langmuir adsorption isotherms. The eOH and eNH_2 groups easily achieved a desorption rate of more than 70% and shown greater uranium adsorption than other groups, and the U-loaded MOFs can be eluted in addition to eNO_2. With 0.1 mol/L nitric acid, the highest desorption rate of 11.29% was noted. The results obtained demonstrate the significant U(VI) adsorption ability of MOF materials modified with particular organic groups in aqueous conditions, and functionalizing the porous materials will boost the capacity for adsorption when compared to the original material.

As uranium (U) ion research progresses, maintaining consistent adsorption performance in a complex matrix environment is more crucial than the material's adsorption performance. Apart from uranium ions, other radioactive ions such europium (Eu), strontium (Sr), cesium (Cs), and iodine (I) must also be efficiently identified and adsorbed [62]. As seen in Fig. 11, Chang and coworkers used a cutting-edge in-situ "green" radiation approach to develop a novel Prussian blue/natural porous material frameworks nanocomposite. The generated adsorbent demonstrates strong dispersibility characteristics and a porous structure, and it is demonstrated to be effective for Cs adsorption in an aqueous solution. The method can be modified to create other comparable porous adsorbents and is straightforward, effective, and safe for the environment. The necessary adsorption material stability was successfully attained by this technique, and the functionality's synergistic improvement has some practical significance [62].

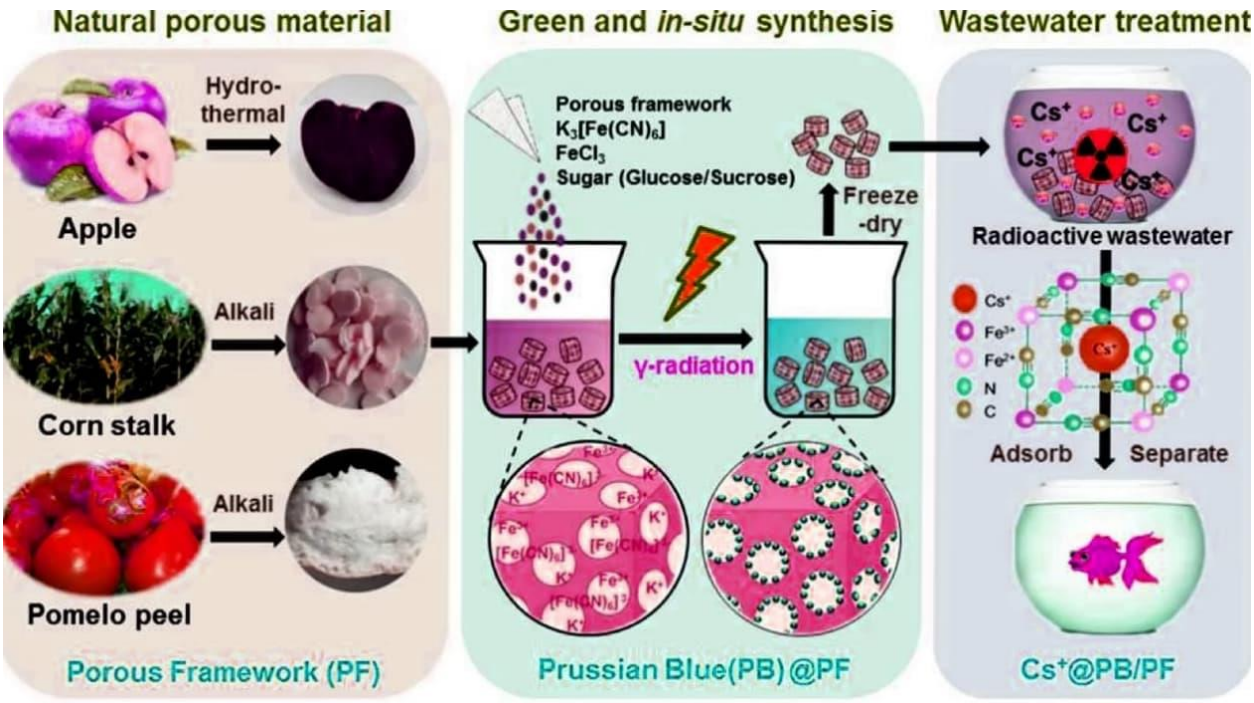


Fig 11: Schematic diagram of in situ green production strategy for Prussian blue/natural porous framework nanocomposites for radioactive Cs removal is reproduced from Ref. [63] with permission from Springer Nature, Copyright 2018.

3.4. Metal organic frame works for Photocatalysis

Metal organic frameworks can be considered as a new platform, and can organize various components to realize the functions of photoresponse, which has gained more interests in application for artificial photosynthesis [10]. Compared to traditional photocatalysts, MOFs possess structural diversity and tailor ability, which makes them have some unique advantages in photocatalysis [11]. irst, MOFs' extremely porous and crystalline structure can allow substrates and products to diffuse readily through their channels that are open and shorten the charge carriers' transportation length to the porous area for reactions, thereby lowering the electron-hole conventional volume recombine [12]. Second, structural flaws that may create recombination centers [55] can be prevented due to the high crystallinity. Third, the high density of the catalytic sites on the substrates placed in well-defined porous MOFs structure makes the enriched substrates available, and this is another advantage of this kind of system [5]. The diversity and tunability of MOFs' structure, in particular, is their greatest advantage over other inorganic materials: the performance of MOF photocatalysts can be adjusted for target structures by choosing the fine-tuning particular functional groups and/or right building blocks of MOFs. The latest developments in MOFs for light-driven energy conversion processes, such as conventional organic reactions, carbon dioxide

reduction, and splitting water, will be the main topic of this section. The degradation of organic pollutants has been the main focus of the early research on MOF photocatalysis. Guo and his colleagues recently examined the relevant studies.

3.5. Metal organic frameworks for Photocatalytic Water Separation

Two half-reactions participate in water splitting, which are water reduction, which yields hydrogen gas, and water oxidation, which yields oxygen. The initial and primarily reported reaction by MOF photocatalysts is the latter of these two half reactions, according to Fateeva and colleagues *at el* [67] , By integrating photosensitizer $Ru(bpy)_3^{2+}$ into the porous MOF [Ru2(p-BDC)2]n (p-BDC = p-benzenedicarboxylate), which is utilized to photoreduce a water to hydrogen, Mori and his coworkers reported MOFs as cocatalysts of sorts. When the -NH_2 group is added to the UiO-66 framework, the resultant NH_2-UiO-66 is a photo-catalyst that, when exposed to UV light, can clearly increase the activity of H_2 production in a aqueous methanolic solution and expand the absorption band to the visible region. In a similar vein a Ti-containing metal organic framework (NH_2-MIL125(Ti)) was shown to be a visible-light sensitive photocatalyst for a typical hydrogen evolution using Pt NPs as the standard cocatalyst and a triethanolamine (TEOA) as the electron sacrificing agent The consequences of coating NH_2-MIL-125 (Ti) with various noble metallic elements gold and platinium on photocatalytic activity under visible light irradiation in saturated carbon dioxide with TEOA present have been studied. In addition, amine functionalized MIL101(Cr) has been reported to be used for photocatalytic generation of hydrogen from water [12]. The longest wavelength is only roughly 500 nm because of the weak visible sensitivity of BDC-amine, despite the fact that MOF modified with -amine groups has been established to make hydrogen from water splitting using light that is visible. Developing MOFs with a broad light response spectrum that spans the visible spectrum is greatly desired[5]. As they absorb almost the entire visible-light spectrum, porphyrins are useful and interesting organic building blocks for the design of porphyrinic-based MOFs for photocatalysis applications. In light of this, a water-stable Al-porphyrinic MOF has a When applied as a photocatalyst for hydrogen gas production by breaking down water under visible light (VL) exposure to sunlight, it has an overall turnover number of 8.16 and a quantum yield of 4.82% Besides the extent of light absorption, charge effectiveness is important in photocatalysis. Throughout the photocatalytic process, catalysts containing elements like POMs, metal complexes, and noble metal NPs may promote more effective charge separation. Lin and colleagues have presented PT@MOF composite containing Pt NPs in MOF cavities. The Pt@ MOF composites showed outstanding productivity and a high turnover number (TON) as photocatalysts for hydrogen evolution. Jiang, Zhang, and colleagues have

created a photocatalyst that uses Pt NPs as electron acceptors in an UiO-66-NH_2 framework to effectively produce $H2$ from water splitting when exposed to visible light, as shown in Fig. 12b

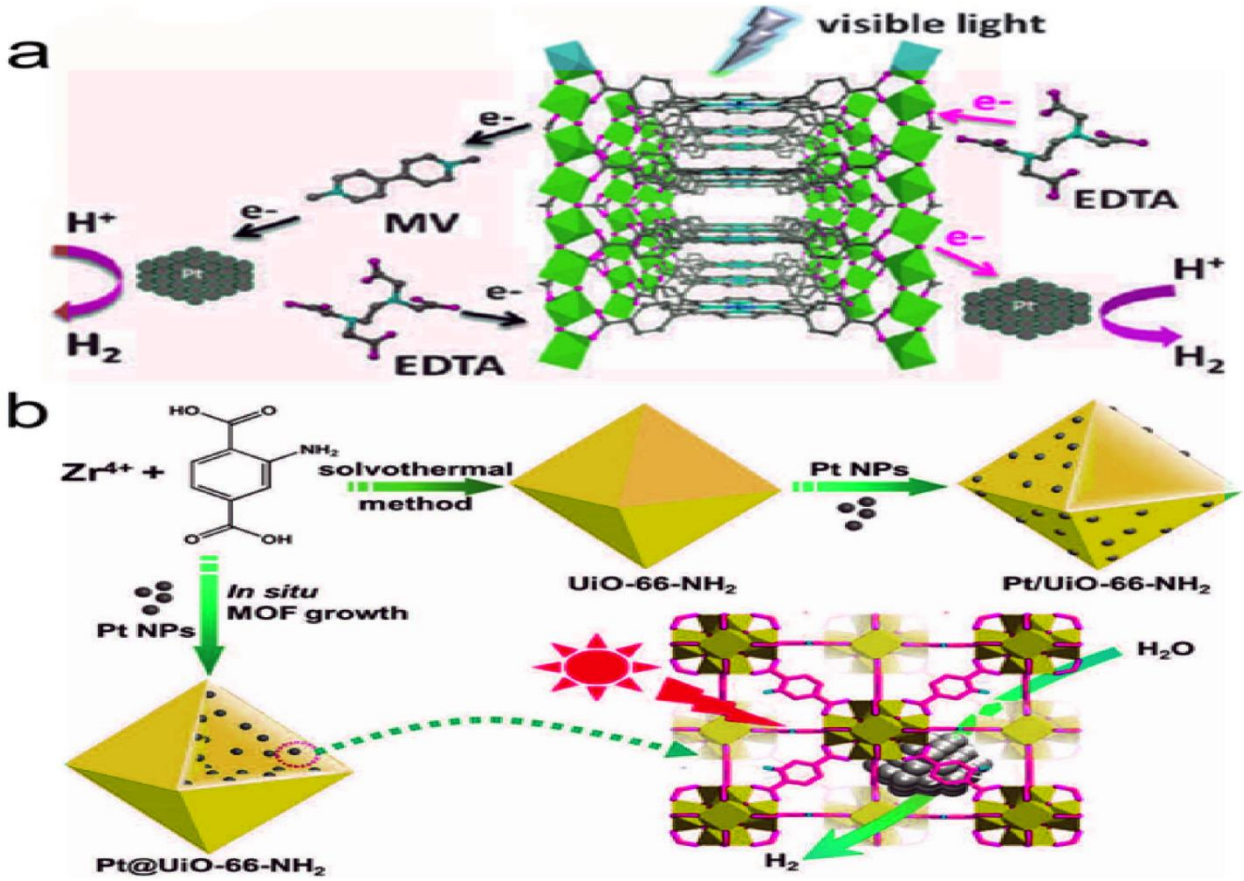


Fig12 a) water-stable Al-porphyrinic Metal organic framework as a photocatalyst for hydrogen prpduction from water separation under visible light b**)** photocatalyst of UiO-66-NH_2 incorporated with Pt NPs as electron acceptors for efficient hydrogen production from water separation under visible. Fig. 12 a and 12 b are Reproduced from Ref. [72] under the Creative Commons CC BY License.

3.6. Metal organic frameworks for Electrocatalysis

An additional option for the storage and conversion of renewable energy is the electrocatalytic system, which primarily consists of ORR, OER/HER, and electrochemical carbon dioxide reduction[10]. A novel synthesis for effectively prerpared chiral amine, amide and Ni consisting Zr-MOF DUT <136 ≥ MOFs respectively1111 by metalation and redox reaction inspired by C:N bond versatile derivatization to check catalytic activity for modified systems on a variety of asymmetric organic conversions as Micheal addition, Friedle-Crafts alkylation, Ni-catalyzed C-C coupling and aldol reaction[70]. However, catalysts of Platinium,Iridium and Ruthium metals are typically required to cover the inherently large kinetic obstacles in electrochemical processes[11]. However, noble metals' limited availability and high cost limit

their use in industry[12]. Finding earth-abundant substitutes with superior activity and stability is crucial. Metallic-containing compounds, transition metal/metal oxides, heteroatom doped carbon materials, etc. are a few examples. Organic ligands that contains carbon,hydrogen, oxygen and nitrogen with first Fe, Co, Ni, Cu, Mn, etc.typically compose the majority of MOFs [55]. MOFs have numerous benefits as non-noble metal electrocatalysts, such as a wide surface area, uniform distribution of open active centers, adjustable pore size and channels, and a designable structure [5]. However, the low conductivity and electrochemical instability of pure MOFs generally limit their electrocatalysis[18]. In order to increase their conductivity, Metal organic frame works have also been combined with conductive materials like carbon nanotubes as well as graphene [19]. Additionally, metal organic frame works were used as perfect sacrificial templates to produce a variety of nanostructured materials with great stability and conductivity, including metal oxides, porous carbons, metal (oxides)/carbon composites, and other metal-containing compounds like metal carbides and metal nitrides[5]. Some of the advantages of pure MOFs, such their high surface area, tunable porosity, and ability to be changed with additional heteroatoms and metal/metal oxides, may be present in the materials generated from MOFs[22]. In addition to significantly lengthening the range of catalytic applications, these MOF derivatives have some significant disadvantages compared to unmodified MOFs [16]. For example, in electrochemical reactions, nanostructures made with MOFs show significantly more durability than pristine MOFs, even under sensitive reaction conditions such highly acidic or basic solutions. Metal organic frame based nanomaterials used in electrocatalysis have received increasing interest and development in recently due to these advantages [69].

Challenges, Limitations, Outcomes of MOFs materials

From the recent years, MOFs have attracted huge interest of researchers worldwide because of their larger number of applications in various fields. However, at present numerous challenges and limitations are concerned includes laborious synthesis, analysis procedures, poor electrical characteristics and low solubilities [1] toxicity, degradation and reuse/recycle/regenerate[2] membrane-based MOFs need improved stability for the practical separation parameters for instance pressure and temperature [71]. The modification of size, morphology, structural arrangement, porosity, backbone framework of multicomponent MOFs is essential to achieve their excellent performance in water [4]. However, the MOFs main disadvantage is its toxicity of metal and linker, stability, size dispersity, colloidal and chemical stability, drug loading and releasing practice etc.. [5]. Furthermore, the challenge of MOFs that is currently unattainable is stability in catalysis[14]. In parallel, there are many problems related to the stability of MOF, including the issue of comparing stability between MOF and other porous fabricated materials like zeolites, porous carbons and mesoporous silica etc. which are more or less stable [7]. The

challenges that are more major for MOFs are: Selectivity, foulings, deactivation, accessibility to active sites, MOF interaction, surface area, synthesis complexity, and environmental toxic hazards. It is important to emphasize the re-use, re-cycle, regenerate and degradation of MOFs. The necessary step for the preparation of large-scale MOFs is synthesis protocol and theoretical prediction (a), preferably the reaction medium should be water (b), the organic linkers should be biodegradable, biocompatible and bio-inspired (c) and bulk organic solvents should be avoided for environment sustainability and safety (d) [8]. To overcome this, there is a need of continuous trans-disciplinary efforts from the outset, and of course, a gathering of the chemists, pharmacologists, clinicians, physicists and biologists involved in the preparation of the various MOFs.

Future Horizon

In the coming future, the synthesis of highly stable MOFs seems like a workable dream that may leads to diverse ends with respect to their applications. MOFs or variants of MOFs with stable and intellectual design with properties of each individual component, for example, can provide excellent performance for the specific applications [1]. As the synthesis of MOFs and their derivatives can be done using numerous technologies by controlling size, shape and porosity parameters. In spite of these efforts, however, there are still several shortcomings that hinder the effectiveness of designed MOFs, primarily low chemical stability, low capacity, low selectivity and high barrier to recycling and regeneration [71]. Moreover, the performance is crucial factor in various applications like catalytic processes and greater need to synthesis larger number of MOFs and their derivatives in coming days [3]. However, many more speculations about the morphology and structures for the MOFs would be prepared with cheap materials [72]. By studying the characteristics of MOFs in various properties, new materials will emerge and probably benefit from the advantages in broad range prospectives [3]. MOFs' degradation and recycling properties are also promising for environmental research to realize a benign and green future [5]. With respect to discarding and waste handling, there is a lot of work to be done with MOFs as there are no legal regulations present [6]. MOFs materials would also be improved in future using the faster-futuristic machine learning and AI methods to cater to the needs of contemporary solutions [7]. Finally, everything should be directed towards future research, not towards one dimension or another dimension to solve problems and limitations with MOFs synthesis and applications to improve human beings.

Conclusion

Metal-organic frameworks are a category of materials in which atoms are arranged in regular pattern consisting of periodic networks of nodes, including metals, connected by bridging features between self-

assembling organic molecules. This review summarizes the mechanochemical process, the primary growth method, the 2ndry growth approach, and the different types which may be in the form of powder/membrane structures and production methods of metal organic frame works materials. The most recent advancements in MOFs for different metal ion enrichment adsorption, analytical detection, and other catalytic applications are then highlighted. Then we discussed the microwave method of radical polymerization of methylmeth acrylate in detail. Future trends in MOF materials were examined, along with technical issues that need to be resolved. Additionally, other MOF applications have been researched.

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Data availability: The statistics supporting the outcomes of this research are accessible upon reasonable request from the first author.

Declarations

Ethical approval: Not applicable
Consent to participate: Not applicable
Consent to publish: All authors have given consent to publish.
Competing interest: The authors have no competing interests to declare.

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