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# Chiral covalent organic frameworks: emerging standalone photocatalysts for asymmetric organic transformations

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Synthetic chemists continue to face significant challenges in synthesis of organic molecules with precise control over absolute stereochemistry. In this review, we cover recent advances in enantioselective transformations enabled by chiral covalent organic frameworks (CCOFs) as standalone photocatalysts. These CCOFs integrate a photoactive unit and a chiral element into a single platform, in which the photocatalytic component activates the substrates, while the chiral component directs stereo induction. Although researchers have so far limited synthetic applications to a small set of benchmark C–C bond formation reactions and oxidation processes, the scope of these transformations is expected to expand steadily in the near future. Inter-disciplinary knowledge transfer from asymmetric catalysis is driving this growth and is also enabling the extension of these materials into broader applications, including chiral separation, asymmetric electrocatalysis for organic synthesis and chiral sensing technologies.

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## 1. Introduction

Enantiopure organic molecules are highly valued in numerous fields due to their distinctive properties and wide ranging applications.<sup>1</sup> In the pharmaceutical industry, enantiomerically pure drugs often exhibit superior pharmacological performance compared to their racemic mixtures.<sup>2</sup> These compounds

interact with biological targets such as receptors and enzymes with greater selectivity and binding affinity, enabling lower therapeutic doses, minimizing adverse effects, and ultimately improving patient outcomes.<sup>3</sup> As a result, the development of enantiopure pharmaceuticals has become a central objective for drug discovery and development programs.

Beyond the pharmaceutical sector, enantiopure agrochemicals, including pesticides, herbicides, and fungicides, frequently demonstrate enhanced activity and selectivity. This

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increased specificity not only improves crop protection efficiency but also helps mitigate environmental impacts.<sup>4</sup> Consequently, considerable research efforts have been directed toward achieving precise stereochemical control in organic transformations through the design of advanced chiral catalysts and chiral auxiliaries, utilizing strategies such as asymmetric catalysis<sup>5</sup> as well as kinetic and dynamic resolution methods.<sup>6</sup>

Asymmetric photocatalysis has evolved as an important strategy, which is based on homogeneous dual-catalytic systems, in which an achiral photocatalyst governs the photochemical steps while a separate chiral catalyst controls asymmetric bond formation.<sup>7</sup> Remarkable advances have been achieved by merging achiral photocatalysis with established asymmetric catalytic modes, including enamine and iminium catalysis,<sup>8</sup> Lewis acid catalysis,<sup>9</sup> Brønsted acid catalysis,<sup>10</sup> transition-metal catalysis,<sup>11</sup> N-heterocyclic carbene (NHC) catalysis,<sup>12</sup> and enzymatic catalysis.<sup>13</sup> In contrast, limited examples exist in which a single catalyst is responsible for both photochemical activation and asymmetric induction as a homogeneous system.<sup>14</sup> Such unified standalone homogeneous photocatalytic systems offer clear economic benefits and enable access to new mechanistic pathways.

Homogeneous chiral photocatalysts suffer from several intrinsic limitations, most notably the difficulty of catalyst separation after completion of the reaction. Inefficient recovery restricts recyclability and increases operational costs, a significant drawback when expensive chiral ligands or noble-metal photocatalysts are employed.<sup>15</sup> Furthermore, many homogeneous chiral systems are susceptible to photobleaching, ligand dissociation, or structural degradation under prolonged light irradiation.<sup>16</sup> Over time, deterioration of the chiral environment can also occur, leading to reduced enantioselectivity. In contrast, heterogeneous

photocatalysts can be easily separated from reaction mixtures by simple techniques such as filtration or centrifugation and reused for multiple cycles. Immobilization of the active species on solid supports often improves structural robustness and resistance to photodegradation. Additionally, well-defined pore architectures in heterogeneous systems can confine substrates within confined spaces, enhancing their proximity and orientation, which may promote improved reactivity and selectivity. Recently, chiral covalent organic frameworks (CCOFs) have emerged as efficient photocatalysts for various photocatalytic asymmetric organic reactions, which are difficult to succeed under thermal conditions. A comparison of the general advantages and challenges of both CCOFs and homogeneous chiral photocatalysts is summarized in Table 1. A careful selection of building blocks enables the construction of porous COFs exhibiting highly ordered pore architectures, structural diversity, facile functionalization, high electrical conductivity, superior chemical stability, and good mechanical processability. These attributes endow chiral COFs (CCOFs) with significant potential for applications in chiral recognition, chiral separation,<sup>17</sup> asymmetric catalysis,<sup>18</sup> and chiral optics. A significant advancement in the development of chiral COFs (CCOFs), particularly in their applications for enantioselective separation and asymmetric catalysis, has been achieved by Cui Yong's group.<sup>19</sup> A key challenge in the development of CCOFs lies in balancing the incorporation of chirality with the preservation of high crystallinity in the resulting materials. As a result, achieving precise control over chirality, functionality, and crystallinity continues to be a central objective. The reported synthetic methods for CCOFs can be broadly classified into three strategies based on their synthetic pathways (Fig. 1). Direct synthesis involves the construction of homochiral COFs from enantiopure monomers, including chiral skeleton monomers or achiral skeleton monomers bearing appended chiral centres that serve as cross-linking building units (Fig. 1a and b).<sup>20</sup> Post-synthetic modification of CCOFs involves introducing chiral functionalities into achiral parent COFs after framework construction (Fig. 1c).<sup>21</sup> Finally, in chiral induction synthesis, homochiral COFs are formed from achiral organic precursors through chiral catalytic induction (Fig. 1d).<sup>22</sup> In this review, we aim to provide a comprehensive understanding of CCOFs with an emphasis on the applications in asymmetric photocatalysis as standalone photocatalysts.

Most reported studies in asymmetric photocatalysis have centred on the benchmark transformation - the  $\alpha$ -alkylation of aldehydes, which is typically performed under homogeneous reaction conditions. To date, new asymmetric reactions employing chiral covalent organic frameworks (CCOFs) remain unexplored. Yu-Bin Dong and co-workers pioneered this field by developing a series of photoactive CCOFs, with their first report appearing in 2019 (Fig. 2).

## 2. Copper-porphyrin-based chiral COFs

Dong's group developed a porphyrin-derived chiral covalent organic framework (CCOF) *via* a direct synthesis strategy



Anjan Das

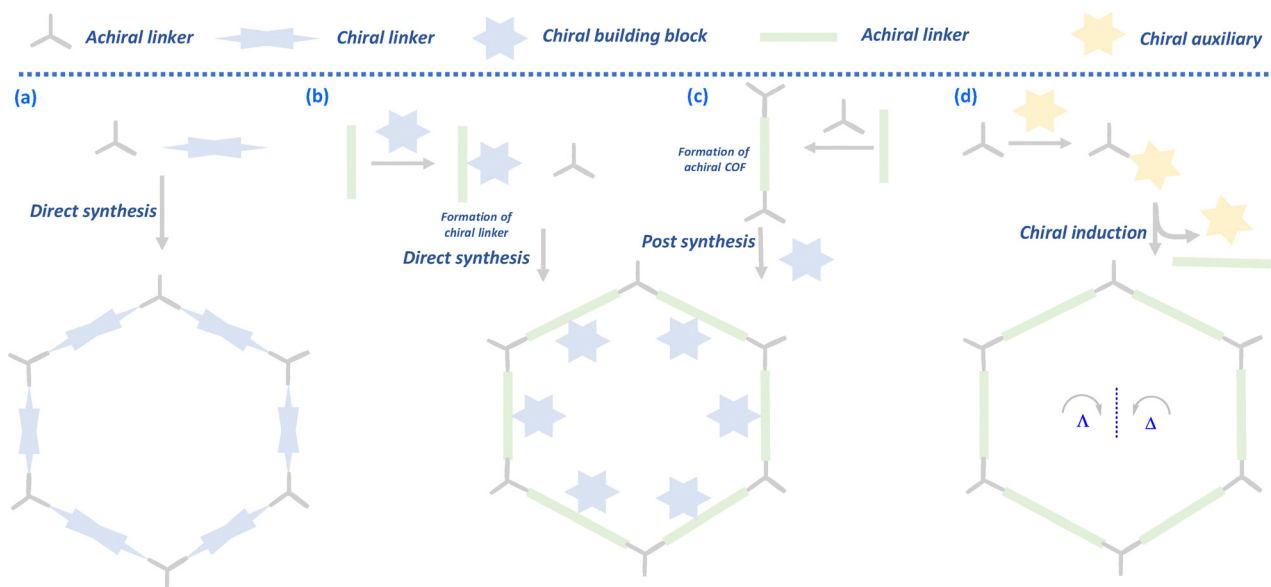
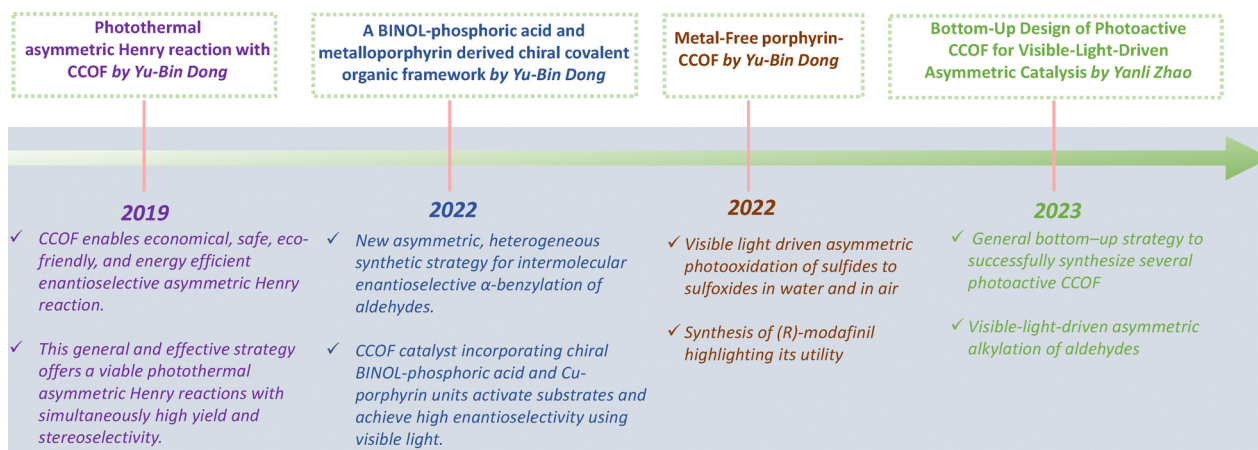
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**Table 1** General comparison of CCOFs and homogeneous chiral photocatalysts for photocatalytic asymmetric reactions

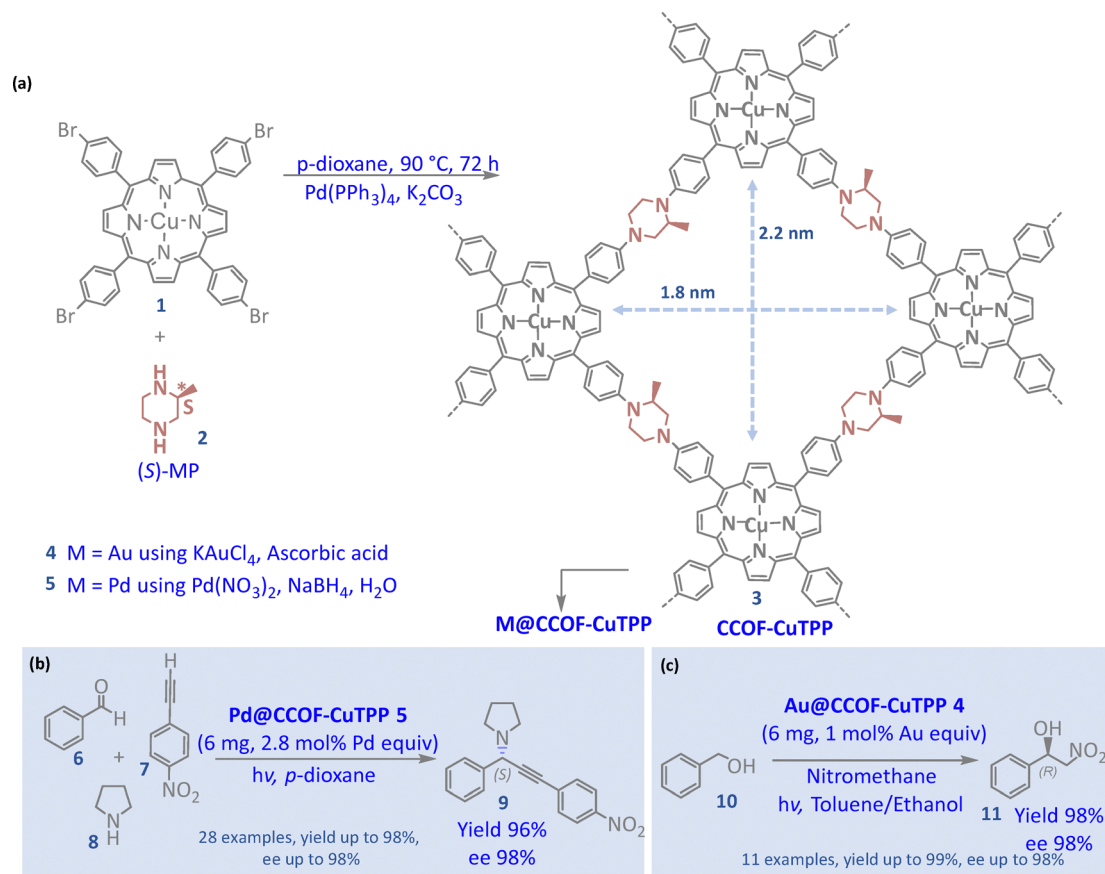
| Parameter                     | Chiral COF photocatalysts (CCOFs)   | Homogeneous chiral photocatalysts   |
|-------------------------------|---|---|
| Enantioselectivity control    | ✓ Achieved <i>via</i> confined chiral pores and spatial organization; sometimes diffusion-limited | ✓ Highly tuneable at the molecular level; typically excellent and predictable stereocontrol |
| Light harvesting              | ✓ Tunable through framework design; extended $\pi$ -conjugation enables broad absorption          | ✓ Well-defined chromophores; absorption properties precisely engineered                     |
| Recyclability and reusability | ✓ Excellent; easy separation and reuse with minimal loss of activity                              | ✗ Poor; difficult separation and often not reusable   |
| Mass transfer                 | ✗ Can be restricted due to pore size, diffusion limitations, and framework rigidity               | ✓ No mass transfer limitations in the homogeneous phase                                     |
| Stability                     | ✓ Generally good thermal and chemical stability   | ✗ Can be sensitive to light, oxygen, or reaction conditions causing possible degradation    |

**Fig. 1** Synthetic routes for chiral covalent organic frameworks (CCOFs); (a–b) direct synthesis; (c) post synthesis and (d) chiral induction method.**Fig. 2** Progress of chiral covalent organic frameworks as standalone chiral photocatalysts.

(Fig. 1a). The framework was constructed by assembling copper tetra bromo phenolphthalein (Cu-TBrPP) **1**, an achiral porphyrin linker, and the chiral organic monomer (*S*)-(+)-2-methylpiperazine (*S*-MP) **2** in anhydrous 1,4-dioxane, using

$\text{Pd}(\text{PPh}_3)_3$  as the catalyst (Scheme 1a).<sup>23</sup> The resulting material **3**, chiral covalent organic framework (CCOF), was obtained as a purple-black crystalline powder that is insoluble in common organic solvents and water, and it was characterized using





Scheme 1 (a) Synthesis of chiral CCOF-CuTPP and photothermal (b) asymmetric Henry and (c) A<sup>3</sup> coupling reaction.

various analytical techniques. Subsequently, CCOF 3 was modified by loading Au and Pd nanoparticles through successive solution impregnation and metal reduction, yielding Au@CCOF-CuTPP 4 and Pd@CCOF-CuTPP 5, respectively. Powder X-ray diffraction (PXRD) analysis confirmed that the main framework remained intact during nanoparticle loading. In addition, PXRD verified the presence of metallic Au(0) and Pd(0) in Au@CCOF-CuTPP 4 and Pd@CCOF-CuTPP 5, respectively, which was further supported by X-ray photoelectron spectroscopy (XPS). No change in the oxidation state of Cu(II) was observed after nanoparticle incorporation.

Pd@CCOF-CuTPP 5 effectively catalysed the asymmetric A<sup>3</sup> coupling (aldehyde 6-alkyne 7-amine 8) reaction *via* a photothermal pathway, producing the corresponding product 9 in 96% yield with an enantiomeric excess of 98% (Scheme 1b). Under visible-light irradiation ( $\lambda > 400$  nm), optimal performance was achieved in *p*-dioxane at room temperature over 10 h using Pd@CCOF-CuTPP 5 with a Pd loading of 2.1 or 3.2 mol%. Under visible-light irradiation, Au@CCOF-CuTPP 4 efficiently catalysed the asymmetric Henry reaction between benzyl alcohol 10 and nitromethane, delivering excellent yield, 98%, TON = 98, and TOF = 9.8 h<sup>-1</sup> along with a high enantioselectivity of 98% of the corresponding nitro alcohol 11 solvent system at room temperature over 10 h using 1 mol% Au@CCOF-CuTPP 4, whereas lower catalyst loadings led to diminished yields. (Scheme 1c). Optimal results were obtained in

toluene/EtOH (1:1) Upon visible-light irradiation ( $\lambda > 400$  nm), the reaction temperature increased to 58 °C, demonstrating that the porphyrin-based Au@CCOF-CuTPP 4 functions as an efficient COF-derived photothermal conversion material (PTCM). Control experiments confirmed that this one-pot asymmetric Henry reaction is both photoinduced and thermally driven. In this catalytic system, CCOF-CuTPP 3 serves multiple roles, including chiral confinement, photothermal conversion, and partial catalytic activity, while the supported Au nanoparticles act as the primary catalytic sites. Notably, the reaction also proceeded under natural sunlight, affording the desired nitroaldol product 11 in a moderate yield of 49% while retaining excellent enantioselectivity (96% ee).

In a later work, Dong's group have described the design and application of a homochiral covalent organic framework (HCCOF) as an efficient heterogeneous catalyst for the asymmetric synthesis of a key pharmaceutical intermediate, (S)-2-(2-chlorophenyl)-2-(6,7-dihydrothieno[3,2-c]pyridin-5(4H)-yl)acetonitrile, in short (S)-CIK 17, which is crucial in the production of the widely used antiplatelet drug (S)-clopidogrel 18 *via* subsequent alkaline hydrolysis and salt formation steps. The CCOF, namely (R)-CuTAPBN-COF 14, by integrating two functional components into a single framework-Cu(II)-porphyrin unit 12 acting as Lewis acid catalytic sites, enables photothermal conversion under visible light, and chiral BINOL-derived linker 13 provides enantioselective control; the

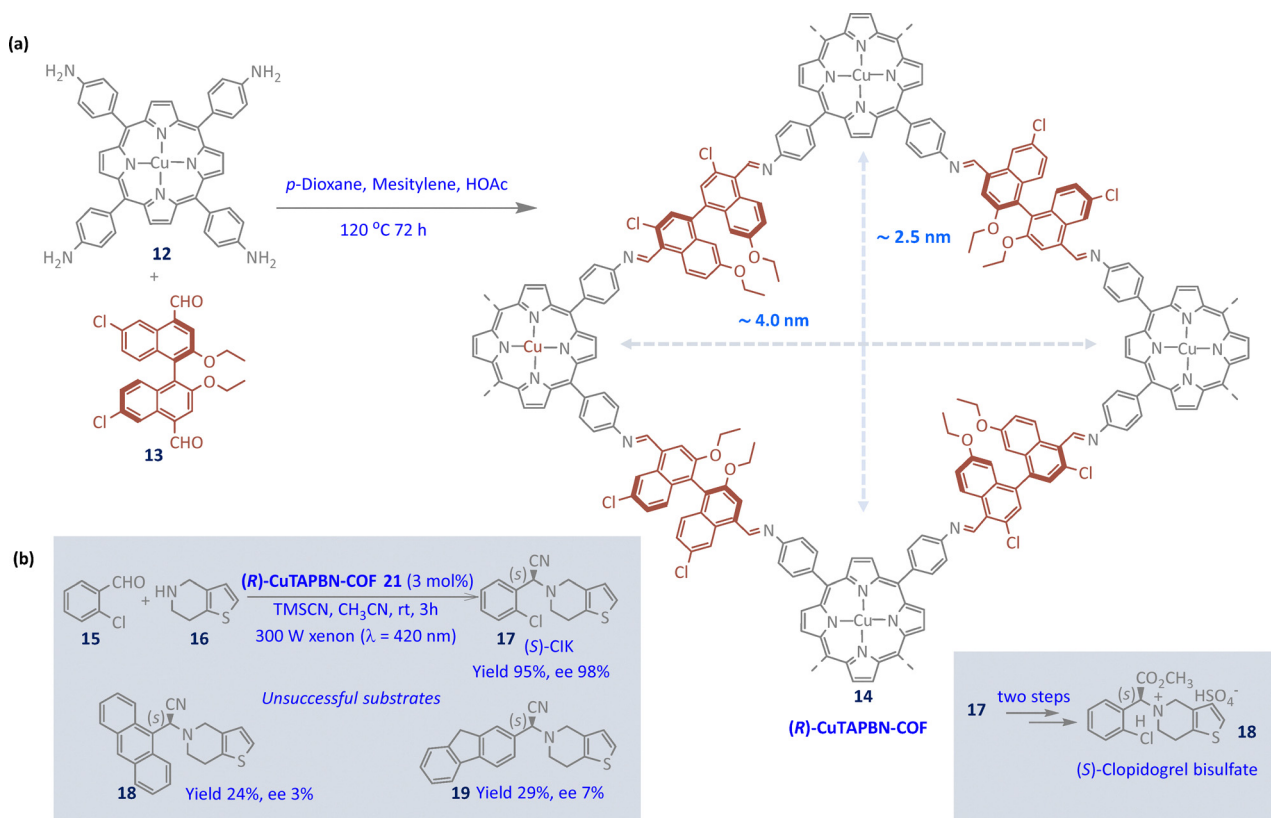


material forms a two-dimensional crystalline porous network with high stability, moderate surface area, and well-defined nanochannels, which facilitate substrate diffusion and provide a confined chiral environment for the reaction (Scheme 2a).<sup>24</sup>

The catalytic performance of this material was evaluated in the asymmetric Strecker reaction for synthesizing (*S*)-CIK **17** starting from *o*-chloro benzaldehyde **15**, 4,5,6,7-tetrahydrothieno [3,2-*c*]pyridine **16** and TMSCN as the source of cyanide (Scheme 2b). Under visible-light irradiation, the catalyst exhibited excellent activity, achieving up to 98% yield with 94% enantiomeric excess/within a short reaction time. Mechanistic investigations revealed that the reaction is thermally driven, where visible light is primarily used to generate heat through photothermal conversion rather than direct photochemical activation. Control experiments confirmed that both the chiral framework and the embedded copper sites are essential. The framework ensures enantioselectivity through chiral confinement, while the metal centre provides catalytic activity. The system was successfully applied in a continuous-flow reactor, enabling gram-scale synthesis of (*S*)-CIK **17** with high yield (90%) and enantioselectivity (93%), which highlights its potential for industrial applications.

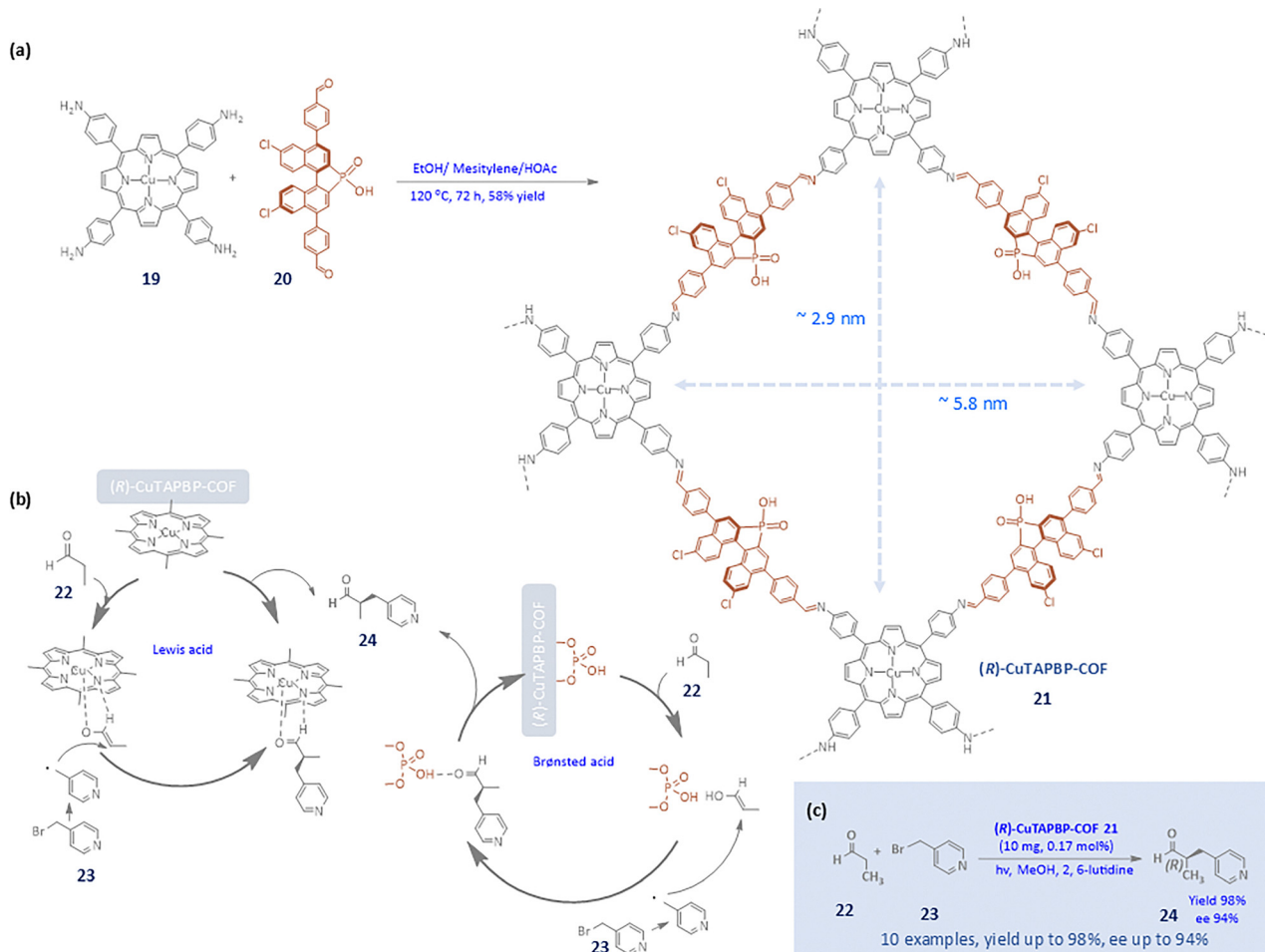
In a subsequent study, a bifunctional photocatalytic system was rationally designed by integrating chiral BINOL-derived phosphoric acid unit **20** and Cu(II)-porphyrin module **19** into a single, well-defined covalent organic framework (COF) **21** (Scheme 3a).<sup>25</sup>

This deliberate architectural integration gives the resulting material, denoted as (*R*)-CuTAPBP-COF **21**, with synergistic and desirable features. Specifically, the framework simultaneously incorporates Brønsted acidic sites originating from the chiral phosphoric acid moieties **20** and Lewis acidic centres provided by the Cu(II)-porphyrin unit **19**. Moreover, the periodic and rigid COF skeleton creates a robust chiral confinement environment, which plays a crucial role in steering enantioselective transformations. Importantly, the embedded Cu(II)-porphyrin chromophores impart efficient visible-light absorption and enable effective photothermal conversion under light irradiation. Owing to this unique combination of dual acidity, chiral microenvironments, and light-responsive photothermal behaviour, (*R*)-CuTAPBP-COF **21** exhibits good catalytic performance in promoting intermolecular asymmetric  $\alpha$ -benzylation of aldehyde **22** with 4-(bromomethyl)pyridine **23** to generate the corresponding enantioenriched product **24** with 98% yield and 94% ee (Scheme 3c). Under visible-light irradiation, the catalyst converts photon energy into localized thermal energy, thereby driving the reaction in a light-induced, thermally activated manner while maintaining high levels of enantioselectivity. The mechanism involves the combination of both Lewis and Brønsted acidic cycles. First, aldehydes bind to the catalyst followed by alkyl radical addition photogenerated from corresponding alkyl bromide in an asymmetric fashion (Scheme 3b). Furthermore, the robustness and efficiency of the COF-based catalyst allow the reaction to be readily scaled



Scheme 2 (a) Synthesis of (*R*)-CuTAPBN-COF **14**, and (b) photocatalytic synthesis of (*S*)-CIK **17**.





Scheme 3 (a) Synthesis of *(R)*-CuTAPBP-COF, and (b) application in enantioselective  $\alpha$ -benzylation of aldehydes.

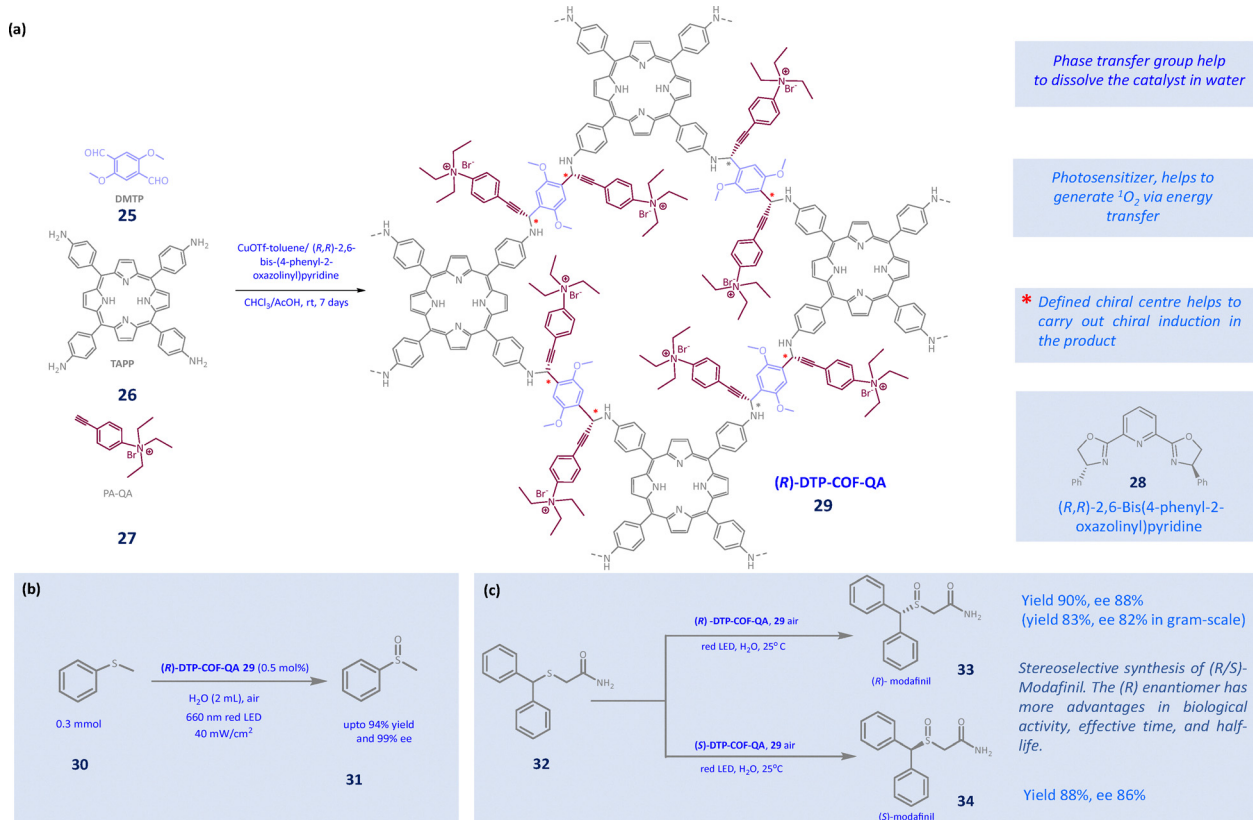
up to the gram level without any significant loss in activity or stereocontrol. The broad applicability of this catalytic system is further demonstrated by its excellent generality across a wide range of substrates, including various substituted aldehydes and diverse alkyl bromides. Collectively, these results underscore the potential of multifunctional, light-responsive chiral COFs as powerful and versatile platforms for sustainable asymmetric catalysis.

### 3. Porphyrin-based chiral COFs with phase transfer groups

In another study, Dong's group reported the development of a quaternary ammonium bromide-decorated chiral photocatalytic system through the integration of multiple functional components into a single covalent organic framework. In this work, a popular photosensitizer, 4-(10,15,20-triphenylporphyrin-5-yl)aniline (TAPP) 26, was combined with a phase-transfer-active quaternary ammonium bromide-functionalized phenylacetylene (PA-QA) 27 and a bis aldehyde (DMTP) 25. The synthesis of *(R)*-DTP-COF-QA 29 was achieved under mild, ambient conditions *via* an asymmetric  $A^3$ -coupling polymerization reaction. Achiral

2,5-dimethoxyterephthalaldehyde (DMTP) 25, together with TAPP 26 and PA-QA 27, underwent polymerization in the presence of a chiral copper catalyst, CuOTf-pybox [pybox = (*R,R*)-2,6-bis(4-phenyl-2-oxazolynil)pyridine] 28, which effectively induced chirality during framework formation (Scheme 4a).<sup>26</sup> Spectroscopic studies further revealed that *(R)*-DTP-COF-QA 29 exhibits a broad and intense absorption band spanning the entire visible-light region, making it particularly well suited for photocatalytic applications under solar irradiation. Benefiting from the synergistic interplay among the porphyrin-based photosensitizer, the chiral propargylamine moieties, and the amphiphilic quaternary ammonium bromide units, *(R)*-DTP-COF-QA 29 demonstrates outstanding performance in visible-light-driven asymmetric catalysis. In particular, the framework efficiently promotes the enantioselective photooxidation of sulfide, Thio anisole 30, to the corresponding sulfoxide 31 in water and in air, without the need for inert atmospheres or harsh reagents (Scheme 4b). The quaternary ammonium bromide functionalities facilitate phase transfer and substrate accessibility in aqueous media, while the chiral environment within the COF channels ensures high levels of stereocontrol. Under optimized reaction conditions, this chiral photocatalyst, (*R* and *S*)-DTP-COF-QA 29, was applied for the synthesis of both enantiomeric forms of modafinil (*R* 33 and





Scheme 4 (a) Synthesis of  $(R)$ -DTP-COF-QA and application for (b) enantioselective photooxidation of sulfides into sulfoxides in water and air, and (c) synthesis of  $(R/S)$ -modafinil.

**S 34**) by simply changing the configuration of DTP-COF-QA **29** starting from **32** (Scheme 4c).

## 4. Porphyrin based COFs

Later in 2023, Y. Zhao and co-workers reported a rational bottom-up strategy for designing photoactive chiral covalent organic frameworks (CCOFs) capable of performing visible-light-driven asymmetric catalysis with high efficiency and selectivity. They designed a series of CCOFs (CCOF **37a–e**) by incorporating porphyrin-based photoactive unit **35** as a structural node and secondary amine-based chiral catalytic site **36** onto the pore walls through benzimidazole linkers (Scheme 5a).<sup>27</sup> The porphyrin units function as light-harvesting probes, absorbing a broad spectrum of light (250–1000 nm), while the chiral amines provide enantioselective catalytic activity. The resulting frameworks exhibit high crystallinity, large surface areas (up to  $1238\text{ m}^2\text{ g}^{-1}$ ), uniform pore sizes ( $\sim 2.1\text{--}2.4\text{ nm}$ ), and excellent thermal stability. The catalytic performance of these materials was evaluated in the visible-light-driven asymmetric alkylation of aldehyde **38** with bromo alkane **39**. The optimized catalyst, CCOF **37a**, demonstrated excellent activity, achieving yields up to 80% and enantiomeric excess (ee) up to 93% of the corresponding enantioenriched product **40**. Control experiments confirmed that both light and the presence of the catalyst are essential for the reaction and that the chiral secondary amine groups are

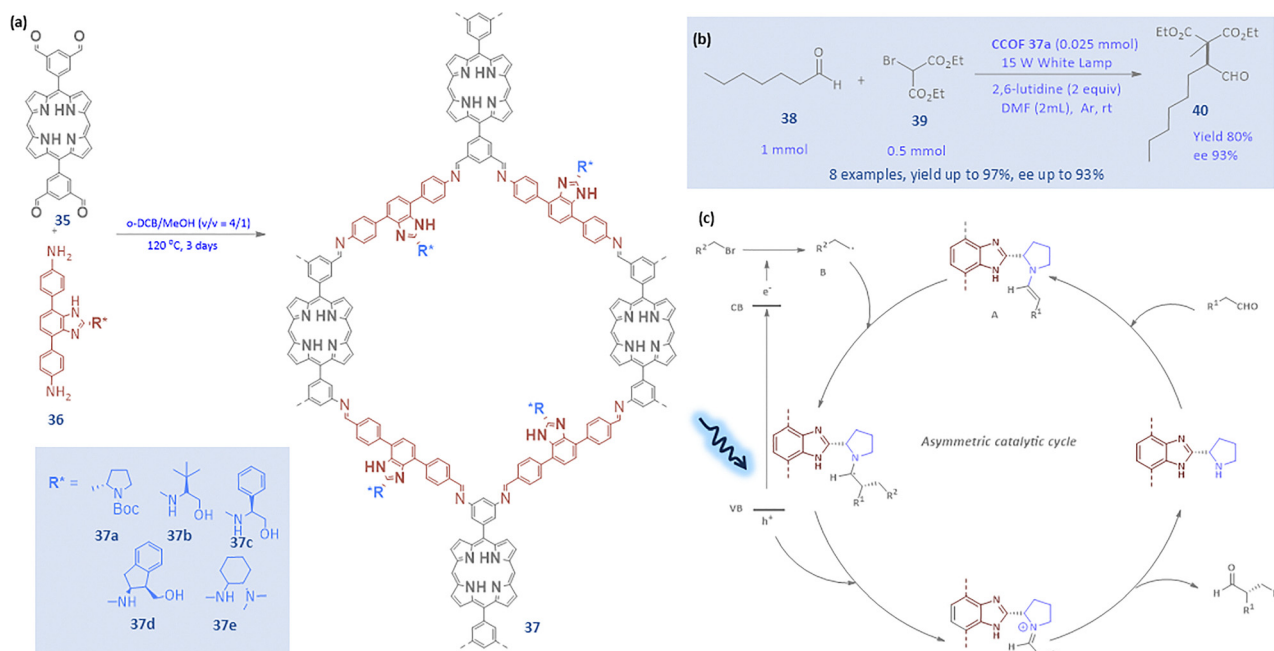
the true active sites. Compared to analogous homogeneous catalysts, the CCOFs showed superior enantioselectivity and the added advantage of easy recovery and reuse. The catalyst retained its activity and crystallinity over multiple cycles, highlighting its robustness. The substrate scope demonstrates that a wide variety of aldehydes and brominated compounds can be successfully transformed, maintaining high yields and good enantioselectivity.

Mechanistically, the reaction proceeds *via* a synergistic combination of photocatalysis and organocatalysis (Scheme 5c). Upon visible light irradiation, the porphyrin units generate electron-hole pairs. The photogenerated electrons reduce the bromide substrate to form a radical species, while the aldehyde is activated by the chiral amine to form an enamine intermediate. These two intermediates couple to form a new radical species, which is subsequently oxidized and hydrolysed to yield the chiral product while regenerating the catalyst. Photophysical studies, including band gap analysis ( $\sim 1.5\text{ eV}$ ), Mott-Schottky measurements, and fluorescence lifetime studies, support efficient charge separation and electron transfer processes within the framework.

## 5. Outlook and future perspectives

Chiral covalent organic frameworks (CCOFs) have recently attracted significant attention in the field of photocatalysis due to their unique structural attributes, ordered porosity,





**Scheme 5** (a) Synthesis of photoactive chiral covalent organic frameworks (CCOFs) and application for (b) visible-light-driven asymmetric alkylation of aldehyde and (c) a possible mechanism.

tunable functionality, and inherent chirality. The integration of photocatalytic activity with enantioselectivity in a single framework offers a promising strategy to address longstanding challenges in asymmetric synthesis. Given the increasing demand for green and efficient catalytic systems, CCOFs present an innovative platform capable of harnessing light energy to drive enantioselective organic reactions under mild conditions. However, despite rapid advancements, still at an early developmental stage, the outlook for CCOFs is highly promising, driven by growing demands for sustainable, metal-free, and reusable catalytic platforms capable of achieving high enantioselectivity under mild conditions. Current challenges of achieving precise and uniform chiral environments within the framework remain difficult. Many reported CCOFs rely on post-synthetic modification (PSM) to introduce chiral moieties, which often leads to incomplete functionalization and non-uniform distribution of chiral sites. This heterogeneity reduces the photocatalytic performance and enantioselectivity of reactions, particularly when compared to well-defined homogeneous chiral photocatalysts. Additionally, efficient photocatalysis requires effective generation, separation, and migration of photoexcited charge carriers (electrons and holes). In many current CCOFs, the conjugated  $\pi$ -systems used to absorb visible light often lack sufficient separation between donor and acceptor units. This results in rapid recombination of charge carriers before they can participate in chemical transformations, lowering quantum efficiency and limiting catalytic turnover. To date, only a limited number of asymmetric photocatalytic transformations have been demonstrated with CCOFs. These reactions tend to focus on model systems with well-behaved substrates. However, for CCOFs

to be widely useful, they must catalyse a broader range of valuable asymmetric reactions, including C–H activation, enantioselective cross-couplings, and heteroatom functionalization, with high efficiency under mild conditions. Current frameworks struggle to accommodate such diversity due to size restrictions, steric hindrance, or insufficient activation energy. While CCOFs are generally stable under inert conditions, many suffer from limited chemical stability under photocatalytic reaction conditions, especially in the presence of protic solvents or reactive intermediates. This can lead to framework degradation, loss of crystallinity, or leaching of active sites. Moreover, the scalability of synthesis, producing large quantities of phase-pure, crystalline CCOFs reproducibly, remains a challenge for industrial translation. Additionally, understanding how CCOFs accomplish chiral induction and photocatalytic turnover at the molecular level remains a major challenge. The heterogeneity and complexity of the porous network complicate mechanistic studies, making it difficult to optimize design principles rationally.

Despite the outlined limitations, several exciting avenues of research are emerging that offer promise for overcoming current barriers and establishing CCOFs as practical asymmetric photocatalysts. Advances in synthetic chemistry now enable the bottom-up inclusion of chiral building blocks, such as enantiopure linkers or chiral macrocycles, during CCOF assembly. By introducing chirality at the monomer level, it becomes possible to generate more uniform and predictable chiral environments within the pores that closely resemble traditional homogeneous chiral catalysts. Coupling this with computational design and machine learning can inform optimal spatial arrangement of chiral centres. To address limited light absorption and



charge recombination, researchers are exploring donor–acceptor architectures, incorporation of photosensitizers, or heteroatom doping to shift absorption toward longer wavelengths and improve separation. For example, integrating metal-free chromophores with strong visible absorption, such as perylene diimides or boron-doped units, can significantly enhance light harvesting. Combining CCOFs with other functional materials, such as metal nanoparticles, semiconductor quantum dots, or molecular catalysts, can create hybrid systems that leverage the strengths of each component. Metal nanoparticles can act as active sites for electron transfer, while the CCOF scaffold provides chirality and porosity. Such synergy could expand the photocatalytic scope while maintaining enantioselectivity. Advances in PSM strategies can allow for fine-tuning of pore environments, enabling the installation of catalytic functionalities after framework formation. Dynamic covalent chemistry enables reversible bonds that can adapt under reaction conditions, potentially improving stability and catalytic efficiency. PSM could also allow for modular introduction of different chiral ligands, making CCOFs more versatile. Emerging analytical techniques, such as *in situ* spectroscopy, time-resolved photoluminescence, and high-resolution electron microscopy-coupled with computational modelling, can help unravel the mechanisms by which CCOFs mediate photocatalytic asymmetric transformations. A deeper mechanistic understanding would accelerate the design of more efficient frameworks and guide synthetic optimization. Future work should aim to broaden the types of asymmetric reactions catalysed by CCOFs. For instance, enantioselective radical reactions, cascade transformations, and C–H functionalization could unlock new synthetic pathways that are difficult to achieve with traditional catalysts. Developing CCOFs that can operate in aqueous media or continuous flow systems would further enhance their synthetic utility. From a broader perspective, CCOFs hold potential for sustainable catalytic processes, especially if derived from bio-based or earth-abundant precursors and powered by sunlight. Improving the scalability of CCOF synthesis and ensuring long-term operational stability are essential steps toward industrial adoption. Collaborations between synthetic chemists, engineers, and materials scientists will be key to translating laboratory success to practical applications.

In summary, chiral covalent organic frameworks represent an exciting frontier in asymmetric photocatalysis. They combine structural order, porosity, and inherent chirality with the ability to harness light energy for chemical transformations. However, current challenges such as limited control over chirality, suboptimal light absorption, narrow reaction scope, and stability issues must be addressed for meaningful progress. Encouragingly, advances in material design, hybrid systems, mechanistic understanding, and synthetic methodology offer promising routes to overcome these obstacles. With sustained interdisciplinary efforts, CCOFs are poised to become powerful, sustainable platforms for enantioselective photocatalysis, contributing significantly to green and efficient synthetic chemistry.

## Author contributions

AD selected the topic, designed and supervised the writing of this review. HI and VKS gathered the references and composed the manuscript.

## Conflicts of interest

There are no conflicts to declare.

## Data availability

No primary research results have been included and no new data were generated or analysed as part of this review.

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