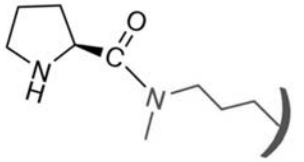
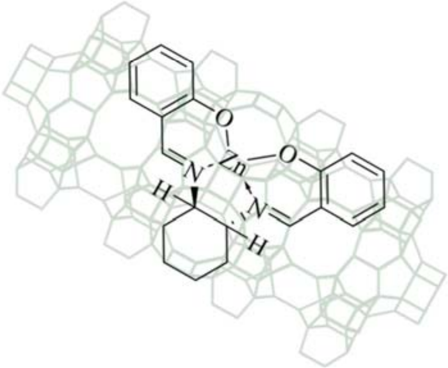
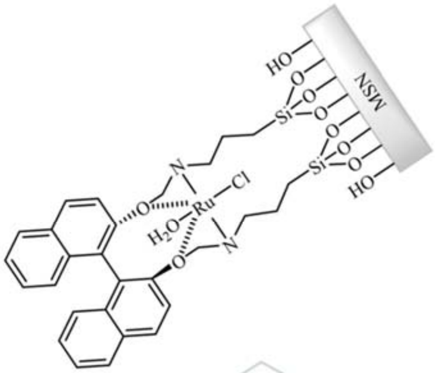
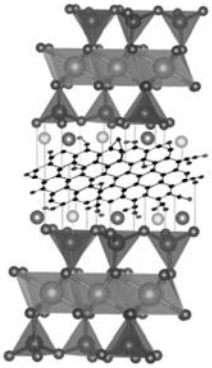
Chapter 7

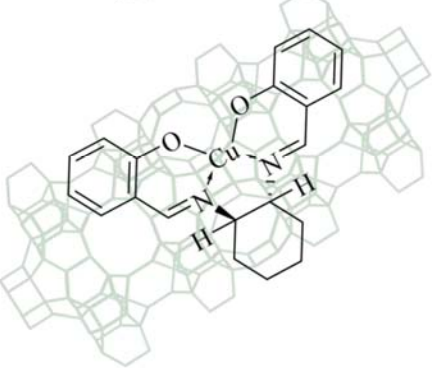
Conclusion & Future perspectives











Overall Conclusion of the Thesis:

In the pursuit of unraveling the intricate world of porous silica materials as catalyst supports, this thesis has embarked on a comprehensive journey through seven illuminating chapters. The work of catalysis conducted on these architecturally diverse platforms has been explored, shedding light on their structural nuances, synthesis strategies, and catalytic prowess, showcasing their far-reaching impacts from fine chemical synthesis to industrial processes. Each chapter paints a vivid panorama of their catalytic innovation and role in sustainable chemical transformations. These materials are clearly pivotal in ushering in an era of selective and sustainable chemistry.

In conclusion, this thesis represents a comprehensive exploration of porous silica materials as catalyst supports across various chapters, each contributing unique insights and innovative approaches. Chapter 1 established the foundational importance of porous silica materials, shedding light on their structural intricacies, synthesis techniques, and catalytic potential. In the Chapters 2, a remarkably effective and enantioselective catalyst has been synthesized by anchoring the *L*-proline chiral framework onto the silica matrix, denoted as *L*-proline-(3°amine)-*f*-SiO_2, eluding the protection/deprotection steps as well without using pricy organic moiety. The as-synthesized catalyst was weigh-up against the asymmetric aldol reaction, demonstrating exceptional performance. In the Chapters 3, we develop a state-of-the-art method to synthesize exceedingly competent and enantioselective system by grafting Ru(III) (*S*) BINOL moiety onto MSNs. Previously reported methods employed a backside approach, but we applied a frontside approach due to its reduced number of steps. It demonstrated unique activity in stereoselective transfer asymmetric hydrogenation. In Chapter 4, we report for the first time the encapsulation of chiral Cu(II)–salen complexes inside MWW-framework zeolite pores and tested for one-pot multicomponent Biginelli reaction in liquid phase. To comprehend the nature of the structural and electronic changes that occur in complexes under the influence of the MWW zeolite framework, a density functional theory (DFT) approach has been applied. Based on theoretical and experimental evidence, chiral Cu(II)–salen complex and MWW zeolite interact well after encapsulation. In Chapter 5, we report a green decorum for synthesizing distinctive Zn(II)–salen ligand encapsulated in MWW-zeolite host as a heterogeneous chiral catalyst, i.e., Zn(II)–salen@MWW-zeolite, and employed for the efficient and rapid synthesis of β-amino ketones under milder conditions using an ultrasound-assisted one-pot approach in solvent-free conditions. In Chapter 6, the synthesis and characterization of composite materials added a new dimension to the research, enhancing thermal stability and catalytic potential. Furthermore, the synthesized chiral thiourea-based (CTU) moiety was incorporated into the MMT-silica-GO-based composite and evaluated for its catalytic performance in the Strecker reaction. Collectively, these findings mark significant advancements in the field of heterogeneous chiral catalysis, offering promising solutions to ongoing challenges and inspiring the development of more robust and environmentally friendly catalysts for various organic transformations. The future of catalysis appears bright, guided by the insights and innovations presented throughout this thesis.

Future perspectives

The field of heterogeneous chiral catalysis holds immense potential for asymmetric synthesis, but it also faces several challenges that need to be addressed to ensure its future success. The synthesis of efficient chiral heterogeneous catalysts has shown promising results, with various immobilization techniques like encapsulation, chemical grafting, layered materials, intercalation, and ionic contact being explored. However, achieving high enantioselectivity and stability remains a significant challenge. The impact of solid supports' surfaces and pores on activity and selectivity has been demonstrated, but a deeper understanding of the confinement effect is needed to enhance enantioselectivity further.

Looking ahead, the future of heterogeneous chiral catalysis is bright with ongoing research aimed at developing new catalysts with improved selectivity, stability, and activity. The advancement of chiral materials and innovative synthetic approaches is expected to uncover new catalytic reactions with unprecedented selectivity and efficiency. An exciting direction for the field involves the increasing use of computational methods to design and optimize heterogeneous chiral catalysts. Computational modeling can offer valuable insights into catalytic mechanisms and guide the synthesis of new catalysts with enhanced properties.
Furthermore, the future of heterogeneous chiral catalysis holds great promise, with continuous research and development leading to the discovery of novel and more effective catalytic systems for a wide range of chemical transformations. By addressing the current challenges and leveraging computational approaches, this field is poised to make significant contributions to the production of industrial chiral chemicals and advance the frontiers of asymmetric synthesis.