ORGANIC CHEMISTRY
FRONTIERS

RESEARCH ARTICLE

View Article Online
View Journal | View Issue

Cite this: *Org. Chem. Front.*, 2024, **11**, 6319

Well-defined chiral dinuclear copper-catalyzed tandem asymmetric propargylic amination–carboxylative cyclization sequence toward chiral 2-oxazolidinone derivatives†

Yu Lan,[a,b] Peng Liu,[b] Zekai Fang,[b] Lili Shao,[b] Qilong Cai*[b] and Xiaoming Wang *[b,c,d,e]

Received 25th July 2024,
Accepted 14th September 2024

DOI: 10.1039/d4qo01368a

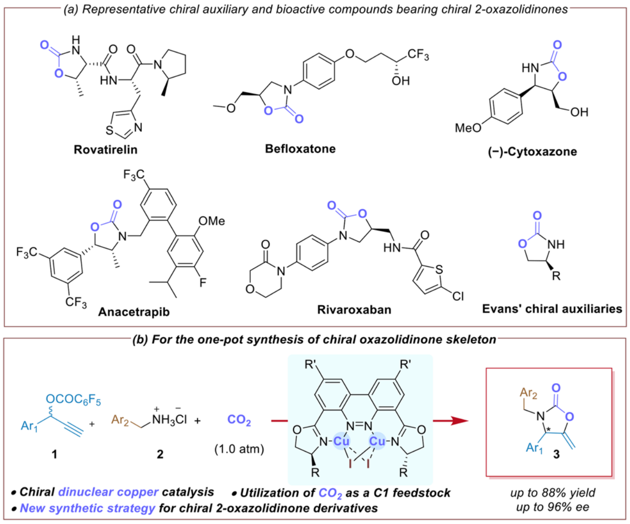
rsc.li/frontiers-organic

We report a novel strategy for the synthesis of chiral 2-oxazolidinones *via* a dinuclear copper-catalyzed asymmetric propargylic amination–carboxylative cyclization sequence of propargylic esters with nucleophilic alkyl amines under ambient pressure of carbon dioxide. A variety of chiral 2-oxazolidinones featuring an exocyclic methylene moiety was obtained in good yields with high enantioselectivities *via* a one-pot operation.

Introduction

Five-membered heterocyclic compounds like 2-oxazolidinones have found wide ranging applications in medicinal chemistry, organic synthesis and agrochemistry (Scheme 1a).[1] Moreover, chiral 2-oxazolidinones have been shown to be of great significance in the realm of asymmetric synthesis, serving as a versatile class of chiral auxiliaries or ligands in the stereoselective synthesis of enantioenriched compounds.[2] Therefore, the efficient synthesis of chiral 2-oxazolidinones and their derivatives is of great interest in organic chemistry and medicinal sciences.[3]

Utilization of carbon dioxide (CO_2) as an inexpensive, non-toxic, and renewable C1 feedstock has attracted attention in the past decades.[4] A variety of methods has been developed for the synthesis of achiral 2-oxazolidinones through the cyclization of propargylamines and carbon dioxide.[5] However, the use of CO_2 in catalytic asymmetric tandem reactions for the synthesis of chiral 2-oxazolidinones in one pot is largely underdeveloped.[6,7] In this context, two elegant methods have been developed for the synthesis of chiral *N*-aryl 2-oxazolidinones based on a tandem process, including the synthesis of chiral propargylamines from an asymmetric aldehyde–alkyne–amine (A^3) coupling reaction[6] or an asymmetric transfer hydrogenation of alkynyl ketimines,[7] followed by a carboxylative cyclization with CO_2. However, the synthesis of chiral 2-oxazolidinones bearing an exocyclic methylene motif has been less explored. Therefore, the development of a novel catalytic strat-



Scheme 1 Asymmetric propargylic amination–carboxylative cyclization sequence toward chiral 2-oxazolidinone derivatives.

---

[a] College of Chemistry and Materials Science, Sichuan Normal University, Chengdu, 610068, China

[b] State Key Laboratory of Organometallic Chemistry and Shanghai Hongkong Joint Laboratory in Chemical Synthesis, Center for Excellence in Molecular Synthesis, Shanghai Institute of Organic Chemistry, University of Chinese Academy of Sciences, Chinese Academy of Sciences, 345 Lingling Road, Shanghai, 200032, China. E-mail: xiaoming@sioc.ac.cn

[c] School of Chemistry and Materials Science, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences, 1 Sub-lane Xiangshan, Hangzhou 310024, China

[d] School of Chemistry and Chemical Engineering, Henan Normal University, Xinxiang, 453007, China

[e] Ningbo Zhongke Creation Center of New Materials, Ningbo 315899, China

† Electronic supplementary information (ESI) available. CCDC 2356244. For ESI and crystallographic data in CIF or other electronic format see DOI: **https://doi.org/10.1039/d4qo01368a**

egy for the asymmetric synthesis of chiral 2-oxazolidinones derivatives is still highly desirable.[3]

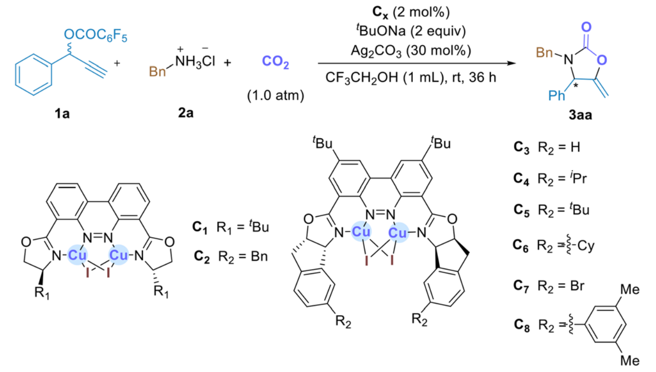
Although various bi/multi-nuclear copper complexes have been reported,[8] their applications in asymmetric catalysis are still much less developed.[9] Recently, we disclosed the successful development of a series of binuclear copper catalysts[10] based on chiral benzo[*c*]cinnoline dioxazoline frameworks,[11] and their applications in catalytic asymmetric propargylic substitution reactions. Since van Maarseveen and Nishibayashi's pioneering work in 2008,[12] copper-catalyzed asymmetric propargylic amination of propargylic esters has been an efficient method for the synthesis of chiral propargyl amines.[13] Herein, we report a novel strategy for the synthesis of chiral 2-oxazolidinones *via* a dinuclear copper-catalyzed asymmetric propargylic amination–carboxylative cyclization sequence of propargylic esters with alkyl amine hydrochlorides under an ambient pressure of carbon dioxide (Scheme 1b).[14] A variety of chiral 2-oxazolidinones featuring an exocyclic methylene motif and a *N*-alkyl group was obtained in good yields with excellent enantioselectivities.

Results and discussion

Reaction development and scope

The studies were initiated by taking the reaction of propargyl carbonate (**1a**) with benzylamine hydrochloride (**2a**) under an atm of CO_2 as the model reaction and the feasibility of the proposed asymmetric propargylic amination–carboxylative cyclization sequence using the binuclear Cu complexes $\mathbf{C_1}$–$\mathbf{C_8}$ as catalysts was investigated. A careful survey of the reaction parameters using catalyst $\mathbf{C_1}$ revealed that the reaction proceeded well in CF_3CH_2OH at room temperature for 36 h in the presence of ^{t}BuONa (2.0 equiv.) and Ag_2CO_3 (30 mol%) as additives, affording the desired product **3aa** in 51% yield with 73% ee (Table 1, entry 1). Under otherwise identical conditions, other bicopper catalysts, $\mathbf{C_2}$–$\mathbf{C_8}$, with different substituents on the oxazoline units or the cinnoline backbone of the ligands were subsequently evaluated in the reaction (Table 1, entries 2–8). The reaction catalyzed by $\mathbf{C_2}$, with a benzyl group on the oxazoline unit, gave product **3aa** in 54% yield with 70% ee (entry 2). To our delight, upon using catalyst $\mathbf{C_3}$ with the ligand derived from 2-aminoindanol, the desired product **3aa** was obtained with an improved ee value of 79% (entry 3). The reaction using catalyst $\mathbf{C_4}$, with increased steric hinderance of the oxazoline units, led to a significant improvement in the ee to 85% (entry 4). Using catalyst $\mathbf{C_5}$ featuring further enhanced steric hindrance of the oxazolyl moiety, the ee value of **3aa** was increased to 87% (entry 5). Proceeding further by using $\mathbf{C_6}$ bearing cyclohexyl groups on the indanyl scaffold as the catalyst, the reaction afforded **3aa** in good isolated yield (64%) with excellent enantioselectivity (91% ee, entry 6). However, the introduction of an electron-withdrawing (–Br) group on the indanyl scaffold of catalyst $\mathbf{C_7}$ significantly decreased the enantioselectivity of the reaction (entry 7). In addition, catalyst $\mathbf{C_8}$, with large steric hinderance on the indenyl scaffold, was also tested, resulting in poor catalytic performance (47% yield, 70% ee) (entry 8). Furthermore, various silver salts had similar impact on the reaction and Ag_2CO_3 was found to be optimal for the reaction (see the ESI† for reaction details). In addition, free benzylamine was also tested under the optimized conditions (as shown in entry 6), and the desired product was obtained in 74% yield with slightly lower ee (88%). In comparison to free amines, amine hydrochloride salts present a more appealing option due to their widespread commercial availability, cost-effectiveness, and relative stability under atmospheric conditions.[15]

Table 1 Investigation of the dinuclear copper-catalyzed asymmetric propargylic amination–carboxylative cyclization sequence[a]

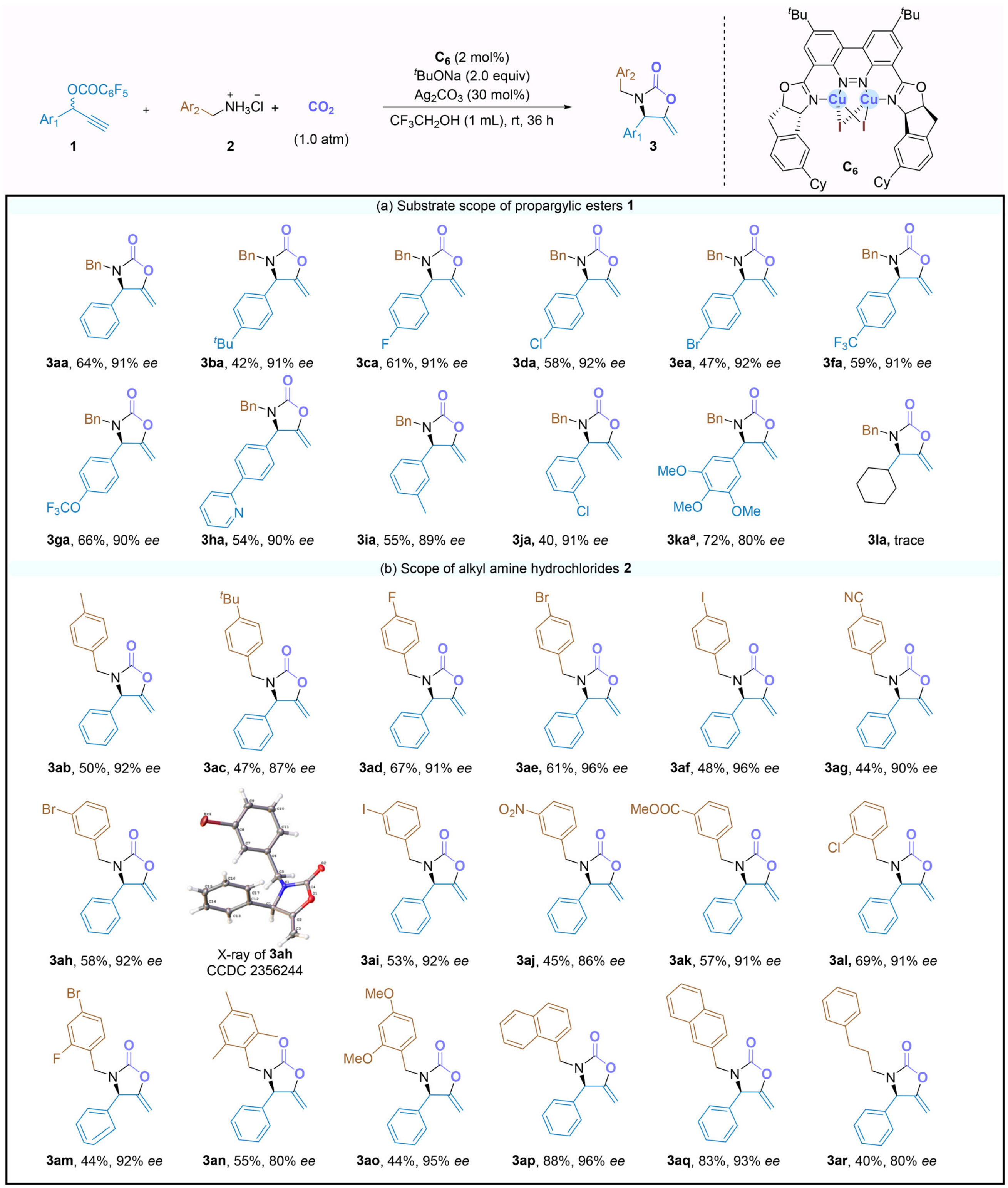


Entry	Cat.	Yield[b] (%)	ee[c] (%)
1	$\mathbf{C_1}$	51	73 (*S*)
2	$\mathbf{C_2}$	54	70 (*S*)
3	$\mathbf{C_3}$	49	79 (*R*)
4	$\mathbf{C_4}$	64	85 (*R*)
5	$\mathbf{C_5}$	59	87 (*R*)
6	$\mathbf{C_6}$	**70 (64)**[d]	**91 (*R*)**
7	$\mathbf{C_7}$	54	65 (*R*)
8	$\mathbf{C_8}$	47	70 (*R*)

[a] Unless otherwise noted, reaction conditions are as follows: **1a** (0.1 mmol), **2a** (0.15 mmol), ^{t}BuONa (2.0 equiv.), Ag_2CO_3 (30 mol%), $\mathbf{C_x}$ (2 mol%), CF_3CH_2OH (1 mL), rt, 36 h. [b] ^{1}H NMR yield using mesitylene as the internal standard. [c] The ee value of **3aa** was determined by HPLC on a chiral column IA. [d] Isolated yield.

Reaction scope

Under the optimized reaction conditions, the scope of propargyl carbonates **1** was first explored in the reaction with benzylamine hydrochloride **2a**, and the results are shown in Scheme 2a. The propargyl carbonates bearing either electron-donating (–^{t}Bu) or electron-withdrawing (–F, Cl, Br, CF_3, $-OCF_3$ and pyridine-containing carbonate) substituents at the *para*-position of the aryl group reacted smoothly with **2a**, affording the corresponding 2-oxazolidinones **3ba**–**3ha** in 42–66% yields with 90–92% ee. Substrates bearing *meta*-methyl, *meta*-chloro, and 3,4,5-trimethoxy substituted arenes were also amenable to the procedure, and the reactions provided **3ia**–**3ka** in good yields (40–72%) with 80–91% ee. However, the reactions using the cycloalkyl substituted propargylic carbonate **1l** only provided a trace amount of the corresponding product **3la**.



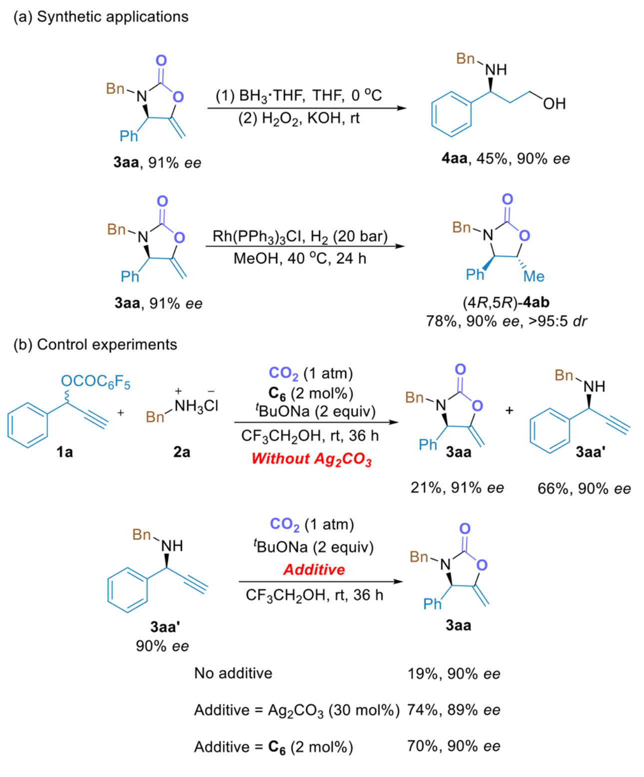
Scheme 2 Substrate scope. Reaction conditions: unless otherwise noted, all reactions were carried out using **1** (0.1 mmol), **2** (0.15 mmol), ^{t}BuONa (2.0 equiv.), Ag_2CO_3 (30 mol%), $\mathbf{C_6}$ (2.0 mol%), CF_3CH_2OH (1.0 mL), rt, 36 h. ^{a} Leaving group of the propargyl substrate = OBoc.

Subsequently, the scope of alkyl amines hydrochloride **2** was further evaluated in the reactions with propargyl carbonate **1a** (Scheme 2b). To our delight, this catalytic system exhibited good tolerance toward various hydrochloride salts of alkyl amines. For instance, the reactions of benzylamines bearing either electronic donating (–Me, and –^{t}Bu) or withdrawing (–F,

–Br, –I and –CN) groups on the phenyl ring afforded the corresponding products **3ab–3ag** in 44–67% yields with good enantioselectivities (87–96% ee). Changing the substituents of the benzylamines from the *para*- to *meta*- or *ortho*-position had no negative effect on the catalysis, smoothly leading to products **3ah–3al** in 45–69% yields with 86–92% ee. The absolute configuration of **3ah** was established as (*R*) by X-ray crystallography (CCDC 2356244†), while those of other chiral 2-oxazolidinone products were assigned by analogy. The catalytic system also turned out to be effective for the reactions of polysubstituted benzylamines **2m–2o**, giving the corresponding products **3am–3ao** in 44–55% yields with 80–95% ee. Furthermore, amine substrates containing an α- or a β-naphthyl group (**2p** and **2q**) were compatible with the protocol, and the reactions gave the corresponding products **3ap** and **3aq** in 83–88% yields with 93–96% ee. In addition, a primary amine hydrochloride bearing a long alkyl chain, such as **2r**, was also a suitable substrate, leading to the formation of the desired 2-oxazolidinone **3ar** in 40% yield with 80% ee. Notably, a variety of important functional groups, including –OMe, –F, –Br, –Cl, –I, $-CF_3$, $-OCF_3$, $-CO_2Me$, –CN, and $-NO_2$, was tolerated in the reaction, and the corresponding products showed good compatibility for downstream transformations.

Synthetic applications and control experiments

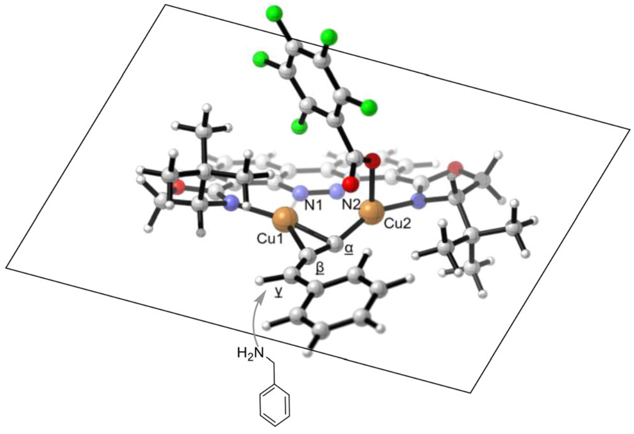
5-Methylene 2-oxazolidinones are useful chiral building blocks, as demonstrated by a two-step transformation of **3aa** to the synthetically useful chiral γ-amino alcohol **4aa** without any erosion of ee value (Scheme 3a). In addition, catalytic hydrogenation of the exocyclic C=C double bond of **3aa** using $Rh(PPh_3)_3Cl$ as the catalyst provided (4*R*,5*R*)-**4ab** in high yield (78%) with excellent diastereoselectivity (>95 : 5 dr). To gain an insight into the reaction mechanism, control experiments were carried out (Scheme 3b). Under otherwise standard conditions, the reaction of **1a** and **2a** in the absence of Ag_2CO_3 delivered the target product **3aa** in a low yield of only 21% with 91% ee, along with the generation of a substantial amount of **3aa′** with similar ee value (66%, 90% ee), suggesting that Ag_2CO_3 might promote the carboxylative cyclization of **3aa′** in the title reaction. This was confirmed by the reaction of the intermediate **3aa′** with CO_2 and without Ag_2CO_3 or the Cu catalyst; in this case, the cyclization product **3aa** was formed in only 19% yield. In contrast, the reaction of intermediate **3aa′** with CO_2 in the presence of Ag_2CO_3 or the binuclear Cu catalyst gave **3aa** in significantly improved yields of 74% and 70%, respectively. These results indicated that the title reaction is a tandem binuclear Cu-catalyzed asymmetric propargylic amination and Ag_2CO_3 promoted the carboxylative cyclization process. The copper catalyst in the first step may also have positive effect on the cyclization process. In addition, the enantioselectivity of **3aa** was determined in the propargylic amination step.



Scheme 3 Synthetic applications and control experiments.

Proposed transition state model

Based on the X-ray crystallographic structure of product **3ah** and previous computational studies by our group,[10] we proposed a stereochemical model to rationalize the observed chiral induction of the system using catalyst $\mathbf{C_1}$ (Scheme 4). Due to the large steric bulkiness of the $-^tBu$ and the $-OCOC_6F_5$ moieties located on the upper part of the ligand plane, the nucleophilic alkyl amines would preferentially attack the terminal carbon of the allene moiety from the bottom side. Subsequent carboxylative cyclization of the resulting chiral propargylamine with CO_2 would form the cycloadduct (*S*)-**3aa** with retention of the stereochemistry, which is consistent with the results obtained using $\mathbf{C_1}$ as the catalyst.



Scheme 4 Proposed chiral induction model based on the catalyst $\mathbf{C_1}$.

Conclusions

In summary, we have developed an efficient dinuclear copper-catalyzed asymmetric propargylic amination–carboxylative cyclization sequence of propargylic esters with alkyl amine hydrochlorides and CO_2, affording a variety of chiral 2-oxazolidinones bearing an exocyclic methylene moiety in good yields with high enantioselectivities.

Author contributions

Y. L., Q. C., and X. W. directed the project; Y. L., P. L., Z. F., L. S. and Q. C. performed all the experiments and analyzed all the data; Y. L., Q. C, and X. W. wrote the manuscript with contributions from all authors.

Data availability

The data supporting this article have been included as part of the ESI.†

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

The authors acknowledge financial support from the National Key R&D Program of China (No. 2022YFA1503200), the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDB0610000), the National Natural Science Foundation of China (92256303, 22171278, and 21821002), the Shanghai Science and Technology Committee (23ZR1482400), the Natural Science Foundation of Ningbo (2023J034) and Open Research Fund of School of Chemistry and Chemical Engineering, Henan Normal University.

References

1 (*a*) M. R. Barbachyn and C. W. Ford, Oxazolidinone Structure–Activity Relationships Leading to Linezolid, *Angew. Chem., Int. Ed.*, 2003, **42**, 2010–2023; (*b*) T. A. Mukhtar and G. D. Wright, Streptogramins, Oxazolidinones, and Other Inhibitors of Bacterial Protein Synthesis, *Chem. Rev.*, 2005, **105**, 529–542.

2 (*a*) G. Diaz-Muñoz, I. L. Miranda, S. K. Sartori, D. Cristina Rezende and M. Alves Nogueira Diaz, Use of chiral auxiliaries in the asymmetric synthesis of biologically active compounds: A review, *Chirality*, 2019, **31**, 776–812; (*b*) L. Y. Chen and P. Q. Huang, Evans' Chiral Auxiliary-Based Asymmetric SyntheticMethodology and Its Modern Extensions, *Eur. J. Org. Chem.*, 2024, 1–25; (*c*) V. Zadsirjan and M. M. Heravi, Oxazolidinones as Chiral Auxiliaries in the Asymmetric 1,4-Conjugate Addition Reaction Applied to the Total Synthesis of Natural Products: A Supplemental Mini-Review, *Curr. Org. Synth.*, 2018, **15**, 3–20; (*d*) E. Nicolás, K. C. Russell and V. J. Hruby, Asymmetric 1,4-addition of organocuprates to chiral *α*, *β*-unsaturated *N*-acyl-4-phenyl-2-oxazolidinones: a new approach to the synthesis of chiral *β*-branched carboxylic acids, *J. Org. Chem.*, 1993, **58**, 766–770; (*e*) M. T. Crimmins and A. L. Choy, An Asymmetric Aldol-Ring-Closing Metathesis Strategy for the Enantioselective Construction of Oxygen Heterocycles: An Efficient Approach to the Enantioselective Synthesis of (+)-Laurencin, *J. Am. Chem. Soc.*, 1999, **121**, 5653–5660; (*f*) A. Padarti, D. Kim and H. Han, Highly Stereoselective 2-Oxonia-Cope Rearrangement: A Platform Enabling At-Will Control of Regio-, Enantio-, and Diastereoselectivity in the Vinylogous Aldol Reactions of Aldehydes, *Org. Lett.*, 2018, **20**, 756–759; (*g*) V. Vigneswaran, S. N. MacMillan and D. C. Lacy, *β*-Amino Phosphine Mn Catalysts for 1,4-Transfer Hydrogenation of Chalcones and Allylic Alcohol Isomerization, *Organometallics*, 2019, **38**, 4387–4391; (*h*) J. M. Fraile, J. I. Garcìa, C. I. Herrerìas, J. A. Mayoral, O. Reiser, A. Socuÿllamos and H. Werner, The Role of Binding Constants in the Efficiency of Chiral Catalysts Immobilized by Electrostatic Interactions: The Case of Azabis(oxazoline)–Copper Complexes, *Chem. – Eur. J.*, 2004, **10**, 2997–3005.

3 (*a*) F. Y. Wang, T. L. Yang, T. Wu, L. S. Zheng, C. C. Yin, Y. J. Shi, X.-Y. Ye, G. Q. Chen and X. M. Zhang, Asymmetric Transfer Hydrogenation of α-Substituted-β-Keto Carbonitriles via Dynamic Kinetic Resolution, *J. Am. Chem. Soc.*, 2021, **143**, 2477–2483; (*b*) N. S. Barta, D. R. Sidler, K. B. Somerville, S. A. Weissman, R. D. Larsen and P. J. Reider, Practical Modifications and Applications of the Sharpless Asymmetric Aminohydroxylation in the One-Pot Preparation of Chiral Oxazolidin-2-ones, *Org. Lett.*, 2000, **2**, 2821–2824; (*c*) C. G. Espino and J. Du Bois, A Rh-Catalyzed C-H Insertion Reaction for the Oxidative Conversion of Carbamates to Oxazolidinones, *Angew. Chem., Int. Ed.*, 2001, **40**, 598–600; (*d*) L. E. Overman and T. P. Remarchuk, Catalytic Asymmetric Intramolecular Aminopalladation: Enantioselective Synthesis of Vinyl-Substituted 2-Oxazolidinones, 2-Imidazolidinones, and 2-Pyrrolidinones, *J. Am. Chem. Soc.*, 2002, **124**, 12–13; (*e*) Y. Cui and C. He, A Silver-Catalyzed Intramolecular Amidation of Saturated C-H Bonds, *Angew. Chem., Int. Ed.*, 2004, **43**, 4210–4212; (*f*) D. B. Berkowitz and G. Maiti, Following an ISES Lead: The First Examples of Asymmetric Ni (0)-Mediated Allylic Amination, *Org. Lett.*, 2004, **6**, 2661–2664; (*g*) H. Lebel, K. Huard and S. Lectard, *N*-Tosyloxycarbamates as a Source of Metal Nitrenes: Rhodium-Catalyzed C-H Insertion and Aziridination Reactions, *J. Am. Chem. Soc.*, 2005, **127**, 14198–14199; (*h*) D. N. Barman and K. M. Nicholas, Copper-Catalyzed Intramolecular C–H Amination, *Eur. J. Org. Chem.*, 2011, 908–911; (*i*) Y. Fukata, K. Asano and S. Matsubara,

Procedure-Controlled Enantioselectivity Switch in Organocatalytic 2-Oxazolidinone Synthesis, *J. Am. Chem. Soc.*, 2013, **135**, 12160–12163; (*j*) Q. L. Wang, X. F. Tan, Z. Y. Zhu, X. Q. Dong and X. M. Zhang, New synthetic strategy for chiral 2-oxazolidinones derivatives via rhodium-catalyzed asymmetric hydrogenation, *Tetrahedron Lett.*, 2016, **57**, 658–662; (*k*) W. Li, M. Wollenburg and F. Glorius, Enantioselective synthesis of 2-oxazolidinones by ruthenium(II)–NHC-catalysed asymmetric hydrogenation of 2-oxazolones, *Chem. Sci.*, 2018, **9**, 6260–6263; (*l*) Y. H. Liu, Z. Y. Yi, X. L. Yang, H. Wang, C. C. Yin, M. Y. Wang, X. Q. Dong and X. M. Zhang, Efficient Access to Chiral 2-Oxazolidinones via Ni-Catalyzed Asymmetric Hydrogenation: Scope Study, Mechanistic Explanation, and Origin of Enantioselectivity, *ACS Catal.*, 2020, **10**, 11153–11161; (*m*) P. K. Yu, D. Y. Chen, Y. W. Liu, C. C. Yin, Q. X. Liu and H. F. Zhou, Synthesis of Chiral 2-Oxazolidinones by Ruthenium-Catalyzed Asymmetric Transfer Hydrogenation of 2-Oxazolones, *Adv. Synth. Catal.*, 2023, **365**, 1–7.

4 (*a*) D. M. D'Alessandro, B. Smit and J. R. Long, Carbon Dioxide Capture: Prospects for New Materials, *Angew. Chem., Int. Ed.*, 2010, **49**, 6058–6082; (*b*) M. Cokoja, C. Bruckmeier, B. Rieger, W. A. Herrmann and F. E. Kühn, Transformation of Carbon Dioxide with Homogeneous Transition-Metal Catalysts: A Molecular Solution to a Global Challenge?, *Angew. Chem., Int. Ed.*, 2011, **50**, 8510–8537; (*c*) M. Y. He, Y. H. Sun and B. X. Han, Green Carbon Science: Scientific Basis for Integrating Carbon Resource Processing, Utilization, and Recycling, *Angew. Chem., Int. Ed.*, 2013, **52**, 9620–9633; (*d*) E. V. Kondratenko, G. Mul, J. Baltrusaitis, G. O. Larrazábal and J. Pérez-Ramírez, Status and perspectives of CO_2 conversion into fuels and chemicals by catalytic, photocatalytic and electrocatalytic processes, *Energy Environ. Sci.*, 2013, **6**, 3112–3135; (*e*) M. Aresta, A. Dibenedetto and A. Angelini, Catalysis for the Valorization of Exhaust Carbon: from CO_2 to Chemicals, Materials, and Fuels. Technological Use of CO_2, *Chem. Rev.*, 2014, **114**, 1709–1742; (*f*) K. Sekine and T. Yamada, Silver-catalyzed carboxylation, *Chem. Soc. Rev.*, 2016, **45**, 4524–4532; (*g*) J. H. Ye, T. Ju, H. Huang, L. L. Liao and D. G. Yu, Radical Carboxylative Cyclizations and Carboxylations with CO_2, *Acc. Chem. Res.*, 2021, **54**, 2518–2531.

5 (*a*) S. F. Cai, H. R. Li and L. N. He, Bifunctionalization of unsaturated bonds via carboxylative cyclization with CO_2: a sustainable access to heterocyclic compounds, *Green Chem.*, 2021, **23**, 9334–9347; (*b*) X. Yang, L. K. Xu, Y. Q. Zhu, S. J. Zhang, G. W. Jia and J. Du, Efficient fabrication of oxazolidinones for the carboxylative cyclization with carbon dioxide, *J. CO_2 Util.*, 2023, **74**, 102531–102553; (*c*) Z. Zhang, J. H. Ye, D. S. Wu, Y. Q. Zhou and D. G. Yu, Synthesis of Oxazolidin-2-ones from Unsaturated Amines with CO_2 by Using Homogeneous Catalysis, *Chem. – Asian J.*, 2018, **13**, 2292–2306; (*d*) C. K. Ran, H. Huang, X. H. Li, W. Wang, J. H. Ye, S. S. Yan, B. Q. Wang, C. Feng and D. G. Yu, Cu-Catalyzed Selective Oxy-Cyanoalkylation of Allylamines with Cycloketone Oxime Esters and CO_2, *Chin. J. Chem.*, 2020, **38**, 69–76; (*e*) L. Sun, J. H. Ye, W. J. Zhou, X. Zeng and D. G. Yu, Oxy-Alkylation of Allylamines with Unactivated Alkyl Bromides and CO_2 via Visible-Light-Driven Palladium Catalysis, *Org. Lett.*, 2018, **20**, 3049–3052; (*f*) S. Wang and C. J. Xi, Recent advances in nucleophile-triggered CO_2-incorporated cyclization leading to heterocycles, *Chem. Soc. Rev.*, 2019, **48**, 382–404; (*g*) M. Yoshida, T. Mizuguchi and K. Shishido, Synthesis of Oxazolidinones by Efficient Fixation of Atmospheric CO_2 with Propargylic Amines by using a Silver/1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU) Dual-Catalyst System, *Chem. – Eur. J.*, 2012, **18**, 15578–15581; (*h*) R. M. Yuan, B. H. Wei and G. Fu, How the Coordinated Structures of Ag(I) Catalysts Affect the Outcomes of Carbon Dioxide Incorporation into Propargylic Amine: A DFT Study, *J. Org. Chem.*, 2017, **82**, 3639–3647; (*i*) S. Arshadi, E. Vessally, M. Sobati, A. Hosseinian and A. Bekhradnia, Chemical fixation of CO_2 to N-propargylamines: A straightforward route to 2-oxazolidinones, *J. CO_2 Util.*, 2017, **19**, 120–129; (*j*) X. Xu, Z. T. Li, H. L. Huang, X. Jing and C. Y. Duan, A novel copper metal–organic framework catalyst for the highly efficient conversion of CO_2 with propargylic amines, *Inorg. Chem. Front.*, 2022, **9**, 3839–3844; (*k*) J. N. Goswami, D. Saha, U. Saha, A. Bera, M. Ouladsmane, N. Bar, S. Biswas, M. Z. Ansari and M. Dolai, Noble metal free double helix binuclear Cu(I) complex as catalyst for carboxylative cyclization of propargylamines with atmospheric carbon dioxide toward oxazolidinones synthesis under mild conditions, *Inorg. Chim. Acta*, 2024, **563**, 121926–121936; (*l*) F. Chen, Sh. Tao, Q. Q. Deng, D. H. Wei, N. Liu and B. Dai, Binuclear Tridentate Hemilabile Copper (I) Catalysts for Utilization of CO_2 into Oxazolidinones from Propargylic Amines, *J. Org. Chem.*, 2020, **85**, 15197–15212.

6 X. T. Gao, C. C. Gan, S. Y. Liu, F. Zhou, H. H. Wu and J. Zhou, Utilization of CO_2 as a C1 Building Block in a Tandem Asymmetric A^3 Coupling-Carboxylative Cyclization Sequence to 2-Oxazolidinones, *ACS Catal.*, 2017, **7**, 8588–8593.

7 Z. Zhang, Z. H. Zhang, F. Zhou and J. Zhou, Catalytic Enantioselective Transfer Hydrogenation–Carboxylative Cyclization to 4-Fluoroalkyl 2-Oxazolidinone with CO_2 as the C1 Synthon, *Org. Lett.*, 2021, **23**, 2726–2730.

8 (*a*) C. J. Fahrni, Allylic Oxidation Catalyzed by Chiral Dinuclear Copper Complexes, *Tetrahedron*, 1998, **54**, 5465–5470; (*b*) C. J. Fahrni and A. Pfaltz, Synthesis of Chiral C_2-Symmetric Binucleating Ligands, *Helv. Chim. Acta*, 1998, **81**, 491–506; (*c*) C. J. Fahrni, A. Pfaltz, M. Neuburger and M. Zehnder, Structure and Properties of Transition-Metal Complexes with Chiral C_2-Symmetric Binucleating Ligands, *Helv. Chim. Acta*, 1998, **81**, 507–524; (*d*) E. Salvadeo, L. Dubois and J. M. Latour, Trinuclear copper complexes as biological mimics: Ligand designs and reactivities, *Coord. Chem. Rev.*, 2018, **374**, 345–375; (*e*) R. B. Ferreira and L. J. Murray, Cyclophanes as Platforms for Reactive

Multimetallic Complexes, *Acc. Chem. Res.*, 2019, **52**, 447–455; (*f*) A. N. Desnoyer, A. Nicolay, P. Rios, M. S. Ziegler and T. D. Tilley, Bimetallics in a Nutshell: Complexes Supported by Chelating Naphthyridine-Based Ligands, *Acc. Chem. Res.*, 2020, **53**, 1944–1956; (*g*) R. Mal, N. Mittal, T. J. Emge and D. Seidel, Facile synthesis of a chiral urea bridged bisoxazoline ligand and structural characterization of its bis-copper(II)-chloride complex, *Chem. Commun.*, 2009, 7309–7311.

9 (*a*) J. Gao, J. H. Reibenspies and A. E. Martell, Structurally Defined Catalysts for Enantioselective Oxidative Coupling Reactions, *Angew. Chem., Int. Ed.*, 2003, **42**, 6008–6012; (*b*) W. J. Li and S. X. Qiu, A Novel D_2-Symmetrical Chiral Tetraoxazoline Ligand for Highly Enantioselective Hydrosilylation of Aromatic Ketones, *Adv. Synth. Catal.*, 2010, **352**, 1119–1122; (*c*) L. Zhang, G. Yang, C. Shen, S. Arghib and W. Zhang, Chiral dinuclear phthalazine bridged bisoxazoline ligands: synthesis and application in enantioselective Cu-catalyzed conjugate addition of $ZnEt_2$ to enones, *Tetrahedron Lett.*, 2011, **52**, 2375–2378; (*d*) S. F. Zhu, B. Xu, G. P. Wang and Q. L. Zhou, Well-Defined Binuclear Chiral Spiro Copper Catalysts for Enantioselective N-H Insertion, *J. Am. Chem. Soc.*, 2012, **134**, 436–442.

10 Q. L. Cai, H. Q. Rao, S. J. Li, Y. Lan, K. L. Ding and X. M. Wang, Well-defined chiral dinuclear copper complexes in enantioselective propargylic substitution: For a long-standing supposition on binuclear mechanism, *Chem*, 2024, **10**, 265–282.

11 (*a*) A. L. Gavrilova and B. Bosnich, Principles of mononucleating and binucleating ligand design, *Chem. Rev.*, 2004, **104**, 349–383; (*b*) P. A. Vigato, V. Peruzzo and S. Tamburini, Acyclic and cyclic compartmental ligands: recent results and perspectives, *Coord. Chem. Rev.*, 2012, **256**, 953–1114; (*c*) A. M. Barrios and S. J. Lippard, Phthalazine-based dinucleating ligands afford dinuclear centers often encountered in metalloenzyme active sites, *Inorg. Chem.*, 2001, **40**, 1060–1064; (*d*) S. Brooker, Some copper and cobalt complexes of Schiff-base macrocycles containing pyridazine head units, *Eur. J. Inorg. Chem.*, 2002, **2002**, 2535–2547; (*e*) L. Zhang, G. Yang and W. Zhang. *China Patent CN* 102464656A, 2012; (*f*) R. Connon, B. Roche, B. V. Rokade and P. J. Guiry, Further developments and applications of oxazoline-containing ligands in asymmetric catalysis, *Chem. Rev.*, 2021, **121**, 6373–6521; (*g*) D. Das, R. Mal, N. Mittal, Z. Zhu, T. J. Emge and D. Seidel, Chiral bisoxazoline ligands designed to stabilize bimetallic complexes, *Beilstein J. Org. Chem.*, 2018, **14**, 2002–2011; (*h*) G. Desimoni, G. Faita and K. A. Jørgensen, C_2-symmetric chiral bis(oxazoline) ligands in asymmetric catalysis, *Chem. Rev.*, 2006, **106**, 3561–3651; (*i*) Y. Z. Zhu, Z. P. Li, J. A. Ma, F. Y. Tang, L. Kang, Q. L. Zhou and A. S. C. Chan, Synthesis of chiral bis(oxazolinyl)bipyridine ligands and related helical metal complexes, *Tetrahedron: Asymmetry*, 2002, **13**, 161–165.

12 (*a*) R. J. Detz, M. M. E. Delville, H. Hiemstra and J. H. van Maarseveen, Enantioselective Copper-Catalyzed Propargylic Amination, *Angew. Chem., Int. Ed.*, 2008, **47**, 3777–3780; (*b*) G. Hattori, H. Matsuzawa, Y. Miyake and Y. Nishibayashi, Copper-Catalyzed Asymmetric Propargylic Substitution Reactions of Propargylic Acetates with Amines, *Angew. Chem., Int. Ed.*, 2008, **47**, 3781–3783.

13 (*a*) G. Hattori, K. Sakata, H. Matsuzawa, Y. Tanabe, Y. Miyake and Y. Nishibayashi, Copper-Catalyzed Enantioselective Propargylic Amination of Propargylic Esters with Amines: Copper–Allenylidene Complexes as Key Intermediates, *J. Am. Chem. Soc.*, 2010, **132**, 10592–10608; (*b*) C. Zhang, Y. H. Wang, X. H. Hu, Z. Zheng, J. Xu and X. P. Hu, Chiral Tridentate P,N,N Ligands for Highly Enantioselective Copper-Catalyzed Propargylic Amination with both Primary and Secondary Amines as Nucleophiles, *Adv. Synth. Catal.*, 2012, **354**, 2854–2858; (*c*) T. Mino, H. Taguchi, M. Hashimoto and M. Sakamoto, Copper-catalyzed asymmetric propargylic amination of propargylic acetates with amines using BICMAP, *Tetrahedron: Asymmetry*, 2013, **24**, 1520–1523; (*d*) A. Yoshida, G. Hattori, Y. Miyake and Y. Nishibayashi, Copper-Catalyzed Enantioselective Propargylic Amination of Nonaromatic Propargylic Esters with Amines, *Org. Lett.*, 2011, **13**, 2460–2463; (*e*) S. J. Li, J. Huang, J. Y. He, R. J. Zhang, H. D. Qian, X. L. Dai, H. H. Kong and H. Xu, Highly enantioselective copper-catalyzed propargylic amination to access N-tethered 1,6-enynes, *RSC Adv.*, 2020, **10**, 38478–38483; (*f*) Z. Zhang, Y. Sun, Y. Gong, D. L. Tang, H. Luo, Z. P. Zhao, F. Zhou, X. Wang and J. Zhou, Enantioselective propargylic amination and related tandem sequences to α-tertiary ethynylamines and azacycles, *Nat. Chem.*, 2024, **16**, 521–532; (*g*) J. S. Ma, H. Y. Lu, Y. W. Chen, W. C. Zhao, Y. Z. Sun, R. P. Li, H. X. Wang, G. Q. Lin and Z. T. He, Copper-catalysed convergent regio- and enantioselective alkynylallylic substitution, *Nat. Synth.*, 2023, **2**, 37–48; (*h*) D. Y. Zhang and X. P. Hu, Recent advances in copper-catalyzed propargylic substitution, *Tetrahedron Lett.*, 2015, **56**, 283–295; (*i*) C. H. Ding and X. L. Hou, Catalytic asymmetric propargylation, *Chem. Rev.*, 2011, **111**, 1914–1937; (*j*) N. Ljungdahl and N. Kann, Transitionmetal-catalyzed propargylic substitution, *Angew. Chem., Int. Ed.*, 2009, **48**, 642–644; (*k*) R. J. Detz, H. Hiemstra and J. H. van Maarseveen, Catalyzed propargylic substitution, *Eur. J. Org. Chem.*, 2009, 6263–6276; (*l*) Y. Miyake, S. Uemura and Y. Nishibayashi, Catalytic propargylic substitution reactions, *ChemCatChem*, 2009, **1**, 342–356.

14 During the submission of this manuscript, a similar Cu-catalyzed reaction *via* CO_2 shuttling or CO_2 fixation was independently reported: H. Li, J. S. Ma, H. Y. Lu, G. Q. Lin and Z. T. He, Asymmetric Multicomponent Propargylations via Carbon Dioxide Shuttling and Fixation, *ACS Catal.*, 2024, **14**, 11646–11656.

15 (*a*) W. J. Yoo and C. J. Li, Highly Efficient Oxidative Amidation of Aldehydes with Amine HydrochlorideSalts, *J. Am. Chem. Soc.*, 2006, **128**, 13064–13065; (*b*) S. C. Ghosh, J. S. Y. Ngiam, A. M. Seayad, D. T. Tuan, C. L. L. Chai and A. Chen, Copper-Catalyzed Oxidative Amidation of

Aldehydes with Amine Salts: Synthesis of Primary, Secondary, and Tertiary Amides, *J. Org. Chem.*, 2012, **77**, 8007–8015; (*c*) W. L. Zhang, Y. J. Yao, Y. L. Xu, X. Y. Zhou and G. Wu, Amine hydrochloride salts as bifunctional reagents for the radical aminochlorination of maleimides, *Org. Chem. Front.*, 2021, **8**, 5766–5770; (*d*) J. Huang, H. H. Kong, S. J. Li, R. J. Zhang, H. D. Qian, D. R. Li, J. Y. He, Y. N. Zheng and H. Xu, Asymmetric copper-catalyzed propargylic amination with amine hydrochloride salts, *Chem. Commun.*, 2021, **57**, 4674–4677.