**A novel 3D Ag(I)-MOF: Surfactant-directed syntheses and catalytic
degradation of *o/m/p*-Nitrophenol**

Xue-Qian Wu^a, Guo-Xuan Wen^b, Ya-Pan Wu^a, Wen-Wen Dong^a, Jun Zhao^a, Dong-Sheng Li^{*a}

^a *College of Materials and Chemical Engineering, Hubei Provincial Collaborative Innovation
Center for New Energy Microgrid, China Three Gorges University, Yichang 443002, P. R. China*

^b *College of Science, China Three Gorges University, Yichang 443002, P. R. China*

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* Corresponding authors

E-mail address: lidongsheng1@126.com (D.-S. Li), Tel./Fax: +86-717- 6397516

Abstract:

For the first time, sodium caprylate has been investigated to direct the crystal growth of 3D Ag-MOF, [Ag₂(ddcba)(4,4'-bipy)₂] (**1**), constructing from 3,5-(di(2',5'-dicarboxylphenyl)benzoic acid and 4,4'-bipy. The single crystal diffraction analyses shows that complex **1** possess 3D neutral framework with a three-connected *ThSi*₂ (10³-b) topology. Compound **1** exhibits predominant catalytic activity towards the degradation of *o*-Nitrophenol (ONP), *m*-Nitrophenol (MNP) and *p*-Nitrophenol (PNP) in aqueous solution. The kinetics of such catalytic degradation reactions was also studied.

Keywords: Ag(I) metal-organic framework; Surfactants; Nitroaromatics; Catalytic property

1. Introduction

Metal-organic frameworks (MOFs) represent a large class of multifunctional crystalline materials in terms of their catalytic, luminescent and adsorption properties, which are prepared via self-assembly of metal cations and organic ligands. [1-3] Traditionally, crystalline metal-organic frameworks can be constructed through hydro(solvo, iono) thermal methods, solid-state reactions and room temperature self-assembly processes. [4,5] Although these synthetic methods have achieved great success in fabrication of MOFs with diverse structures and abundant properties, there is still much room left for improvement. It has been widely demonstrated that surfactants can be employed as powerful agents in controlling the shape and size of nanostructures. For example, it was confirmed that the molar ratio of cationic surfactants to Si of alkoxysilanes (Surf/Si) can affect the degree of mesostructure formation, the particle diameter and the dispersibility of silica nanoparticles. [6] Moreover, the effect of surfactants on the growth of Co/Cu multilayers also has been studied in early time. [7] Given that surfactants have been widely used to control the morphologies of materials, it is logic to consider whether these surfactants also can be employed to direct the growth of crystalline inorganic materials. Actually, Zhang groups has synthesized many crystalline materials by utilizing several different surfactants as reaction media. [8,9] For instance, Zhang et al. studied surfactant-thermal syntheses of Mn-Ge-Sulfides/selenides. [10] Four novel chalcogenides have been obtained by employing PEG-400 as reaction media. Furthermore, Zhang and his co-workers investigated three different surfactants (PEG 400, octanoic acid, and hexadecyltributyl phosphonium bromide) as reaction media to fabricate metal-organic frameworks and found that surfactants shows strong effects on the crystal's growth and resulted in different secondary building units. [11] The similar results have also been gained in our group related to separate pure single-phase of metal-organic frameworks by a new surfactant-introduced strategy. [12] Two previous mixed-phase Ni(II)-MOFs were successfully isolated to two pure products through the introduction of different surfactants. Clearly, the application of different surfactants should provide new opportunities for the design and preparation of metal-organic frameworks.

In this work, we choose a pentacaboxylate ligand and a N-donor ligand, which could react with AgNO_3 to give a 3D metal organic framework $[\text{Ag}_2(\text{ddcba})(4,4'\text{-bipy})_2]$, where sodium caprylate has been applied as additives in the conversion of precipitate into crystalline material. To the best of our knowledge, this is the first Ag-MOF, constructing with the aid of surfactant.

Several silver (I) coordination compounds have been proved to be efficient catalysts for many organic reactions, including cycloaddition of azides and alkynes, oxygenation of sulfide, and partial oxidation of primary amines. Meanwhile, the catalytic activity of the metal-organic complexes based on N-donor ligand has been attracted more and more attentions. Thus, the catalytic properties of complex **1** has also been explored and we found that complex **1** shows outstanding catalytic activity. [13]

2. Experimental section

Synthesis of compound **1**: A mixture of H₃ddcba (3,5-(di(2',5'-dicarboxylphenyl)benzoic acid) (0.05mmol, 22.5 mg), 4,4'-bipy (4,4'-bipyridine) (0.05mmol, 7.8 mg), AgNO₃ (0.05mmol, 8.5 mg), NaOH (0.4 ml, 0.1mmol/ml), Sodium caprylate (10 mg), and H₂O (8ml) was placed in a 25ml Teflon-lined stainless steel vessel, heated to 110°C for 72h, and then cooled to room temperature over 24h. Colourless crystals of **1** were obtained. Yield: 75% based on Ag. Elemental analysis(%): calcd for (C₄₃H₂₈N₄O₁₀Ag₂): C, 52.87; H, 2.87; N, 5.74. Found: C, 52.80; H, 2.79; N, 5.69. IR (KBr, cm⁻¹): 3436 (m), 1683 (w), 1600 (w), 1556 (w), 1403 (s), 813 (s), 759 (m), 705 (w).

Crystal data: C₄₃H₂₈N₄O₁₀Ag₂, *M*=976.43, Monoclinic, *a*=10.954(4) Å, *b*=9.664(4) Å, *c*=17.4127(7) Å, α = 90°, β = 97.711(5)°, γ =90°, *V*=1826.6(13) Å³, *Z*=2, Space group *Pc*, 6438 reflections measured, 6091 independent reflections (*R*_{int}=0.0403). The final *R*₁ value was 0.0346 (*I*>2σ(*I*)). The final *wR*(*F*²) value was 0.1001 (*I*>2σ(*I*)). The goodness of fit on *F*² was 1.068.

These crystal data and the selected bond length and angles of **1** were shown in table S1 and S2

3. Results and discussion

Structure of [Ag₂(ddcba)(4,4'-bipy)₂] (**1**)

Single-crystal X-ray diffraction analysis reveals that complex **1** crystallizes in the *monoclinic* system with *Pc* space group. The minimum asymmetric unit contains two crystallographically independent Ag(I) centers, one *ddcba* anion and two molecules of 4,4'-bipy. The coordination environment around Ag(I) is shown in Fig. 1a. Both Ag 1 and Ag 2 adopt a slightly distorted triangle mode, in which the metal center is coordinated by two nitrogen atoms and one oxygen atom (AgN₂O). Two coordinated nitrogen atoms originates from pyridine ring (Ag1-N1 = 2.2167(49), Ag1-N3 = 2.1833(49), Ag2-N4^{#3} = 2.2010(49), Ag2-N2 = 2.1900(48)Å) while oxygen atoms come from *ddcba* anion (Ag1-O1 = 2.4638(39), Ag2-O6^{#4} = 2.4784(37)Å). In **1**, each *ddcba* anion adopts one type of coordinating mode μ_2 - η^1 : η^1 to connect metal ions as well as

4,4'-bipy ligands. The overall structure of **1** is a three-dimensional framework, as illustrated in Fig. 1c. From the viewpoint of topology, the structure is a three-connected net with the vertex symbol of $(10^2 \cdot 10^4 \cdot 10^4)$, which represents $ThSi_2$ (10^3 -b) network topology. This mode has been observed in the framework $[Ag_2(HPIDC)]$ (HPIDC = 2-(pyridin-4-yl)-1H-imidazole-4,5-dicarboxylic acid). [14] Moreover, The construction of metal organic frameworks derived from Ag(I) ions and bridging N-or polycarboxylic acid ligands, which could greatly stabilize the Ag(I) ions through the formation of coordination polymer. [15] In addition, the catalytic properties of complex **1** have also been investigated.

Fig. 1 (a) Coordination environments of the Ag(I) ions in complex **1**. Symmetry code: #1 = $-1+x, 2+y, z$; #2 = $-1+x, 1-y, -0.5+z$; #3 = $1+x, -2+y, z$; #4 = $1+x, 1-y, 0.5+z$. (b) The $ThSi_2$ topology of **1**. (c) The 3D packing structure of **1**.

Although extensive efforts have been made on the synthesis of complex **1**, the crystalline materials cannot be obtained without the addition of sodium caprylate, suggesting that surfactant plays an important role in controlling the growth of crystals. Although we have demonstrated the surfactants' effect on growing metal-organic frameworks with the application of surfatant, there is still a long way to understanding how surfactans control the growth of crystalline materials.

Thermal analysis

The PXRD experimental and computer-simulated patterns are in good agreement with each other, indicating that **1** phase purity of the as-synthesized products (Fig. S1). Thermogravimetric analysis of **1** has been performed in study its thermal stability. The operation were carried out

under N₂ with a heating rate of 10 °C min⁻¹ (Fig. S2). For complex **1**, the weight loss related to the release of *ddcba* and 4,4'-bipy ligands is observed from 230-316°C, resulting in the collapse of the framework. At this stage, it also accompanied with the formation of Ag originating from the decompose of Ag₂O, which have been confirmed by X-ray powder diffraction experiment (Fig. S3). The second gradual weight loss in the temperature range of 319 to 565°C corresponds to the decomposition of the remaining ligands. (obsd 76.3%, calcd 78%).

Catalytic properties

Currently, industrial liquid wastes have become one of the most serious environmental problems and have attracted increasing attentions. Among them, nitroaromatics such as ONP (*o*-Nitrophenol), MNP (*m*-Nitrophenol) and PNP (*p*-Nitrophenol) are commonly encountered. Even at low concentrations, ONP, MNP and PNP may bring detrimental effects to the environment and human health. [16,17] Traditional methods for treating such wastes include ozonation, adsorption, biodegradation and catalytic degradation, which have been widely studied and applied to remove contaminant from liquid waste system. [18-20] Among all the proposed techniques, catalytic degradation has been processed as an effective, economical and convenient approach, in which a variety of materials have been selected as catalytic, such as metal oxides, metal sulfides and metal or non-metal-doped composites. [21,22]

Apart from the above-mentioned materials, some metal coordination compounds also have potential advantages in the removal of hazardous substance. [23] Taking into account of the silver-containing composites, nanoparticles, simple salts and composite materials are widely used as catalytic for the degradation reactions. Only a few Ag(I) coordination compounds have been utilized as catalysts for decomposing. [24,25]

Thus, the degradation of ONP, MNP and PNP in aqueous solutions were chosen as a model reaction to study the catalytic performance of complex **1**. The degradation experiment was conducted in a typical canal, observing the intensity of the characteristic absorption band of ONP, MNP and PNP at 414, 390 and 400 nm, respectively, after the addition the catalyst and KBH₄. Each of the three nitroaromatics exhibits a negligible change in the adsorption spectroscopy after the addition of KBH₄, indicating that KBH₄ itself has no catalytic activity for the reaction. Upon the addition of small amount of complex **1** (1 mg), the absorption of substrates significantly decreases at the monitored wavelength. Ultimately, three nitroaromatics were decomposed

completely in the presence of **1** and KBH_4 within the time of 3 min to 12 min (Fig. 2). In order to deeply understand the process of catalytic, the kinetics of the degradation reaction was further investigated. Liner relationship between $\ln(C_t/C_0)$ and reaction time is obtained, implying that such a catalytic reaction could be of pseudo-first-order reaction, which has been observed in several similar degradation progress. (The correlation coefficient of relationship between $\ln(C_t/C_0)$ and reaction time is 0.90 (PNP), 0.98 (ONP) and 0.93 (MNP)) [26] The slope of fitted lines was k value, which is calculated to be $5.0 \times 10^{-3} \text{ s}^{-1}$ for ONP, $1.0 \times 10^{-2} \text{ s}^{-1}$ (MNP) and $7.6 \times 10^{-3} \text{ s}^{-1}$ (PNP), respectively. Note that there are only a few pseudo-first-order reaction examples involved in the degradation of nitrophenol. For example, Md. Rashid et al. reported that degradation of PNP by silver nanostructures with the k value of $0.41 \times 10^{-3} \text{ s}^{-1}$. [27] Tang et al. synthesized Ag-C

Fig. 2 UV-vis spectra showing gradual reduction of PNP (a), ONP (b) and MNP (c) over complex **1**. Inset: the relationship between $\ln(C_t/C_0)$ and reaction time (t).

composites and investigated its catalytic properties towards the degradation of PNP with the k value of $6.46 \times 10^{-3} \text{ s}^{-1}$. [28] The activity of compound **1** is much higher than these previously reported materials, providing an evidence that **1** can be used as an efficient catalyst. Besides,

replacing complex **1** by the filtrate after degradation results in no appreciable degradation of nitroaromatics, which suggested that there were no active catalytic components (such as Ag^+ ion) produced in the water during the progress (Fig. S7).

Mechanism of the catalytic reduction of nitrophenol to its daughter derivatives aminophenol in the presence of KBH_4 has been discussed in previously reported literature. [29] Thus, we speculate that the catalyst stimulate the reduction by relaying electrons from the donor BH_4^- to the acceptor PNP, in this way, degradation reaction occurs smoothly.

4. Conclusions

In summary, a metal-organic framework with Ag nodes and pentacarboxylate linker has been constructed under surfactant system and the as-prepared material can be employed as a highly effective catalysts for the degradation of nitroaromatics in which surfactants have been applied to direct the crystal growth of Ag-MOF successfully. Complex **1** features a 3D framework with a three-connected $ThSi_2$ (10^3 -b) topology. Moreover, Catalytic experiments reveal that compound **1** exhibits good catalytic activity towards the degradation of ONP, MNP and PNP in aqueous solution. The present work not only provides some new insight into the design and preparation of new metal-organic frameworks as catalyst for high performance degradation of poisonous and permanent organic species existed in industrial liquid waste, but also allows us to better understand the synergic action of surfactants on the crystallization of metal-organic frameworks.

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References

- [1] (a) F.Q. Wang, C.G. Wang, Z.C. Yu, Q.G. He, X.Y. Li, C.G. Shang, Y.G. Zhao, Two luminescent metal-organic frameworks with multifunctional properties nitroaromatic compounds sensing and photocatalysis, *Rsc. Adv.* 5 (2015) 70086-70093.
- (b) D.S. Li, Y.P. Wu, J. Zhao, J. Zhang, J.Y. Lu, Metal-organic frameworks based upon non-zeotype 4-connected topology, *Coord. Chem. Rev.* 261 (2015) 1-27.
- [2] (a) Y.L. Wu, G.P. Yang, Y.Q. Zhao, W.P. Wu, B. Liu, Y.Y. Wang, Three new solvent-directed Cd(ii)-based MOFs with unique luminescent properties and highly selective sensors for Cu^{2+} cations and nitrobenzene, *Dalton Trans.* 44 (2015) 3271-3277.
- (b) J. Zhao, W.W. Dong, Y.P. Wu, Y.N. Wang, C. Wang, D.S. Li, Q.C. Zhang, Two (3,6)-connected porous metal-organic frameworks based on linear trinuclear $[\text{Co}_3(\text{COO})_6]$ and paddlewheel dinuclear $[\text{Cu}_2(\text{COO})_4]$ SBUs: gas adsorption, photocatalytic behaviour, and magnetic properties, *J. Mater. Chem. A* 3 (2015) 6962-6969.
- (c) W.W. Xiong, J.W. Miao, K.Q. Ye, Y. Wang, B. Liu, Q.C. Zhang, Threading chalcogenide layers with polymer chains, *Angew. Chem. Int. Ed.* 54 (2015) 546-550.
- [3] X. Duan, R.J. Song, J.C. Yu, H.L. Wang, Y.J. Cui, Y. Yang, B.L. Chen, G.D. Qin, A new microporous metal-organic framework with open metal sites and exposed carboxylic acid groups for selective separation of CO_2/CH_4 and $\text{C}_2\text{H}_2/\text{CH}_4$, *Rsc. Adv.* 4 (2014) 36419-36424.
- [4] S.T. Zheng, T. Wu, C.T. Chou, A. Fuhr, P.Y. Feng, X.H. Bu, Development of composite inorganic building blocks for MOFs, *J. Am. Chem. Soc.* 134 (2012) 4517-4520.
- [5] C.P. Li, M. Du, Role of solvents in coordination supramolecular systems, *Chem. Commun.* 47 (2011) 5958-5972.
- [6] H. Yamada, C. Urata, S. Higashitani, Y. Aoyama, Y. Yamauchi, K. Kuroda, Critical roles of cationic surfactants in the preparation of colloidal mesostructured silica nanoparticles: control of mesostructure, particle size, and dispersion, *Acs. Appl. Mater. Inter.* 6 (2014) 3491-3500.
- [7] M. Marszałek, A. Polit, V. Tokman, Y. Zabala, I. Protsenko, The effect of surfactants on the growth of Co/Cu multilayers, *Surf. Sci.* 601 (2007) 4454-4458.
- [8] (a) W.W. Xiong, Q.C. Zhang, Surfactants as promising media for the preparation of crystalline inorganic materials, *Angew. Chem. Int. Ed.* 54 (2015) 11616-11623.
- (b) W.W. Xiong, G.D. Zhang, Q.C. Zhang, New strategies to prepare crystalline chalcogenides, *Inorganic Chemistry Frontiers* 1 (2014) 292-301.

-
- (c) W.W. Xiong, E.U. Athresh, Y.T. Ng, J.F. Ding, T. Wu, Q.C. Zhang, Growing crystalline chalcogenidoarsenates in surfactants: from zero-dimensional cluster to three-dimensional framework, *J. Am. Chem. Soc.* 135 (2013) 1256-1259.
- [9] (a) X.L. Yu, Y.S. Toh, J. Zhao, L. Nie, K.Q. Ye, Y. Wang, D.S. Li, Q.C. Zhang, Surfactant-thermal method to prepare two new cobalt metal-organic frameworks, *J. Solid State Chem.* 232 (2015) 14-18.
- (b) J.K. Gao, K.Q. Ye, M. He, W.F. Cao, W.W. Xiong, Z.Y. Lee, Y. Wang, T. Wu, F.W. Huo, X.G. Liu, Q.C. Zhang, Tuning metal-carboxylate coordination in crystalline metal-organic frameworks through surfactant media, *J. Solid State Chem.* 206 (2013) 27-31.
- (c) J.K. Gao, K.Q. Ye, L. Yang, W.W. Xiong, L. Ye, Y. Wang, Q.C. Zhang, Growing crystalline zinc-1,3,5-benzenetricarboxylate metal-organic frameworks in different surfactants, *Inorg. Chem.* 53 (2014) 691-693.
- (d) W.W. Xiong, P.Z. Li, T.H. Zhou, A.L.Y. Tok, R. Xu, Y.L. Zhao, Q.C. Zhang, Kinetically controlling phase transformations of crystalline mercury selenidostannates through surfactant media, *Inorg. Chem.* 52 (2013) 4148-4150.
- [10] G.D. Zhang, P.Z. Li, J.F. Ding, Y. Liu, W.W. Xiong, L. Nie, T. Wu, Y.L. Zhao, A.I.Y. Tok, Q.C. Zhang, Surfactant-thermal syntheses, structures, and magnetic properties of Mn-Ge—sulfides/selenides, *Inorg. Chem.* 53 (2014) 10248–10256.
- [11] (a) J.K. Gao, M. He, Z.Y. Lee, W.F. Cao, W.W. Xiong, Y.X. Li, R. Ganguly, T. Wu, Q.C. Zhang, A surfactant-thermal method to prepare four new three-dimensional heterometal-organic frameworks, *Dalton Trans.* 42 (2013) 11367-11370.
- (b) H.S. Lu, L.L. Bai, W.W. Xiong, P.Z. Li, J.F. Ding, G.D. Zhang, T. Wu, Y.L. Zhao, J. Lee, Y.H. Yang, B.Y. Geng, Q.C. Zhang, Surfactant media to grow new crystalline Cobalt-1, 3, 5-benzenetricarboxylate metal-organic frameworks, *Inorg. Chem.* 53 (2014) 8529–8537.
- [12] J. Zhao, Y.N. Wang, W.W. Dong, Y.P. Wu, D.S. Li, B. Liu, Q.C. Zhang, A new surfactant-introduced strategy for separating pure single-phase of metal-organic frameworks, *Chem. Commun.* 51 (2015) 9479-9482.
- [13] (a) J.G. Álvarez, J. Díez, C. Vida, C. Vicent, New Ag(I)-iminophosphorane coordination polymers as efficient catalysts precursors for the MW-assisted meyer-schuster rearrangement of propargylic alcohols in water, *Inorg. Chem.* 52 (2013) 6533–86542.

-
- (b) A.Q. Ma, L.G. Zhu, Diverse silver(I) sulfobenzoate coordination polymers and their recycling property as homogeneous catalyst in oxygenation of sulfide, *Rsc. Adv.* 4 (2014) 14691-11699.
- [14] L.Z. Chen, D.D. Huang, J.Z. Ge, F.M. Wang, A novel Ag(I) coordination polymers based on 2-(pyridin-4-yl)-1H-imidazole-4,5-dicarboxylic acid: syntheses, structures, ferroelectric, dielectric and optical properties, *Inorg. Chim. Acta* 406 (2013) 95-99.
- [15] X.Y. Wu, H.X. Qi, J.J. Ning, J.F. Wang, Z.G. Ren, J.P. Lang, One silver(I)/tetraphosphine coordination polymer showing good catalytic performance in the photodegradation of nitroaromatics in aqueous solution, *Appl. Catal. B: Environ.* 168 (2015) 98-104.
- [16] B.X. Zhao, G. Mele, L. Pio, J. Li, L. Palmisano, G. Vasapollo, Degradation of 4-nitrophenol (4-NP) using Fe-TiO₂ as a heterogeneous photo-Fenton catalyst, *J. Hazrd. Mater.* 176 (2010) 569-574.
- [17] X.T. Shen, L.H. Zhu, N. Wang, T. Zhang, H.Q. Tang, Selective photocatalytic degradation of nitrobenzene facilitated by molecular imprinting with a transition state analog, *Catal. Today* 225 (2014) 164-170.
- [18] J.J. Pan, B.H. Guan, Adsorption of nitrobenzene from aqueous solution on activated sludge modified by cetyltrimethylammonium bromide, *J. Hazrd. Mater.* 183 (2010) 341-346.
- [19] S.A. Boyd, G.Y. Sheng, B.J. Teppen, C.T. Johnston, Mechanisms for the adsorption of substituted nitrobenzenes by smectite clays, *Environ. Sci. Technol.* 35 (2001) 4227-4234.
- [20] A. Latifoglu, M.D. Gurol, The effect of humic acids on nitrobenzene oxidation by ozonation and O₃/UV processes, *Water Res.* 37 (2003) 1879-1889.
- [21] X.T. Hong, Z.P. Wang, W.M. Cai, F. Lu, J. Zhang, Y.Z. Yang, N. Ma, Y.J. Liu, Visible-light-activated nanoparticle photocatalyst of iodine-doped titanium dioxide, *Chem. Mater.* 17 (2005) 1548-1552.
- [22] X.Q. Qiao, F.C. Hu, F.Y. Tian, D.F. Hou, D.S. Li, Equilibrium and kinetic studies on MB adsorption by ultrathin 2D MoS₂ nanosheets, *Rsc. Adv.* 6 (2016) 11631-11636.
- [23] C.N. Lu, M.M. Chen, W.H. Zhang, D.X. Li, M. Dai, J.P. Lang, Construction of Zn(II) and Cd(II) metal-organic frameworks of diimidazole and dicarboxylate mixed ligands for the catalytic photodegradation of rhodamine B in water, *CrystEngComm* 17 (2015) 1935-1943.
- [24] Y. Hu, F. Luo, F.F. Dong, Design synthesis and photocatalytic activity of a novel lilac-like

310 silver-vanadate hybrid solid based on dicyclic rings of $[V_4O_{12}]^{4-}$ with $\{Ag_7\}^{7+}$ cluster, Chem.
311 Commun. 47 (2011) 761-763.

312 [25] M. Wałęsa-Chorab, V. Patroniak, M. Kubicki, G. Kądziołka, J. Przepiórski, B. Michalkiewicz,
313 Synthesis, structure, and photocatalytic properties of new dinuclear helical complex of
314 silver(I) ions, J. Catal. 291 (2012) 1-8.

315 [26] H.X. Zhang, M. Liu, X.H. Bu, J. Zhang, Zeolitic BIF crystal directly producing noble-metal
316 nanoparticles in its pores for catalysis, Sci. Rep. 4 (2014) 3923.

317 [27] M.H. Rashid, T.K. Mandal, Synthesis and catalytic application of nanostructured silver
318 dendrites, J. Phys. Chem. C 111 (2007) 16750-16760.

319 [28] S.C. Tang, S. Vongehr, X.K. Meng, Controllable incorporation of Ag and Ag-Au
320 nanoparticles in carbon spheres for tunable optical and catalytic properties, J. Mater. Chem.
321 20 (2010) 5436-5445.

322 [29] H.Y. Niu, S.L. Liu, Y.Q. Cai, F.C. Wu, X.L. Zhao, MOF derived porous carbon supported
323 Cu/Cu₂O composite as high performance non-noble catalyst, Micropor. Mesopor. Mat. 219
324 (2016) 48-53.

Graphical abstract:

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