J Mater Sci (2009) 44:6576–6582
DOI 10.1007/s10853-009-3633-2

MESOSTRUCTURED MATERIALS

Solvent influence on isomer separation and conformation control of the cyclohexanedicarboxylate ligand toward La(III) coordination polymeric framework

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Received: 7 December 2008 / Accepted: 19 May 2009 / Published online: 17 June 2009

Abstract Two novel coordination polymers have been synthesized using 1,4-cyclohexanedicarboxylic acid (chdcH$_2$) by the solvent diffusion method. In the presence of different solvents, *cis* and *trans* conformations of chdcH$_2$ were completely separated. The reaction in DMF/glycol resulted in a 1D chain framework La(*cis*-chdc)(DMF)$_2$(NO$_3$) (**1**) and the reaction in DMSO resulted in the formation of a novel 3D ReO$_3$ topology La$_2$(*trans*-chdc)$_3$(DMSO)$_4$ (**2**). Additionally, the solvent molecules (DMF and DMSO) also acted as coordination ligands in the formation of extended structures.

Introduction

Rational design and construction of coordination polymers are receiving intense attention because of their potential properties, as well as their fascinating framework structures [1–9]. In the last few years, large amounts of coordination polymers based on metal ions and rigid spacer ligands such as di- or tri-carboxylates have been successfully synthesized [10–15]. Interestingly, compared to a lot of attempts aimed at the development of compounds containing rigid ligands, the use of flexible ligands offers a greater degree of structural diversity, which is more difficult to predict, and conformational flexibility that enhances the possibility of forming supramolecular isomers [16–22]. However, the control of the conformation of flexible ligands such as 1,4-cyclohexanedicarboxylic acid (chdcH$_2$) in the synthetic reaction remains a great challenge. ChdcH$_2$ possesses three preponderant conformations of two carboxylate groups, *a*,*a*-*trans*-, *e*,*e*-*trans*-, and *e*,*a*-*cis*-chdcH$_2$. As shown in Scheme 1, the *a*,*a*-*trans*-form is the least stable one and is able to change to *e*,*e*-*trans*-form easily because of 1,3-diaxial hindrance. The *e*,*e*-*trans*-form is thermodynamically more stable than *e*,*a*-*cis*-form due to the presence of two equatorial substituents, but it is difficult to change *e*,*a*-*cis*-form to *e*,*e*-*trans*-form because the α-protons located on the carbon atoms 1 and 4 of cyclohexane should be deprotonated to accelerate the equilibrium state [23–26].

The self-assembly of the frameworks is influenced by many factors, such as coordination nature of the metal ions [27, 28], the structure of the ligands [29, 30], the solvent system [31], the template [32], the pH value of the solution, and the reaction temperature [33, 34]. In the synthesis of coordination polymer, solvent molecules were found to play two significant roles in the formation of extended structures: (1) as a coordination ligand and (2) as a template for the assembly [21, 31, 35, 36]. Moreover, the same components could selectively form different coordination polymers if the arrangement of a ligand in the coordination could be changed by the variation of synthesis conditions such as the solvent system. However, the solvent effect in the formation of various types of structure is still relatively

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Electronic supplementary material The online version of this article (doi:10.1007/s10853-009-3633-2) contains supplementary material, which is available to authorized users.

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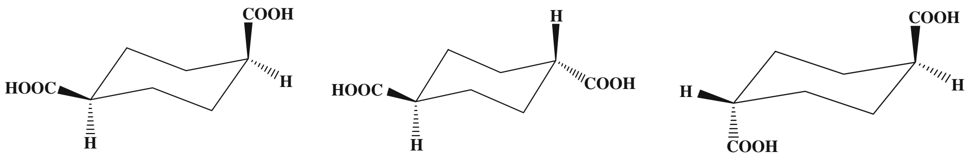
Scheme 1 Conformations of 1, 4-cyclohexanedicarboxylic acid



e,*a*-*cis*-$chdcH_2$ *e*,*e*-*trans*-$chdcH_2$ *a*,*a*-*trans*-$chdcH_2$

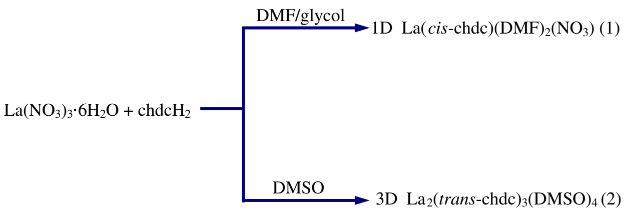
poorly understood and systematic investigations are rare [21, 36].

In this respect, our research has been focused on complete separation of *cis* and *trans* conformations of $chdcH_2$ in different solvent systems of the same metal ion. In previous examples, the molar ratios of *cis* and *trans* conformations of $chdcH_2$ have been controlled by changing the pH value in hydrothermal reactions [24]. By changing the reaction temperature and pH value, *cis* and *trans* conformations of $chdcH_2$ have also been successfully separated in hydrothermal reactions [25]. But, there is no research on complete separation of *cis* and *trans* conformations of $chdcH_2$ in different solvent systems. Owing to the higher coordination numbers, the lanthanum ion was chosen to form the coordination polymers. The synthesis of lanthanide coordination polymers with novel structures offers great challenges and opportunities in terms of controlling their shape and dimensionality [37–40]. In this work, we have obtained two novel polymeric frameworks, La(*cis*-chdc)$(DMF)_2(NO_3)$ (**1**) (DMF = *N*,*N*′-dimethylformamide) constructed from 1D chain and La_2(*trans*-chdc$)_3(DMSO)_4$ (**2**) (DMSO = dimethyl sulfoxide) with 3D ReO_3 topology, in which *cis* and *trans* conformations of $chdcH_2$ were completely separated in the different solvent systems (Scheme 2).

Experimental

Materials

All chemicals were purchased commercially and used without further purification.



Scheme 2 Two polymeric frameworks with *cis* and *trans* conformations of $chdcH_2$

Methods

Synthesis of La(cis-chdc)(DMF)$_2$(NO$_3$) (1)

A mixture of $La(NO_3)_3 \cdot 6H_2O$ (0.086 g, 0.2 mmol) and 1,4-$chdcH_2$ (0.034 g, 0.2 mmol) was dissolved in *N*, *N*′-dimethylformamide (DMF) (10 mL) and glycol (3 mL), and this mixture was placed in a 20 mL test tube. Then, a small vial containing triethylamine (0.5 mL) was placed in the test tube. The test tube was left undisturbed at room temperature for 15 days to give colorless crystals. Calc. elem. anal. for $C_{28}H_{48}La_2O_{18}N_6$(%): C 34.08; H 4.12; N 9.21. Found(%): C 32.51; H 4.68; N 8.13.

Synthesis of La$_2$(trans-chdc)$_3$(DMSO)$_4$ (2)

A mixture of $La(NO_3)_3 \cdot 6H_2O$ (0.130 g, 0.3 mmol) and 1,4-$chdcH_2$ (0.052 g, 0.3 mmol) was dissolved in dimethyl sulfoxide (DMSO) (8 mL), and this mixture was placed in a 20 mL test tube. Then, a small vial containing triethylamine (0.5 mL) was placed in the test tube. The test tube was left undisturbed at room temperature for 30 days to give colorless crystals. Calc. elem. anal. for $C_{16}H_{27}LaO_8S_2$(%): C 35.08; H 4.12; S 10.21. Found(%): C 34.91; H 4.94; S 11.65.

Determination of crystal structure

The single-crystal data of the compounds were collected on a Bruker Smart CCD diffractometer using the graphite-monochromated Mo*Kα* radiation ($\lambda = 0.71073$ Å). The data were collected at 293 K. For compound **1**, totally 11352 reflections, including 7822 unique reflections ($R_{int} = 0.0775$), were measured in the $1.40^\circ < \theta < 27.63^\circ$ range. For compound **2**, totally 12868 reflections, including 4858 unique reflections ($R_{int} = 0.0601$), were measured in the $2.13^\circ < \theta < 28.13^\circ$ range. Both structures were solved with a direct method using SHELXS-97 [41] and were refined by full-matrix least-square methods using SHELXTL-97 [42]. The data were corrected for Lorentz-polarization effects as well as for absorption. All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were fixed at calculated positions and refined by using a riding mode. The crystallographic data and structure refinement details of the two compounds are given in Table 1, and selected bond

Table 1 Crystal data and structure refinement for compound **1** and **2**

	1	2
Empirical formula	$C_{14}H_{24}N_3O_9La$	$C_{16}H_{27}S_2O_8La$
Formula weight	517.27	550.41
Temperature	293 (2) K	293 (2) K
Wavelength	0.71073Å	0.71073Å
Crystal system	Triclinic	Monoclinic
Space group	$P-1$	$P2(1)/n$
Unit cell dimensions	$a = 10.808$ (3) Å, $\alpha = 77.012$ (5)°	$a = 10.5826$ (11) Å, $\alpha = 90$°
	$b = 12.394$ (4) Å, $\beta = 86.247$ (5)°	$b = 18.147$ (2) Å, $\beta = 110.074$ (2)°
	$c = 14.998$ (5) Å, $\gamma = 88.601$ (6)°	$c = 12.0075$ (13) Å, $\gamma = 90$°
Volume	1953.3 (10) Å^3	2165.8 (4) Å^3
Z	2	4
Density (calculated)	1.759 mg/m^3	1.688 mg/m^3
Absorption coefficient	2.238 mm^{-1}	2.202 mm^{-1}
F (0 0 0)	1032	1104
θ range for data collection	1.40°–27.63°	2.13°–28.13°
Limiting indices	$-13 \le h \le 11$, $-15 \le k \le 14$, $-19 \le l \le 19$	$-12 \le h \le 13$, $-23 \le k \le 22$, $-15 \le l \le 8$
Reflections collected/unique	11352/7822 [R(int) = 0.0775]	12868/4858 [R(int) = 0.0601]
Absorption correction	Empirical	Empirical
Refinement method	Full-matrix least-squares on F^2	Full-matrix least-squares on F^2
Data/restraints/parameters	7822/0/507	4858/0/257
Goodness-of-fit on F^2	0.941	1.025
Final R indices [$I > 2\sigma(I)$]	$R_1{}^a = 0.0513$, $wR_2{}^b = 0.1115$	$R_1{}^a = 0.0794$, $wR_2{}^b = 0.1645$
R indices (all data)	$R_1 = 0.0688$, $wR_2 = 0.1211$	$R_1 = 0.1010$, $wR_2 = 0.1758$

[a] $R_1 = \Sigma||F_o|-|F_c||/\Sigma|F_o|$

[b] $wR_2 = \left[\Sigma w\left(F_o^2 - F_c^2\right)^2/\Sigma w\left(F_o^2\right)^2\right]^{1/2}$

$w = 1/\left[\sigma^2\left(F_o^2\right) + (ap)^2 + bp\right]$, where p $= \left(F_o^2 + 2F_c^2\right)/3$

lengths and bond angles are presented in Tables 2 and 3, respectively.

Crystallographic data for compounds **1** and **2** have been deposited with the Cambridge Crystallographic Data Centre (deposition number CCDC 288344 for **1** and CCDC 288343 for **2**).

Results and discussion

Structure of La(*cis*-chdc)(DMF)$_2$(NO$_3$) (1)

Single-crystal X-ray analysis reveals that **1** is a 1D coordination polymer. As shown in Fig. 1a, an extend framework contains two crystallographically distinct La atoms. The two La atoms are each coordinated by nine oxygen atoms: five oxygen atoms from four carboxylate groups of four different 1,4-chdcH$_2$ ligands, two oxygen atoms from a nitrate anion, and two oxygen atoms from two DMF molecules. In the structure, the La1-O distances range from 2.460(4) Å to 2.707(4) Å. The bond angles around the La1 center range from 47.67(15)° to 146.84(15)°. The bond lengths of La2–O range from 2.431(4) Å to 2.822(5) Å. The bond angles around the cadmium center range from 47.87(13)° to 163.80(15)°.

For **1**, 1,4-cyclohexanedicarboxylic acid is deprotonated and only *e*,*a*-*cis*-chdc^{2-} (L$_1$) ligand is present in the compound. The *e*,*a*-*cis*-chdcH$_2$ ligand has two coordination fashions. In one fashion, the ligand contains two chelating/bridging bidentate carboxylate groups (Fig. 2a), while in the other, the ligand contains two monodentate carboxylate groups (Fig. 2b). The compound is composed of La and 1,4-cyclohexanedicarboxylic acid, and each carboxylate moiety bridges four La atoms in the two fashions mentioned above to form 1D chains with paddlewheel-like building blocks (Fig. 2c). On the other hand, the nitrate anion and DMF molecules occupy the other coordination positions of metal ions. Hence, the *e*,*a*-*cis*-chdc^{2-} ligand with an angle of about 90° in the two coordination fashions easily constructs 1D chain structure. One uncoordinated nitrate oxygen atom and the hydrogen atom of the carbon atom of DMF molecule of the adjacent chain form

Table 2 Selected bond lengths (Å) and bond angles (°) for compound **1**

O(1)–La(1)	2.475(4)	O(2)–La(2)	2.452(4)
O(3)–La(1)	2.577(4)	O(5)–La(2)	2.557(4)
O(4)–La(1)	2.492(4)	O(6)–La(2)	2.462(4)
O(4A)–La(1)	2.707(4)	O(6A)–La(2)	2.822(5)
O(13)–La(1)	2.460(4)	O(7)–La(2)	2.431(4)
O(14)–La(1)	2.515(4)	O(8)–La(2)	2.520(5)
O(15)–La(1)	2.567(5)	O(9)–La(2)	2.583(5)
O(16)–La(1)	2.662(4)	O(10)–La(2)	2.646(5)
O(17)–La(1)	2.639(5)	O(12)–La(2)	2.671(5)
O(13)–La(1)–O(1)	134.68(15)	O(13)–La(1)–O(4)	73.58(15)
O(1)–La(1)–O(4)	74.82(14)	O(13)–La(1)–O(14)	124.70(16)
O(1)–La(1)–O(14)	76.64(15)	O(4)–La(1)–O(14)	76.01(15)
O(13)–La(1)–O(15)	144.83(15)	O(1)–La(1)–O(15)	75.15(15)
O(4)–La(1)–O(15)	141.01(14)	O(14)–La(1)–O(15)	73.30(16)
O(13)–La(1)–O(3)	90.48(16)	O(1)–La(1)–O(3)	81.35(14)
O(4)–La(1)–O(3)	124.29(14)	O(14)–La(1)–O(3)	144.50(15)
O(15)–La(1)–O(3)	74.34(15)	O(13)–La(1)–O(17)	73.51(16)
O(1)–La(1)–O(17)	144.73(16)	O(4)–La(1)–O(17)	140.41(15)
O(14)–La(1)–O(17)	106.05(16)	O(15)–La(1)–O(17)	72.28(16)
O(3)–La(1)–O(17)	77.23(15)	O(13)–La(1)–O(16)	71.18(16)
O(1)–La(1)–O(16)	146.84(15)	O(4)–La(1)–O(16)	100.53(15)
O(14)–La(1)–O(16)	70.46(15)	O(15)–La(1)–O(16)	91.33(17)
O(3)–La(1)–O(16)	124.59(14)	O(17)–La(1)–O(16)	47.67(15)
O(13)–La(1)–O(4A)	71.83(14)	O(1)–La(1)–O(4A)	69.40(13)
O(4)–La(1)–O(4A)	75.56(14)	O(14)–La(1)–O(4A)	140.18(14)
O(15)–La(1)–O(4A)	115.55(14)	O(3)–La(1)–O(4A)	48.88(13)
O(17)–La(1)–O(4A)	113.64(15)	O(16)–La(1)–O(4A)	142.31(15)
O(7)–La(2)–O(2)	133.78(15)	O(7)–La(2)–O(6)	74.77(15)
O(2)–La(2)–O(6)	73.77(15)	O(7)–La(2)–O(8)	78.10(16)
O(2)–La(2)–O(8)	135.18(16)	O(6)–La(2)–O(8)	91.42(15)
O(7)–La(2)–O(5)	96.77(17)	O(2)–La(2)–O(5)	73.44(16)
O(6)–La(2)–O(5)	122.65(15)	O(8)–La(2)–O(5)	143.31(16)
O(7)–La(2)–O(9)	144.4(2)	O(2)–La(2)–O(9)	69.55(17)
O(67)–La(2)–O(9)	92.3(2)	O(8)–La(2)–O(9)	69.07(18)
O(5)–La(2)–O(9)	117.7(2)	O(7)–La(2)–O(10)	117.95(15)
O(2)–La(2)–O(10)	100.39(15)	O(6)–La(2)–O(10)	163.80(15)
O(8)–La(2)–O(10)	82.17(15)	O(5)–La(2)–O(10)	68.11(15)
O(9)–La(2)–O(10)	71.5(2)	O(7)–La(2)–O(12)	70.31(15)
O(2)–La(2)–O(12)	136.81(15)	O(6)–La(2)–O(12)	144.68(15)
O(8)–La(2)–O(12)	76.57(17)	O(5)–La(2)–O(12)	67.67(17)
O(9)–La(2)–O(12)	113.2(2)	O(10)–La(2)–O(12)	47.93(15)
O(7)–La(2)–O(6A)	70.37(15)	O(2)–La(2)–O(6A)	70.23(14)
O(6)–La(2)–O(6A)	77.12(14)	O(8)–La(2)–O(6A)	148.26(14)
O(5)–La(2)–O(6A)	47.87(13)	O(9)–La(2)–O(6A)	139.78(16)
O(10)–La(2)–O(6A)	115.67(13)	O(12)–La(2)–O(6A)	95.73(15)

Symmetry transformations used to generate equivalent atoms: #1 *x*, *y*, *z*; #2 −*x*, −*y*, −*z*

Table 3 Selected bond lengths (Å) and bond angles (°) for compound **2**

O(1)–La(1)	2.475(4)	O(2)–La(1)	2.483(6)
O(2A)–La(1)	2.673(6)	O(3)–La(1)	2.613(7)
O(4)–La(1)	2.582(7)	O(5)–La(1)	2.530(6)
O(6)–La(1)	2.635(7)	O(7)–La(1)	2.485(8)
O(8)–La(1)	2.535(8)		
O(2)–La(1)–O(7)	142.5(3)	O(2)–La(1)–O(1)	74.3(2)
O(7)–La(1)–O(1)	79.3(2)	O(2)–La(1)–O(5)	71.2(2)
O(7)–La(1)–O(5)	143.4(3)	O(1)–La(1)–O(5)	135.4(2)
O(2)–La(1)–O(8)	141.0(2)	O(7)–La(1)–O(8)	72.6(3)
O(1)–La(1)–O(8)	143.1(2)	O(5)–La(1)–O(8)	71.2(2)
O(2)–La(1)–O(4)	91.0(3)	O(7)–La(1)–O(4)	84.0(3)
O(1)–La(1)–O(4)	126.8(2)	O(5)–La(1)–O(4)	81.3(2)
O(8)–La(1)–O(4)	73.9(3)	O(2)–La(1)–O(3)	76.0(2)
O(7)–La(1)–O(3)	72.5(3)	O(1)–La(1)–O(3)	77.2(2)
O(5)–La(1)–O(3)	119.4(3)	O(8)–La(1)–O(3)	115.1(3)
O(4)–La(1)–O(3)	49.6(2)	O(2)–La(1)–O(6)	121.8(2)
O(7)–La(1)–O(6)	77.5(3)	O(1)–La(1)–O(6)	79.1(3)
O(5)–La(1)–O(6)	95.9(3)	O(8)–La(1)–O(61)	71.9(3)
O(4)–La(1)–O(6)	144.6(3)	O(3)–La(1)–O(6)	144.6(3)
O(2)–La(1)–O(2A)	73.5(2)	O(7)–La(1)–O(2A)	120.8(3)
O(1)–La(1)–O(2A)	69.2(2)	O(5)–La(1)–O(2A)	74.5(2)
O(18)–La(1)–O(2A)	105.4(3)	O(4)–La(1)–O(2A)	154.4(2)
O(3)–La(1)–O(2A)	139.4(2)	O(6)–La(1)–O(2A)	48.7(2)

Symmetry transformations used to generate equivalent atoms: #1 *x*, *y*, *z*; #2 −*x* + 1/2, *y* + 1/2, −*z* + 1/2; #3 −*x*, −*y*, −*z*; #4 *x* − 1/2, −*y* − 1/2, *z* − 1/2

interchain H-bond with the O18···H28A-C28 distance of 2.687 Å. Therefore, the C–H···O hydrogen bonds further extend the 1D chains into 3D supramolecular framework of the compound (Fig. 2d).

Structure of La_2(*trans*-chdc)$_3$(DMSO)$_4$ (2)

Single-crystal X-ray analysis shows that compound **2** is a 3D coordination polymer. The asymmetric unit of **2** includes one crystallographically distinct La atom, 1.5 1, 4-chdc groups and two DMSO molecules As shown in Fig. 1b, the lanthanum atom adopts a nine-coordinated manner by coordinating to seven oxygen atoms from five different 1,4-chdc ligands and another two oxygen atoms from two DMSO molecules. In the structure, the La–O distances range from 2.483(6) Å to 2.673(6) Å. The bond angles around the La center range from 48.7(2)° to 154.4(2)°.

The interesting feature of **2** is that the 1,4-chdc ligands possess only one type of *e*,*e*-*trans* conformation (L_2). Two different coordination modes of 1,4-chdc ligands and

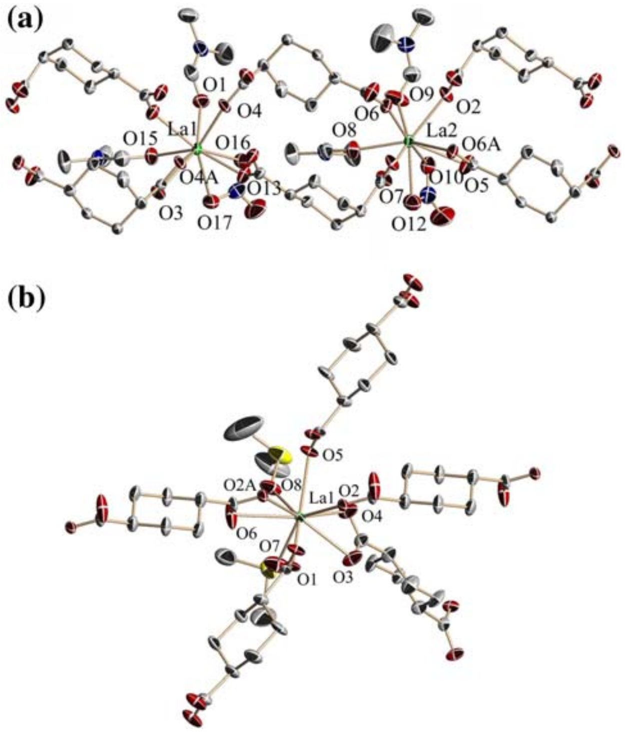


Fig. 1 **a** The asymmetric unit compound **1**. **b** The coordination environment of La in compound **2**. All hydrogen atoms are omitted for clarity

lanthanum ions exist in compound **2**. The couple carboxylate groups of 1,4-chdc ligand are in a chelating/bridging bidentate fashion (Fig. 3a). In another 1,4-chdc ligand, there are one chelating bidentate carboxylate group and one bridging dimonodentate carboxylate group (Fig. 3b). In the structure, two lanthanum ions are connected by six carboxylate groups in the two modes to form octahedral $La_2C_6O_{12}$ cluster secondary building units (SBUs) (Fig. 3c). A representation of the six-coordinated mode of each SBU is shown in Fig. 3e. Then the SBUs are connected by struts, cyclohexane rings, to give a 3D network structure (Fig. 3d). The topology of the structure is described in terms of the 6-connected net of the ReO_3 structure (Fig. 3f). Meanwhile, there are two DMSO molecules pointing into the channels. Here sulfur atom (S1) from one DMSO molecule splits into two different positions (S1 and S1A) with occupancies of 70% and 30%, respectively. Compared to *e*,*a*-*cis*-chdc^{2-} conformation, the angle of the carboxylate groups of *e*,*e*-*trans*-conformation is approximately 180° . Therefore, the *e*,*e*-*trans*-chdc^{2-} as linear ligand can yield 3D architecture.

IR spectrum

The IR spectrum of compound **1** shows a band at 3355 cm^{-1}, which is attributed to the vibrations of the

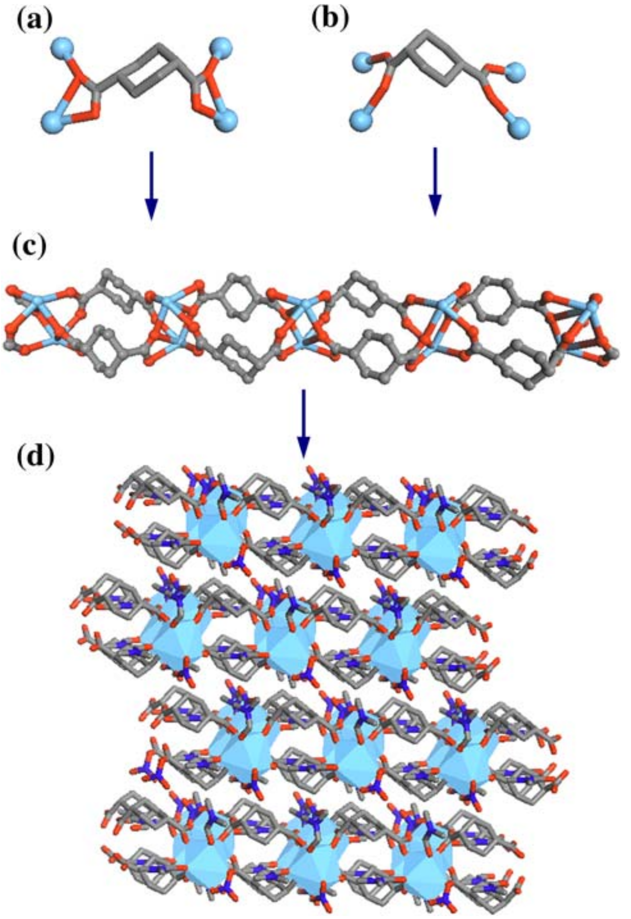


Fig. 2 **a** and **b** Two coordination modes of *e*,*a*-*cis*-chdc^{2-} (L_1) ligand in compound **1**. **c** The 1D polymeric chain of compound **1.** Nitrate anion and DMF molecules are omitted for clarity. **d** Packing of the 1D chains

water molecule. A couple of weak bands at around 2931 cm^{-1} are due to the C–H bonds of the cyclohexane rings. The bands at 1615 and around 900 cm^{-1} identify the stretch vibrations. The bands located around 1400 cm^{-1} are characteristic of the C–N bonds of DMF molecules. The lack of the characteristic bands of the carboxylic groups of any protonated forms around 1700 cm^{-1} indicates the complete deprotonation of 1,4-chdc after the reaction (Fig. S1).

The IR spectrum of compound **2** shows the characteristic band of the water molecules at 3272 cm^{-1} range. The absorptions at 2935 and 2850 cm^{-1} are attributed to the C–H bonds of the cyclohexane rings. The bands at 1544, 1406, 1344, and 1296 cm^{-1} are characteristic of the asymmetric stretching and the symmetric vibrations of the carboxylic groups of 1,4-chdc. The bands located around 1000 cm^{-1} are attributed to the S=O bonds of DMSO molecules. The absence of the bands around 1700 cm^{-1} is attributed to the protonated C=O bonds on the spectra of

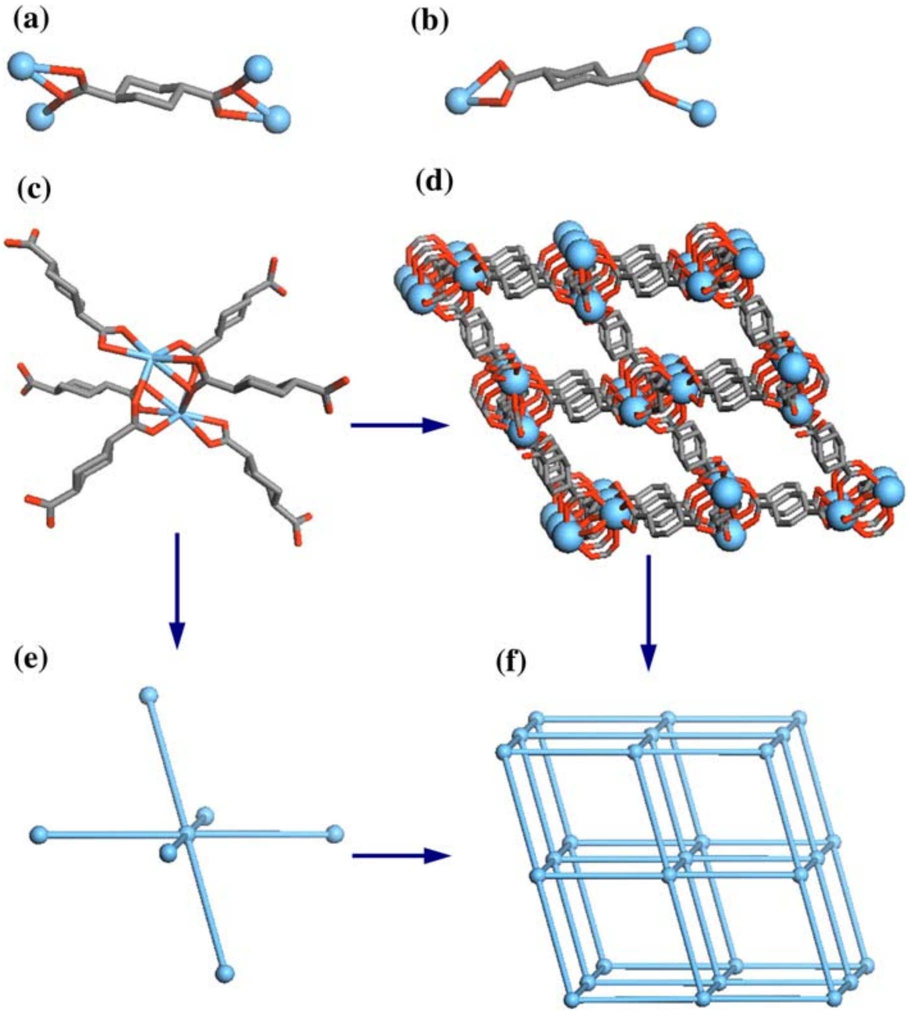


Fig. 3 **a** and **b** Two coordination modes of *e*,*e*-*trans*-chdc^{2-} (L_2) ligand in compound **2**. **c** Octahedral $La_2C_6O_{12}$ building units with the DMSO molecules not shown. **d** Infinite 3D network structure **e** A representation of this SBU. **f** The ReO_3 topology structure of compound **2**

the compounds, which agrees with the structural results (Fig. S1).

Thermogravimetric analysis

The thermogravimetric analysis (TGA) shows that compound **1** is stable up to 170°C. The TG curve of compound **1** showed two weight loss steps. The first weight loss of 13.4% from 170 to 250°C corresponds to the loss of nitrate anion (calculated: 12%). The second weight loss of 51.95% between 250 and 800°C is attributed to the loss of all organic ligands (Fig. S2).

The TGA shows that compound **2** is stable up to 300°C. The curve exhibits the first weight loss of 6.72% from 100 to 160°C, which corresponds to half DMSO molecule (calculated: 7.08%). The weight loss of 7.24% during the second step from 160 to 300°C is attributed to another half DMSO molecule. The major weight loss of 53.34% from 300 to 600°C is in good agreement with the dissociation of the organic components (calculated, 56.22%) (Fig. S2).

Conclusion

In the presence of different solvents, the *cis* and *trans* conformations of 1,4-cyclohexanedicarboxylic acid were successfully separated. Structure analysis shows that the angle of the carboxylate groups of the *cis* and *trans* ligands has an effect on the structure of the compounds. The two compounds were synthesized by using the solvent diffusion method. In this work, we have obtained a new 1D chain framework La(*cis*-chdc)$(DMF)_2(NO_3)$ (**1**) in DMF/glycol and a novel 3D ReO_3 topology La_2(*trans*-chdc)$_3(DMSO)_4$ (**2**) in DMSO.

In addition, the solvent molecules (DMF and DMSO) were found to act as a coordination ligand in the formation of extended structures. These results suggest that the choice of solvent is clearly critical in determining conformations of $chdcH_2$. It is believed that other metal coordination polymers with *cis* and *trans* conformations of 1,4-cyclohexanedicarboxylic acid can also be synthesized by using different solvent molecules.

Acknowledgements This work was supported by the State Basic Research Project (G2000077507), the National Nature Science Foundation of China (Grant nos. 29873017, 20101004, and 20371020), and the Belgian Federal Government IUAP-PAI program (INANOMAT P6/17) project.

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