Electronic Supplementary Material (ESI) for Green Chemistry.

Supporting information

Effective combination catalyst of CeO_2 and zeolite for direct synthesis of diethyl carbonate from CO_2 and ethanol with 2,2-diethoxypropane as a dehydrating agent

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Materials

All catalysts and substrates were purchased or supplied from chemical companies. The details are shown below. Before the activity test, CeO_2, Al_2O_3, Nb_2O_5, ZrO_2, and Ta_2O_5 were calcined at 873 K for 3 hours, and SiO_2 and $SiO_2 \cdot Al_2O_3$ were calcined at 773 K.

Table S1 (a) List of solid catalysts

Solid catalyst	Company name product name
Al_2O_3	Nippon Aerosil, AEROXIDE Alu C
Nb_2O_5	Sigma-Aldrich (purity: 99.99 %)
Ta_2O_5	FUJIFILM Wako Pure Chemical Corporation (purity: 99.9 %)
ZrO_2	Daiichi Kigenso Kagaku Kogyo, RC-100
SiO_2	Fuji Silysia Chemical LTD., G-6
CeO_2	Daiichi Kigenso Kagaku Kogyo, CeO_2-HS
SiO_2-Al_2O_3	JGC C&C, LA silica-alumina
H-FAU (SiO_2/Al_2O_3=25)	Tosoh Corporation, HSZ-371NHA
H-MFI (SiO_2/Al_2O_3=24)	Tosoh Corporation, HSZ-822HOA
H-*BEA (SiO_2/Al_2O_3=28)	Tosoh Corporation, HSZ-931HOA
H-MOR (SiO_2/Al_2O_3=18)	Tosoh Corporation, HSZ-640HOA
H-FAU (SiO_2/Al_2O_3=5.5)	Tosoh Corporation, HSZ-320HOA

Table S1 (b) List of organic and inorganic acids

Reagent and substrate	Company name	Purity /%
HNO_3	FUJIFILM Wako Pure Chemical Corporation	69~70
H_2SO_4	FUJIFILM Wako Pure Chemical Corporation	95.0
H_3PO_4	Nacalai Tesque	85
Benzenesulfonic acid monohydrate	Tokyo Chemical Industry	>98.0
Maleic acid	Kanto Chemical	>99.0
Pyridine-2-carboxylic acid	Tokyo Chemical Industry	>99.0
Benzoic acid	FUJIFILM Wako Pure Chemical Corporation	>99.5
2,2-Diethoxypropane	Tokyo Chemical Industry	>95.0
Ethanol	Kanto Chemical	>99.5
2,2-Dimethoxypropane	Tokyo Chemical Industry	>98.0
Methanol	Kanto Chemical	>99.5
1-Hexanol	Tokyo Chemical Industry	>98.0

Activity test

The typical reaction procedure for DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 and an acid catalyst is as follows: Reactions were carried out in autoclaves with 190 ml inner volume. A magnetic stirrer, CeO_2 0.5 g, an acid catalyst 0.01 g, EtOH 140 mmol, and 2,2-diethoxypropane 21 mmol were added into the autoclave in order. The autoclave was sealed up and purged by 1 MPa (r.t.) CO_2 two times, and then pressured to 5 MPa (r.t.) by CO_2. The autoclave was heated to 393 K, and the time when the autoclave reached 393 K was defined as beginning of the reaction (0 h). The CO_2 pressure reached 6.5 MPa at 393 K. After reaction, the autoclave was cooled down to room temperature by a water bath. The reaction mixture was recovered with 1-hexanol (0.2 g) as the internal standard and analyzed by GC-FID (TC-WAX). Figure S3 showed the typical GC chart of DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 + H-FAU. Conversion, yield, and balance were calculated by the following equations.

$$\text{DEP conversion /\%} = [1 - \text{DEP}_{(\text{Residual})}) / \text{DEP}_{(\text{Introduced})}] \times 100$$

$$\text{DEC yield (on DEP basis)/\%} = \text{DEC}_{(\text{detected after reaction})} / \text{DEP}_{(\text{Introduced})} \times 100$$

When the DEP conversion was below 20 %, the DEP conversion was calculated by the following equation.

$$\text{DEP conversion /\%} = [\text{Acetone}_{(\text{detected after reaction})} + \text{2-Ethoxypropene}_{(\text{detected after reaction})} + \text{By-products}_{(\text{acetone-derived})}] / [\text{Acetone}_{(\text{detected after reaction})} + \text{2-Ethoxypropene}_{(\text{detected after reaction})} + \text{DEP}_{(\text{residual})} + \text{By-products}_{(\text{acetone-derived})}] \times 100$$

$$\text{DEP balance /\%} = [\text{Acetone}_{(\text{detected after reaction})} + \text{2-Ethoxypropene}_{(\text{detected after reaction})} + \text{By-products}_{(\text{acetone-derived}} + \text{DEP}_{(\text{Residual})}] / \text{DEP}_{(\text{Introduced})} \times 100$$

Measurement of reaction rates

The typical procedure for measurement of the reaction rates is as follows: A magnetic stirrer, CeO_2 0.03 g, an acid catalyst 0.01 g, EtOH 140 mmol, and 2,2-diethoxypropane 21 mmol were put into the autoclave reactor with 190 ml inner volume under air. The autoclave reactor was sealed, and the air content was purged by 1 MPa Ar twice. The autoclave was heated to 393 K, and the autoclave was pressured by CO_2 to 5 MPa at 393 K, and the time was defined as beginning of the reaction (0 h). After the reaction, the autoclave reactor was cooled to room temperature by a water bath. Recovery and analyses of the reaction mixture were the same as the above procedure.

Reusability test

The typical method for reusability test is as follows: Some reactions (2-4 batches) were carried out at the same time, and the reaction operation is the same as the typical procedure described in the activity test. After the reaction, the reaction mixtures were analyzed by GC first, and the reaction mixtures were separated into the liquid phase and solid phase by centrifugation. The liquid phase was removed, and ethanol was added into the collected solid and well-mixed for washing. The obtained solid solutions were separated by centrifugation again. The washing operation of the collected solid with ethanol was repeated at least 5 times. The obtained wet solids were dried at 383 K overnight and calcined at 623 K for 3 hours (The catalyst loss was about 5~10 %). The second activity test was carried out with the collected catalyst under the same reaction conditions as the first one (The catalyst amount was kept constant by decreasing the reaction numbers.)

Characterization of CeO_2, H-FAU, and CeO_2 + H-FAU

The specific surface area of the catalysts was measured by the Brunauer–Emmett–Teller (BET) isotherm analysis of N_2 physical adsorption using Gemini VII (Micromeritics). The X-ray powder diffraction patterns were obtained under air by miniflex600 (Rigaku) with Cu K_α (40kV/15mA). The TEM images were recorded by the STEM/SEM HD-2700 (Hitachi). The preparation of TEM sample is that the catalyst was dispersed in ethanol under air, and then dropped on Cu microgrids.

Table S2 Previous reports of dimethyl carbonate (DMC) synthesis from CO_2 and methanol with 2,2-dimethoxypropane (DMP) hydrolysis

Catalyst	Reactant (mmol)		Temperature (K)	CO_2 Pressure (MPa)	Time (h)	$Yield_{DMC}$[a] (%)	Ref.
	Methanol	DMP					
$Bu_2Sn(OMe)_2$	200	10	453	30	96	57	[S1]
$Bu_2Sn(OMe)_2$	200	10	453	200	24	88	[S1]
$Ce_{0.2}Zr_{0.8}O_2$	192	10	383	5	140	41	[S2]
$Bu_2Sn(OMe)_2$ /$[Ph_2NH_2]$-OTf	100	50	453	30	24	40	[S3]
Ti $(OiPr)_4$/decyl-18-crown-6	200	10	473	30	24	58	[S4]
Spindle-CeO_2	370	30	413	5	2	9	[S5]
$Ce_{0.5}Zr_{0.5}O_2$	618	10	413	7.5	3	236[b]	[S6]

[a]DMC yield based on DMP.

[b]The DMC yield based on DMP was higher than 100 % because the formed DMC amount was larger than that of the introduced DMP.

Table S3 Details of diethyl carbonate (DEC) synthesis from CO_2 and ethanol over CeO_2 with or without 2,2-diethoxypropane (DEP)

(a) DEC synthesis from CO_2 and ethanol over CeO_2 without DEP

Reaction time /h	Product /mmol	Ethanol balance /%
	DEC	
1	0.134	93
2	0.150	99
3	0.143	100
4	0.157	98
24	0.155	98

Reaction conditions: CeO_2 0.5 g, ethanol 140 mmol, CO_2 6.5 MPa (393 K), 393 K.

(b) DEC synthesis from CO_2 and ethanol over CeO_2 with DEP

Reaction time /h	DEP conversion /%	Products /mmol					DEC Yield[a] /%	DEP balance /%
		DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	10	0.4	1.1	1.2	<0.1	<0.1	2	108
4	7	0.8	1.0	0.4	<0.1	<0.1	4	91
10	15	1.3	2.3	0.8	<0.1	<0.1	6	99
16	17	1.7	2.5	0.9	<0.1	<0.1	8	105
24	19	1.9	2.9	1.1	<0.1	<0.1	9	101
36	18	2.2	3.1	0.8	<0.1	<0.1	10	106

Reaction conditions: CeO_2 0.5 g, ethanol 140 mmol, DEP 21 mmol, CO_2 6.5 MPa (393 K), temperature 393 K.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

Table S4 Comparison of different homogeneous acid additives of CeO_2 in DEC synthesis with DEP hydrolysis

Entry	Acid additive	pK_a	DEP conversion /%	Products /mmol					DEC Yield[a] /%	DEP balance /%
				DEC	Acetone	2-Ethoxy propene	Mesityl oxide	Others[b]		
1	-		16	0.8	1.0	0.4	<0.1	<0.1	4	91
2	HNO_3	-1.3	25	2.3	3.2	0.4	<0.1	<0.1	11	92
3	H_2SO_4	-3.0, 1.9	56	9.9	10.0	0.3	<0.1	<0.1	48	93
4	H_3PO_4	2.1, 7.2, 12.3	20	1.1	1.8	0.5	<0.1	<0.1	5	91
5	Benzenesulfonic acid monohydrate	0.7	19	0.7	1.6	0.7	<0.1	<0.1	3	92
6	Maleic acid	1.9, 6.2	21	0.6	2.1	0.7	<0.1	<0.1	3	92
7	Pyridine-2-carboxylic acid	3.1	18	0.4	1.6	0.7	<0.1	<0.1	2	93
8	Benzoic acid	4.2	20	0.6	1.9	0.5	<0.1	<0.1	3	91
9	H-FAU	-	65	13.1	13.4	0.2	<0.1	0.6	62	103

Reaction conditions: CeO_2 (873 K 3 h) 0.5 g, additive amount: 0.05 mmol (HNO_3, benzenesulfonic acid monohydrate, pyridine-2-carboxylic acid, benzoic acid, *p*-toluenesulfonic acid) 0.025 mmol (H_2SO_4, H_3PO_4, maleic acid), 393 K, 4 h, CO_2 6.5 MPa (393 K).

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

Table S5 Effect of H-FAU amount in DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 + H-FAU

Entry	H-FAU amount /g	DEP conversion /%	Products /mmol					DEC Yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	0	10	0.4	1.1	1.2	<0.1	<0.1	2	108
2	0.002	30	3.6	4.1	0.5	<0.1	<0.1	17	91
3	0.005	44	6.4	6.7	0.4	<0.1	0.2	30	91
4	0.010	42	8.2	8.6	0.4	<0.1	<0.1	40	101
5	0.020	65	10.9	10.8	0.2	<0.1	0.7	51	92
6	0.050	74	11.8	11.7	0.1	0.1	1.2	56	89

Reaction conditions: catalyst: CeO_2 (873 K 3 h) 0.5 g, CO_2 6.5 MPa (393 K), 1 h.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

Table S6 Details of time-course of DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 + H-FAU (Figure 2)

Entry	Reaction time /h	DEP conversion /%	Products /mmol					DEC yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	0.5	37	6.6	6.6	0.6	<0.1	<0.1	31	97
2	1	42	8.2	8.6	0.4	<0.1	<0.1	40	101
3	4	65	13.1	13.4	0.2	<0.1	0.6	62	103
4	24	67	13.0	13.1	0.1	<0.1	0.3	62	98

Reaction conditions: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, 393 K. CO_2 6.5 MPa (393 K).

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

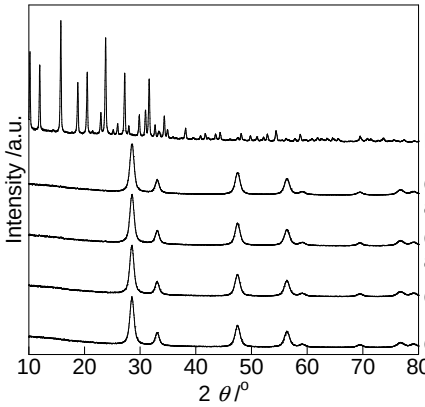
Table S7 Recyclability test of CeO_2 + H-FAU in DEC synthesis with the presence of DEP (Figure 3)

Entry	Reuse time	DEP conversion /%	Products /mmol					DEC yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	0	47	8.1	9.6	0.3	<0.1	0.1	39	101
2	1	45	8.2	9.1	0.4	<0.1	0.1	39	101
3	2	45	8.3	9.2	0.4	<0.1	0.1	39	101
4	3	40	8.2	9.2	0.4	<0.1	<0.1	39	106

Reaction conditions: CeO_2 0.5 g, ethanol 140 mmol, DEP 21 mmol, H-FAU 0.01 g (reusing times: 0), mixed catalyst 0.5 g (reusing times 1~3), 393 K, CO_2 6.5 MPa (393 K), 1 h.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.



	Specific surface area* (m^2 g^{-1})
H-FAU	550
CeO_2 + H-FAU after fourth reaction	-
CeO_2 + H-FAU after first reaction	93
CeO_2 + H-FAU (Fresh)	93
CeO_2 (Fresh)	84

Figure S1 XRD patterns and specific surface area of fresh CeO_2, H-FAU and mixture of CeO_2 and H-FAU before and after reaction

CeO_2 : H-FAU(1) = 50 : 1 (weight ratio).

*Specific surface areas were determined by BET method.

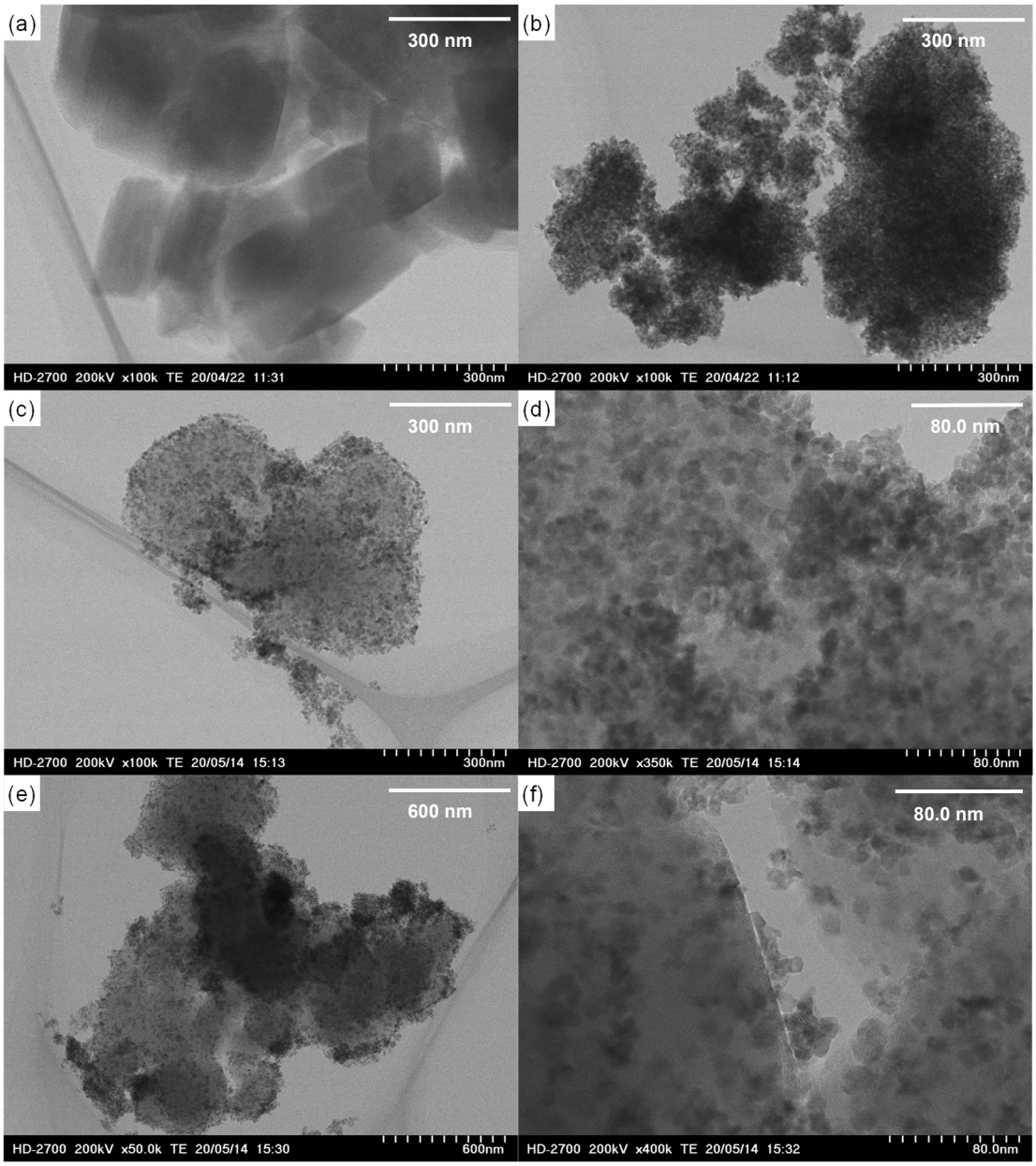


Figure S2 TEM analyses of CeO_2, H-FAU and mixture of CeO_2 and H-FAU after reaction.

(a) H-FAU, (b) CeO_2, (c) Mixture of CeO_2 and H-FAU after reaction, (d) Expanded figure of (c), (e) Mixture of CeO_2 and H-FAU after reaction (another view), (f) Expanded figure of (e)

Reaction conditions: CeO_2 0.5 g, ethanol 140 mmol, DEP 21 mmol, H-FAU 0.01 g, 393 K, CO_2 6.5 MPa 393 K), 1 h.

Table S8 Effect of ethanol amount in DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 + H-FAU

Entry	EtOH amount /mmol	DEP conversion /%	Products / mmol					DEC yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1[c]	0	16	0.3	1.3	1.6	0.3	0.3	1	86
2	20	21	0.7	1.5	2.5	0.3	<0.1	3	91
3	60	34	4.4	4.6	0.9	0.2	0.3	21	96
4	100	39	7.4	7.7	0.6	0.1	0.4	35	103
5	140	42	8.2	8.6	0.4	<0.1	<0.1	40	101
6	180	44	9.5	10.3	0.4	<0.1	<0.1	45	107

Reaction conditions: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 0-180 mmol, DEP 21 mmol, 1 h, 393 K, CO_2 6.5 MPa at 393 K.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

[c]2.6 mmol ethanol was detected after the reaction

Table S9 Effect of reaction temperature in DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 and H-FAU

Entry	Temp. /K	DEP conversion /%	Products /mmol					DEC Yield[a] /%	Balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		DEP
1	363	14	0.3	0.7	0.1	<0.1	<0.1	1	92
2	373	21	1.7	2.1	0.1	<0.1	<0.1	8	92
3	383	28	4.0	4.2	0.2	<0.1	<0.1	19	93
4	393	41	8.2	8.6	0.4	<0.1	<0.1	40	101
5	403	60	9.6	9.7	0.5	0.1	0.2	45	90

Reaction conditions: catalyst: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, CO_2 6.5 MPa at 393 K, 1 h.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

Table S10 Effect of CO_2 pressure on DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 + H-FAU (Figure 4)

Entry	CO_2 Pressure at 393 K /MPa	Reaction time /h	DEP conversion /%	Products /mmol					DEC yield[a] /%	DEP balance /%
				DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	3.9	0.5	32	5.2	5.4	0.6	<0.1	<0.1	25	97
2	3.9	1	36	7.2	7.3	0.3	<0.1	<0.1	34	101
3	3.9	4	51	8.9	9.9	0.2	<0.1	0.3	42	99
4	3.9	24	54	10.4	10.6	0.2	<0.1	<0.1	49	98
5	3.9	72	60	10.3	10.7	0.2	0.1	<0.1	49	92
6	6.5	0.5	37	6.6	6.6	0.6	<0.1	<0.1	31	97
7	6.5	1	41	8.2	8.6	0.4	<0.1	<0.1	40	101
8	6.5	4	65	13.1	13.4	0.2	<0.1	0.6	62	103
9	6.5	24	67	13.0	13.1	0.1	<0.1	0.3	62	98
10	6.5	72	69	12.7	12.3	0.2	0.1	<0.1	60	91
11	8.3	0.5	41	6.8	6.8	0.3	<0.1	<0.1	32	93
12	8.3	1	40	8.3	8.6	0.5	<0.1	<0.1	41	103
13	8.3	4	64	12.4	12.5	0.2	0.3	<0.1	59	99
14	8.3	24	77	13.1	13.2	0.2	0.2	0.7	63	92
15	8.3	72	74	14.0	14.5	0.1	<0.1	0.5	66	97
16	9.5	0.5	32	6.6	6.7	0.7	<0.1	<0.1	29	103
17	9.5	1	40	8.4	8.5	0.5	<0.1	<0.1	40	102
18	9.5	4	60	11.3	11.4	0.2	<0.1	0.1	53	96
19	9.5	24	76	13.5	13.4	0.1	0.1	0.8	64	93
20	9.5	72	74	15.2	15.3	0.2	0.1	0.7	72	104

Reaction conditions: catalyst: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, 393 K.

[a]DEC yield based on DEP.

[b]Others include products derived from acetone.

Table S11 Details of comparison of DEC formation with different reaction systems in DEC synthesis from CO_2 and ethanol (Figure 5)

(a) DEC formation from CO_2 and C_2H_5OH with CeO_2

Entry	Time /min	Products /mmol
		DEC
1	0	0.006
2	10	0.018
3	20	0.031

Reaction conditions: CeO_2 0.03 g, ethanol 140 mmol, CO_2 5 MPa (393 K).

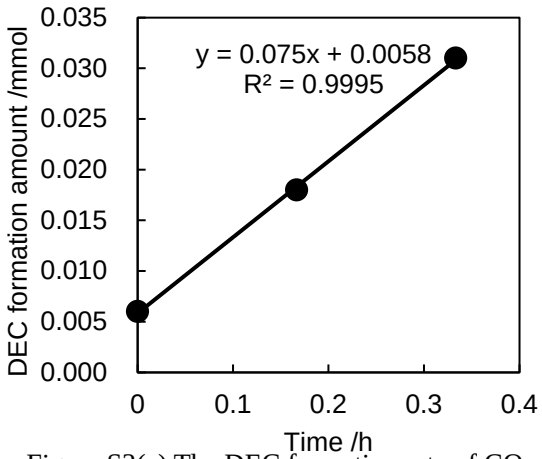


Figure S3(a) The DEC formation rate of CO_2 +C_2H_5OH on CeO_2

(b) DEC formation from CO_2 and C_2H_5OH with CeO_2 + H-FAU

Entry	Reaction time /min	Product /mmol
		DEC
1	0	0.004
2	10	0.017
3	20	0.030

Reaction conditions: CeO_2 0.03 g, ethanol 140 mmol, H-FAU 0.01 g, CO_2 5 MPa (393 K).

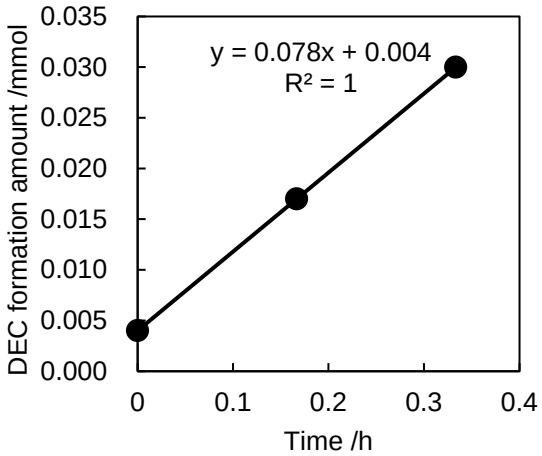


Figure S3(b) The DEC formation rate of CO_2 +C_2H_5OH on CeO_2 + H-FAU

(c) DEC formation from CO_2 and C_2H_5OH in the presence of DEP with CeO_2

Entry	Reaction time /min	DEP conversion /%	Products /mmol					DEC Yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	0	3	0.007	0.1	0.4	<0.1	<0.1	<1	94
2	7	4	0.021	0.2	0.6	<0.1	<0.1	<1	96
3	17	5	0.044	0.2	0.8	<0.1	<0.1	<1	96

Reaction conditions: CeO_2 0.03 g, ethanol 140 mmol, DEP 21 mmol, CO_2 5 MPa (393 K).
[a]DEC yield based on DEP.
[b]Others include products derived from acetone.

(d) DEC formation from CO_2 and C_2H_5OH in the presence of DEP with CeO_2 + H-FAU

Entry	Reaction time /min	DEP conversion /%	Products /mmol					DEC Yield[a] /%	DEP balance /%
			DEC	Acetone	2-Ethoxypropene	Mesityl oxide	Others[b]		
1	0	9	0.096	0.8	0.8	<0.1	<0.1	<1	97
2	7	10	0.278	1.1	0.8	<0.1	<0.1	1	101
3	17	10	0.470	1.3	0.6	<0.1	<0.1	2	100

Reaction conditions: CeO_2 0.03 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, CO_2 5 MPa (393 K).
[a]DEC yield based on DEP.
[b]Others include products derived from acetone.

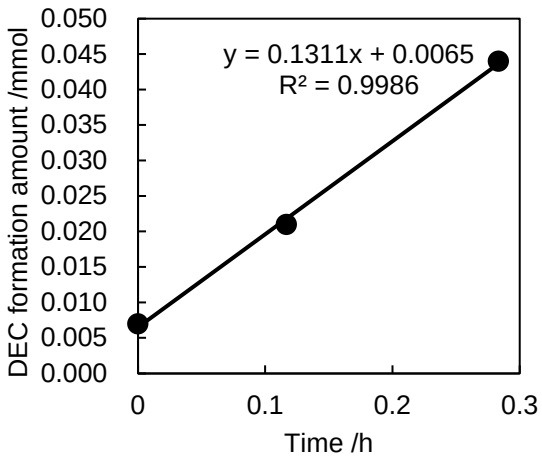


Figure S3(c) The DEC formation rate of CO_2 +C_2H_5OH + DEP on CeO_2

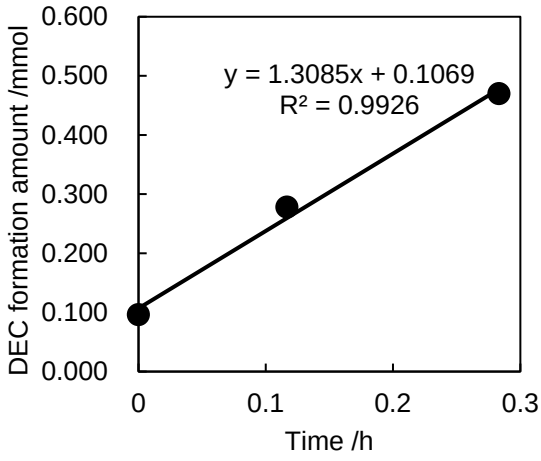
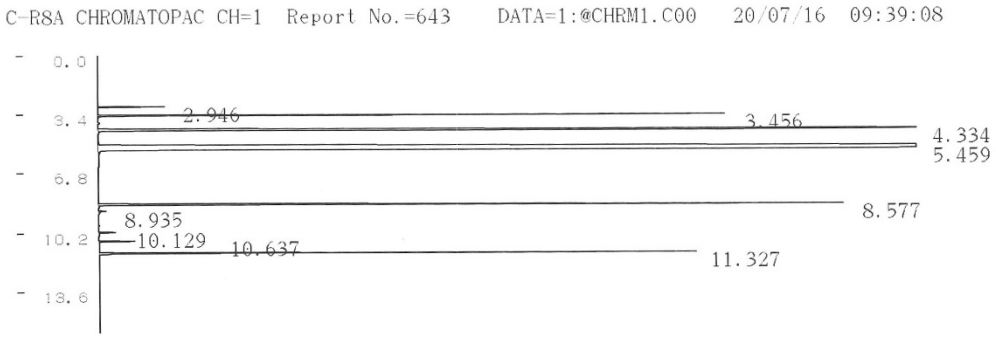


Figure S3(d) The DEC formation rate of CO_2 +C_2H_5OH + DEP on CeO_2 + H-FAU



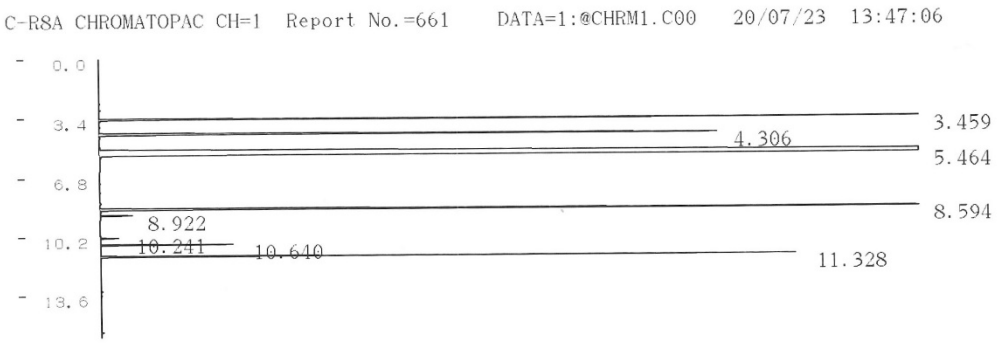
** CALCULATION REPORT **

CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
1	2	2.946	9905	5229			0.3964	
	3	3.456	104813	49007			4.1942	
	5	4.334	449720	114117			17.9958	
	7	5.459	1680265	166777			67.237	
	12	8.577	156525	58258			6.2635	
	13	8.935	1474	604			0.059	
	17	10.129	2489	1346			0.0996	
	19	10.637	5083	2810			0.2034	
	21	11.327	88744	46715			3.5512	
		TOTAL	2499019	444862			100	

Figure S4 (a) Typical GC chart of DEC synthesis from CO_2 and ethanol in the presence of DEP with CeO_2 and H-FAU

Reaction conditions: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, 393 K, 1 h, CO_2 6.5 MPa (393 K)

Retention time (min)	Compound
2.946	2-Ethoxypropene
3.456	Acetone
4.334	2,2-Diethoxypropane
5.459	Ethanol
8.577	Diethyl carbonate
8.935	Mesityl oxide
10.129, 10.637	Polymerized products of acetone
11.327	1-Hexanol (internal standard)



** CALCULATION REPORT **

CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
1	3	3.459	162582	71746			6.5282	
	5	4.306	176235	48265			7.0764	
	7	5.464	1762094	171213			70.7538	
	13	8.594	261394	83425			10.4958	
	15	8.922	4902	2545			0.1968	
	19	10.241	2811	1429			0.1129	
	21	10.64	18646	10375			0.7487	
	23	11.328	101796	54293			4.0874	
		TOTAL	2490459	443292			100	

Figure S4 (b) GC chart of entry 20 in Table S10

Reaction conditions: CeO_2 0.5 g, H-FAU 0.01 g, ethanol 140 mmol, DEP 21 mmol, 393 K, 72 h, CO_2 9.5 MPa (393 K)

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