Data in Brief

Dataset for the synthesis and application of single-component heterogeneous catalysts based on zinc and tin for the cycloaddition of pure, diluted, and impure CO₂ to epoxides under mild conditions

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A B S T R A C T

The cycloaddition of CO₂ to epoxides under mild conditions is a growing field of research and a viable strategy to recycle CO₂ in the form of cyclic carbonates as useful intermediates, solvents, and additives. This target requires readily accessible and recyclable catalysts whose synthesis does not involve expensive monomers, multistep procedures, coupling reagents, etc. Additionally, the catalysts should be active under atmospheric pressure and tolerate impurities such as methane and H₂S. In a recent manuscript (Rational engineering of single-component heterogeneous catalysts based on abundant metal centers for the mild conversion of pure and impure CO₂ to cyclic carbonates; Chemical Engineering Journal 422 (2021) 129930) we have developed strategies to prepare efficient heterogeneous catalysts for the cycloaddition reaction of CO₂ to epoxides. Such materials consist of dispersions of metal halides (ZnCl₂ or SnCl₄) on silica support that is further functionalized with ionic liquids bearing nucle-
Specifications Table

| Subject                  | Chemical Engineering: Catalysis |
|--------------------------|---------------------------------|
| Specific subject area    | Inorganic Chemistry and Physical Characterization |
| Type of data             | Table                           |
|                          | Image                           |
|                          | Figure                          |
| How data were acquired   | SEM/EDS mappings were acquired on a JEOL JSM-7610F field emission scanning electron microscope equipped with an Oxford Instruments X-Max150 EDS. TEM images were acquired on a JEOL JEM-ARM 200F electron microscope equipped with Energy dispersive X-ray analyser (EDS) JEOL EX-37001. Images acquired by TEM Center Ver. 2.0.15.6527 and analysed by Gatan Digital Micrograph Ver. 3.22.1461.0 XPS survey spectra and high-resolution spectra were acquired on a JEOL JPS-9010MC spectrometer with SpectraSurf Ver. 1.9.3 acquisition and analysis software. BET physisorption isotherms were acquired on a BELSORP-Mini II analyser with BELSORP-mini Ver. 2.5.10 measuring software and BELMaster™ Version 6.3.2.1 analysing software. ¹H NMR spectra were acquired on a Bruker Avance III 600 MHz with Topspin 3.6.2 software |
| Data format              | Raw                             |
|                          | Analyzed                        |
| Parameters for data collection | SEM/EDS – High resolution SEM mode; 1 kV electron acceleration, 11–1 mA filament current. EDS mode; 15 kV electron acceleration, 7–8 mA filament current. Chamber pressure = 2.0·10⁻⁵ Pa TEM – High resolution mode; 200 kV electron acceleration, 11–1 μA filament current. Chamber pressure = 2.0·10⁻⁵ Pa XPS – Mg Kα source (1253.6 eV) working at 12 kV and 25 mA. Chamber pressure = 10⁻⁸ Pa, temperature = 25°C. Energy pass = 50 eV, binding energy range = 0–1100 eV, steps = 1 eV BET – Measurement by N₂ adsorption/desorption at -196°C NMR – 600 MHz Avance III NMR spectrometer operating at 25°C with 5 mm TCI CryoProbe Prodigy and z-gradients ¹H frequency = 600.13 MHz |
| Description of data collection | SEM/EDS – Finely dispersed catalyst powders were deposited on carbon tape glued to Al stubs in a N₂-filled glove box and transferred to the XPS instrument by a sealed sample holder for air sensitive samples. TEM – Catalyst powders were dispersed in dry dichloromethane and deposited by dipping on Cu TEM grids. Coated grids were kept under N₂ |

(continued on next page)
before plasma treated and loaded in the TEM pre-chamber.
XPS – samples in the form of powder were deposited on carbon tape glued to
the sample holder in a N₂ filled glove box and transferred to the XPS
instrument by a sealed manipulator for air sensitive samples.
BET – Catalyst powders were filled to the sample tubes and pretreated at
100°C for 16 h under 10⁻² kPa vacuum before measurement.
NMR – All compounds were measured in CDCl₃ at room temperature by
adding a drop of crude reaction mixture to 0.7 mL CDCl₃ in a standard NMR
tube.

Data source location
Vidyasirimedhi Institute of Science and Technology (VISTEC), department
of materials science engineering, school of molecular science engineering, 555
Moo 1, 21210, Payupnai, WangChan, Rayong, Thailand. (13.002395649932376,
101.44350075242147).

Data accessibility
https://data.mendeley.com/datasets/dx5zpgmwp6/3
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Related research article
O. Sodpiban, C. Phungpanya, S. Del Gobbo,* S. Arayachukiat, T. Piromchart and
V. D’Elia*
Rational engineering of single-component heterogeneous catalysts based on
abundant metal centers for the mild conversion of pure and impure CO₂ to
cyclic carbonates
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Value of the Data

• These data are important for the complete characterization (electron microscopy, XPS and
BET isotherms) of efficient catalytic materials for the cycloaddition of CO₂ to epoxides under
mild conditions and for assessing (¹H NMR of crude catalytic reactions) the reproducibility
of the catalytic reactions using the most efficient catalysts among the synthesized materials.
• Researchers in materials science and catalysis can find the spectroscopic data, microscopic
images, physicochemical characterization, and spectra of catalytic reactions helpful when
characterizing comparable materials and applying them in catalytic cycloaddition reactions
of epoxides.
• Reported data can be used for the design of new catalysts based on co-immobilized metal
centres and ionic liquids and for the interpretation of crude spectra of catalytic cycloaddition
reactions involving epoxides.

1. Data Description

The data in this article refer to the materials in Table 1 that were prepared as catalysts for
the cycloaddition of CO₂ to epoxides [1–5] and that are described in detail (including the structure
of ionic liquids IL-I and IL-Br) in Rational engineering of single-component heterogeneous cat-
alysts based on abundant metal centers for the mild conversion of pure and impure CO₂ to cyclic
carbonates [6].

The SEM and TEM images of the tt-SiO₂_{2.150} sample in Fig. 1 show the aggregated nature of
the Aerosil fumed silica nanoparticles used as the support in this work and their morphology by
using two different magnifications. The SEM images of IL-I@SiO₂ and IL-Br@SiO₂ in Fig. 2 show
that the aggregated nature of the silica materials is preserved after grafting ionic liquids on
the support. The SEM images of ZnCl₂-based catalysts in Fig. 3 and of SnCl₄-based catalysts in
Fig. 4 show a clear effect of increasing metal and ionic liquid loadings on particles aggregation.
The SEM-EDS images for ZnCl₂-based catalysts (Figs. 5–7) and SnCl₄-based catalysts (Figs. 8–10)
show the uniform distribution of Zn, Cl, I elements (for ZnCl₂-based catalysts) and of Sn, Cl, Br
elements (for Sn-based catalysts).
Table 1
List of materials mentioned in this article.

| Material                           | Brief description                                      |
|------------------------------------|-------------------------------------------------------|
| tt-SiO$_2$                         | Support                                               |
| IL-1@SiO$_2$                       | Ionic liquid IL-I (iodide anion) grafted on support   |
| IL-Br@SiO$_2$                      | Ionic liquid IL-Br (bromide anion) grafted on support |
| ZnCl$_2$(0.36)-IL-I               | Catalytic material based on ZnCl$_2$ with IL-I        |
| ZnCl$_2$-0.45@SiO$_2$              | Precursor of ZnCl$_2$(0.36)-IL-I prior to IL-I grafting|
| ZnCl$_2$(1.99)-IL-I               | Catalytic material based on ZnCl$_2$ with IL-I        |
| ZnCl$_2$-2.26@SiO$_2$              | Precursor of ZnCl$_2$(1.99)-IL-I prior to IL-I grafting|
| ZnCl$_2$(3.29)-IL-I               | Catalytic material based on ZnCl$_2$ with IL-I        |
| ZnCl$_2$-4.23@SiO$_2$              | Precursor of ZnCl$_2$(3.29)-IL-I prior to IL-I grafting|
| ZnCl$_2$(5.62)-IL-I               | Catalytic material based on ZnCl$_2$ with IL-I        |
| ZnCl$_2$-7.89@SiO$_2$              | Precursor of ZnCl$_2$(5.62)-IL-I prior to IL-I grafting|
| SnCl$_2$(0.24)-IL-Br              | Catalytic material based on SnCl$_2$ with IL-Br       |
| SnCl$_4$-0.32@SiO$_2$              | Precursor of SnCl$_4$(0.24)-IL-Br prior to IL-Br grafting|
| SnCl$_4$(0.66)-IL-Br              | Catalytic material based on SnCl$_4$ with IL-Br       |
| SnCl$_4$-0.84@SiO$_2$              | Precursor of SnCl$_4$(0.66)-IL-Br prior to IL-Br grafting|
| SnCl$_2$(1.06)-IL-Br              | Catalytic material based on SnCl$_2$ with IL-Br       |
| SnCl$_4$-1.45@SiO$_2$              | Precursor of SnCl$_4$(1.06)-IL-Br prior to IL-Br grafting|
| SnCl$_4$(1.93)-IL-Br              | Catalytic material based on SnCl$_4$ with IL-Br       |
| SnCl$_4$-2.89@SiO$_2$              | Precursor of SnCl$_4$(1.93)-IL-Br prior to IL-Br grafting|

The survey XPS spectrum of ZnCl$_2$-2.26@SiO$_2$ (Fig. 11) confirms the presence of relevant elements Zn and Cl from grafting of the ZnCl$_2$ precursor by ball milling. A high-resolution overview of all relevant spectral regions of this material (C 1s, O 1s, Zn 2p, Cl 2p, Si 2p) is provided in Fig. 12. The survey spectrum of SnCl$_4$-0.84@SiO$_2$ (Fig. 13) shows the presence of tin and chlorine elements from the SnCl$_4$ precursor grafted by impregnation with the relevant spectral regions (C 1s, O 1s, Si 2p, Sn 3d and Cl 2p) being displayed in high-resolution in Fig. 14. The survey XPS spectrum of ZnCl$_2$(1.99)-IL-I (Fig. 15) shows the presence of Zn, Cl, N, I elements from ZnCl$_2$ and IL-I with the relevant spectral regions (C 1s, N 1s, O 1s, Si 2p, Cl 2p, I 3d and Zn 2p) being provided in high-resolution in Fig. 16. This is also the case of SnCl$_4$(0.66)-IL-Br (See Fig. 17 for survey spectrum, Fig. 18 for the high-resolution spectra in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, Br 3d and Sn 3d regions) showing the presence of characteristic elements Sn, Cl (from SnCl$_4$) and N, Br from IL-Br. The XPS spectra in Figs. 19-22 refer to the spent materials ZnCl$_2$(1.99)-IL-I (Fig. 19 (survey), Fig. 20 (high-resolution in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, I 3d and Zn 2p regions)) and SnCl$_4$(0.66)-IL-Br ((Fig. 21 (survey), Fig. 22 (high-resolution in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, Br 3d and Sn 3d regions)) after five catalytic cycles with a CO$_2$ feed containing H$_2$S. These figures show the apparent absence of sulfur contaminant in the survey spectra and the presence of the same elements as in the pristine materials but with lower intensity in the case of halides (due to dehalogenation).

The BET adsorption/desorption isotherms in Fig. 23 are for the ZnCl$_2$-based catalytic materials and those in Fig. 24 for the SnCl$_4$-based catalytic materials. Such isotherms show the lack of porosity of these materials as expected given the non-porous nature of the support (See isotherm shown in Fig. 25 along with metal-free catalytic materials IL-1@SiO$_2$ and IL-Br@SiO$_2$).

The $^1$H NMR spectra of catalytic cycloaddition reactions carried out under different reaction conditions[6] in Figs. 26-63 generally show the formation of signals relative to the cyclic carbonate products in the 4-5 ppm region and the disappearance of the signals relative to the epoxide substrates in the 2-3 ppm region [7-9]. These data are useful to estimate the conversion of epoxides and to calculate conversion values based on the integration of corresponding signals of products and epoxides [10-12]. These data generally confirm the complete or nearly complete conversion of epoxide substrates and the absence of evident reaction by-products and the reproducible application of the catalysts.

Supplementary material includes the raw data for XPS spectra, BET physisorption experiments and $^1$H NMR experiments.
2. Experimental Design, Materials and Methods

The preparation of all compounds in Table 1 and the experimental procedure for catalytic reactions is described in Rational engineering of single-component heterogeneous catalysts based on abundant metal centers for the mild conversion of pure and impure CO2 to cyclic carbonates [6].

2.1. Scanning electron microscopy (SEM)

SEM images of materials were acquired by a JEOL JSM-7610F field emission scanning electron microscope equipped with an Oxford Instruments X-Max150 EDS. Samples were prepared by tapping adhesive carbon stabs on paper smeared with the catalyst powders. No sputtering metallization was used.

2.2. Transmission electron microscopy (TEM)

TEM images were obtained on a JEOL JEM-ARM 200F electron microscope. All samples were dispersed in dry dichloromethane and coated by three dipping/drying cycles on TEM grids (Ted Pella Ultrathin C Type-A 400 mesh, Cu). All samples were plasma-treated before the insertion in the microscope vacuum pre-chamber.

2.3. X-ray photoelectron spectroscopy (XPS)

X-ray photoelectron spectroscopy (XPS) was performed by a JEOL JPS-9010MC spectrometer utilizing a Mg Kα source (1253.6 eV) working at 12 kV and 25 mA. All XPS spectra were acquired under high vacuum (10⁻⁸ Pa) at room temperature. All samples were prepared by compacting the catalysts powders on carbon tape (9 × 9 mm² area). The survey scans were acquired with a pass energy of 50 eV, a binding energy range of 0-1100 eV and steps of 1 eV. Spectral regions relative to specific elements of interest were acquired with high resolution by averaging over a large number of spectra in order to have a good signal to noise ratio. All binding energies were charge corrected by referencing to the carbon peak C 1s at 284.80 eV.

2.4. Brunauer-emmett-teller (BET) analysis

The surface areas of tt-SiO2-150 support and of powder catalysts were measured using a BELSORP-mini II instrument (BEL Japan) via N2 adsorption/desorption isotherm at liquid nitrogen temperature (-196°C). Prior to the measurement, the samples were added to the sample tubes and subsequently pretreated under vacuum (at 100°C for 16 h) by a BELPREP-vac II instrument (MicrotracBEL) to remove undesired moisture adsorbed on the surface. The surface area was calculated by BET method using a linearity range of the relative pressure (P/P0) = 0.05-0.35.

2.5. Nuclear magnetic resonance (NMR) spectroscopy

All NMR spectra of catalytic reactions were collected using a 600 MHz Bruker Avance III NMR spectrometer operating at 25°C with 5 mm TCI CryoProbe Prodigy and z-gradients. All chemical shifts (δ ppm) were referenced to the internal standard tetramethyl silane (TMS; ¹H resonances appear at 0.00 ppm) present in CDCl₃. ¹H frequency = 600.13 MHz. To collect the crude reaction spectra, an aliquot of the reaction product was withdrawn and added into an NMR tube containing 0.7 mL CDCl₃.
Electron microscopy images

**Fig. 1.** a.) SEM image, b.) TEM image at 100k magnifications and c.) TEM image at 500k magnifications of tt-SiO$_2$-150.

**Fig. 2.** SEM images of a.) IL-I@SiO$_2$ and b.) IL-Br@SiO$_2$.

**Fig. 3.** SEM images of a.) ZnCl$_2$(0.36)-IL-I, b.) ZnCl$_2$(3.29)-IL-I and c.) ZnCl$_2$(5.62)-IL-I.
Fig. 4. SEM image of a.) SnCl$_4$(0.24)-IL-Br, b.) SnCl$_4$(1.06)-IL-Br and c.) SnCl$_4$(1.93)-IL-Br.

Fig. 5. a.) EDS mapping and b-d.) dispersion of Zn, Cl and I elements for ZnCl$_2$(0.36)-IL-I.

Fig. 6. a.) EDS mapping and b-d.) dispersion of Zn, Cl and I elements for ZnCl$_2$(3.29)-IL-I.

Fig. 7. a.) EDS mapping and b-d.) dispersion of Zn, Cl and I elements for ZnCl$_2$(5.62)-IL-I.

Fig. 8. a.) EDS mapping and b-d.) dispersion of Sn, Cl and Br elements for SnCl$_4$(0.24)-IL-Br.
Fig. 9. a.) EDS mapping and b-d.) dispersion of Sn, Cl and Br elements for SnCl$_4$(1.06)-IL-Br.

Fig. 10. a.) EDS mapping and b-d.) dispersion of Sn, Cl and Br elements for SnCl$_4$(1.93)-IL-Br.
XPS Spectra

Fig. 11. XPS survey spectrum of ZnCl$_2$-2.26@SiO$_2$ prepared by ball-milling of ZnCl$_2$ on tt-SiO$_2$-150.
**Fig. 12.** High resolution XPS spectra of ZnCl$_2$-2.26@SiO$_2$ in the C 1s, O 1s, Zn 2p, Cl 2p and Si 2p spectral regions.
Fig. 13. XPS survey spectrum of SnCl$_4$-0.84@SiO$_2$ prepared by impregnation of SnCl$_4$ on tt-SiO$_2$-150.
Fig. 14. High resolution XPS spectra of SnCl$_4$-0.84@SiO$_2$ in the C 1s, O 1s, Si 2p, Sn 3d and Cl 2p spectral regions.
Fig. 15. XPS survey spectrum of ZnCl$_2$(1.99)-IL-I produced by grafting IL-I on ZnCl$_2$-2.26@SiO$_2$. 
Fig. 16. High resolution XPS spectra of ZnCl$_2$(1.99)-IL-I in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, I 3d and Zn 2p spectral regions.
Fig. 17. XPS survey spectrum of SnCl$_4$(0.66)-IL-Br produced by the grafting of IL-Br on SnCl$_4$-0.84@SiO$_2$. 
Fig. 18. High resolution XPS spectra of SnCl$_4$(0.66)-IL-Br in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, Br 3d and Sn 3d spectral regions.
Fig. 19. XPS survey spectrum of spent ZnCl$_2$(1.99)-IL-I after five catalytic cycles.
Fig. 20. High resolution XPS spectra of spent ZnCl$_2$(1.99)-IL-I in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, I 3d and Zn 2p spectral regions.
Fig. 21. XPS survey spectrum of spent SnCl$_4$(0.66)-IL-Br after five catalytic cycles.
Fig. 22. High resolution XPS spectra of spent SnCl$_4$(0.66)-IL-Br in the C 1s, N 1s, O 1s, Si 2p, Cl 2p, Br 3d and Sn 3d spectral regions.
BET isotherms

Fig. 23. BET adsorption/desorption isotherms of ZnCl₂-based materials (ZnCl₂(0.36)-IL-I, ZnCl₂(1.99)-IL-I, ZnCl₂(3.29)-IL-I, ZnCl₂(5.62)-IL-I) as indicated in the graphics.
Fig. 24. BET adsorption/desorption isotherms of SnCl$_4$-based materials (SnCl$_4$(0.24)-IL-Br, SnCl$_4$(0.66)-IL-Br, SnCl$_4$(1.06)-IL-Br, SnCl$_4$(1.93)-IL-Br) as indicated in the graphics.
Fig. 25. BET adsorption/desorption isotherms of materials prepared without metal halides (IL-I@SiO$_2$, IL-Br@SiO$_2$) and of the tt-SiO$_2$-150 support.
$^1$H NMR spectra of catalytic reactions

Fig. 26. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to propylene oxide using 2 mol\% ZnCl$_2$(1.99)-IL-I at room temperature, 1 bar CO$_2$ for 24 h.
Fig. 27. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to propylene oxide using 2 mol% SnCl$_4$(0.66)-IL-Br at room temperature, 1 bar CO$_2$ for 24 h.

Fig. 28. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-butene oxide using 2 mol% ZnCl$_2$(1.99)-IL-I at room temperature, 1 bar CO$_2$ for 24 h.
Fig. 29. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-butene oxide using 2 mol% SnCl$_4$(0.66)-IL-Br at room temperature, 1 bar CO$_2$ for 24 h.

Fig. 30. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-butene oxide using 2 mol% ZnCl$_2$(1.99)-IL-I at room temperature, 1 bar CO$_2$ for 12 h.
Fig. 31. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-butene oxide using 2 mol% SnCl$_4$(0.66)-IL-Br at room temperature, 1 bar CO$_2$ for 12 h.

Fig. 32. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-hexene oxide using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar CO$_2$ for 24 h.
Fig. 33. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to 1-hexene oxide using 2 mol% SnCl$_4$(0.66)-IL-Br at room temperature, 1 bar CO$_2$ for 4 h.

Fig. 34. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to epichlorohydrin using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar CO$_2$ for 24 h.
**Fig. 35.** ¹H-NMR spectrum of the cycloaddition of CO₂ to epichlorohydrin using 2 mol% SnCl₄(0.66)-IL-Br at room temperature, 1 bar CO₂ for 24 h.

**Fig. 36.** ¹H-NMR spectrum of the cycloaddition of CO₂ to styrene oxide using 2 mol% ZnCl₂(1.99)-IL-I at 40°C, 1 bar CO₂ for 24 h.
Fig. 37. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to styrene oxide using 2 mol% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar CO$_2$ for 48 h.

Fig. 38. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to furfuryl glycidyl ether using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar CO$_2$ for 24 h.
Fig. 39. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to furfuryl glycidyl ether using 2 mol% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar CO$_2$ for 24 h.

Fig. 40. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to furfuryl glycidyl ether using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar CO$_2$ for 12 h.
Fig. 41. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to furfuryl glycidyl ether using 2 mol% SnCl$_4$(-IL)-Br at 40\degree C, 1 bar CO$_2$ for 12 h.

Fig. 42. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(-IL)-I at 40\degree C, 1 bar CO$_2$ for 24 h.
Fig. 43. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar CO$_2$ for 24 h.

Fig. 44. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar CO$_2$ for 12 h.
Fig. 45. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol\% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar CO$_2$ for 12 h.

Fig. 46. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to epoxy cyclohexane using 2 mol\% ZnCl$_2$(1.99)-IL-I at 100°C, 15 bar CO$_2$ for 48 h.
**Fig. 47.** $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to epoxy cyclohexane using 2 mol% SnCl$_4$(0.66)-IL-Br at 100°C, 15 bar CO$_2$ for 48 h.

**Fig. 48.** $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar 50% CO$_2$ in N$_2$ for 24 h.
Fig. 49. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar 50% CO$_2$ in N$_2$ for 24 h.

Fig. 50. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 40°C, 1 bar 20% CH$_4$ in CO$_2$ for 24 h.
Fig. 51. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 40°C, 1 bar 20% CH$_4$ in CO$_2$ for 24 h.

Fig. 52. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% ZnCl$_2$(1.99)-IL-I at 100°C, 10 bar CO$_2$ for 1 h.
Fig. 53. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% ZnCl$_2$(1.99)-IL-I at 100°C, 20 bar CO$_2$ for 1 h.

Fig. 54. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% ZnCl$_2$(1.99)-IL-I at 100°C, 30 bar CO$_2$ for 1 h.
Fig. 55. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% SnCl$_4$(0.66)-IL-Br at 100°C, 10 bar CO$_2$ for 1 h.

Fig. 56. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% SnCl$_4$(0.66)-IL-Br at 100°C, 20 bar CO$_2$ for 1 h.
Fig. 57. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 1 mol% SnCl$_4$(0.66)-IL-Br at 100°C, 30 bar CO$_2$ for 1 h.

Fig. 58. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 60°C, 10 bar CO$_2$ for 1 h.
Fig. 59. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 80°C, 10 bar CO$_2$ for 1 h.

Fig. 60. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% ZnCl$_2$(1.99)-IL-I at 100°C, 10 bar CO$_2$ for 1 h.
Fig. 61. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 60°C, 10 bar CO$_2$ for 1 h.

Fig. 62. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 80°C, 10 bar CO$_2$ for 1 h.
Fig. 63. $^1$H-NMR spectrum of the cycloaddition of CO$_2$ to glycidyl methacrylate using 2 mol% SnCl$_4$(0.66)-IL-Br at 100°C, 10 bar CO$_2$ for 1 h.
CRediT Author Statement

Chalida Phungpanya: Investigation, data curation; Onjjit Sodpiban: Data curation, Investigation, Writing - Original draft preparation; Silvano Del Gobbo: Visualization, Investigation, Data curation; Sunatda Arayachukiat: Validation, Data curation; Taradon Pimochart: Validation, Supervision; Valerio D’Elia: Supervision, data curation, Writing - reviewing & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2021.107190.

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