Supporting Information

Catalytic degradation of polyurea: Synthesis of N-substituted carbamates with CuO-ZnO as the catalyst

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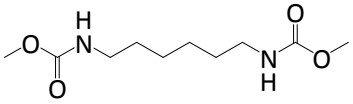
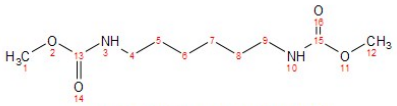
I. ^{1}H NMR characterization results of products

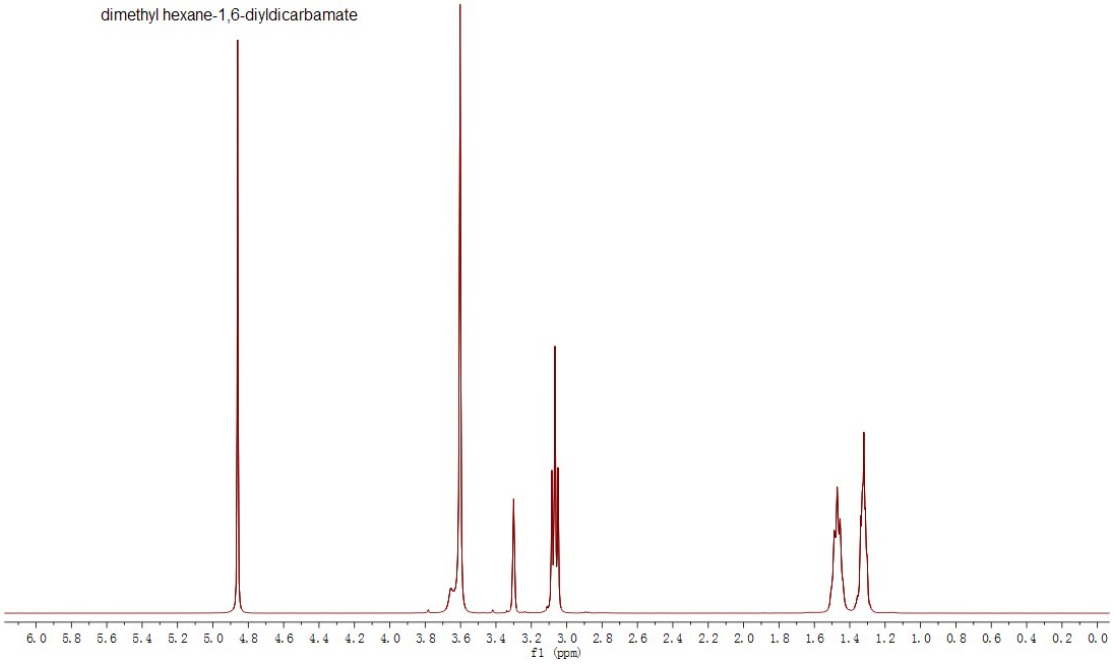
^{1}H NMR spectra of the carbamates spectra were measured using an INOVA NMR system at 400 MHz. All spectra were recorded in CD_3OD and chemical shifts (δ) are reported in ppm relative to tetramethylsilane referenced to the residual solvent peaks.

1) Dimethyl-hexane-1, 6-diyldicarbamate

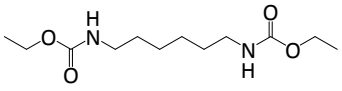


^{1}H NMR (400 MHz, CD_3OD): δ 4.86 (s, 1H), 3.63 (s, 3H), 3.08 (m, 2H), 1.47 (m, 2H), 1.33 (m, 2H).

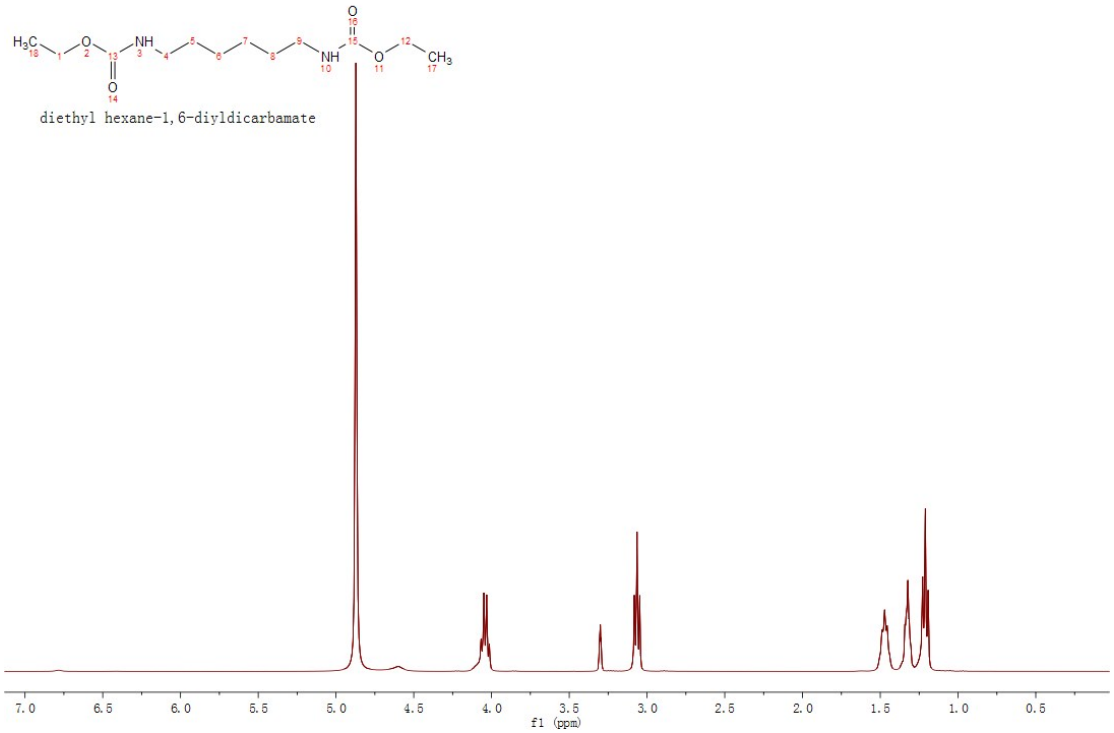




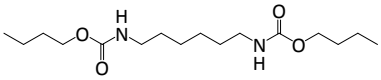
2) Diethyl-hexane-1, 6-diyldicarbamate



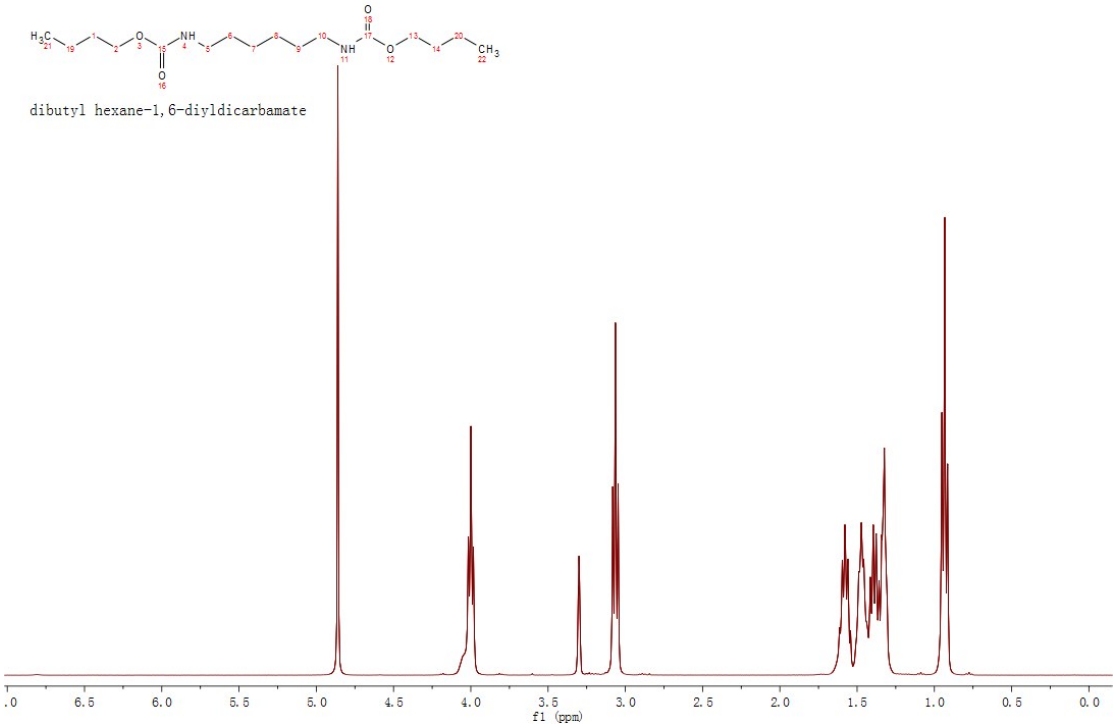
^{1}H NMR (400 MHz, CD_3OD): δ 4.87 (s, 1H), 4.04 (q, 2H), 3.06 (t, 2H), 1.47 (m, 2H), 1.31 (m, 2H), 1.21 (t, 3H).



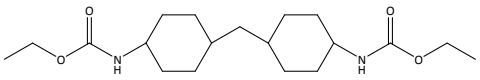
3) Dibutyl-hexane-1, 6-diyldicarbamate



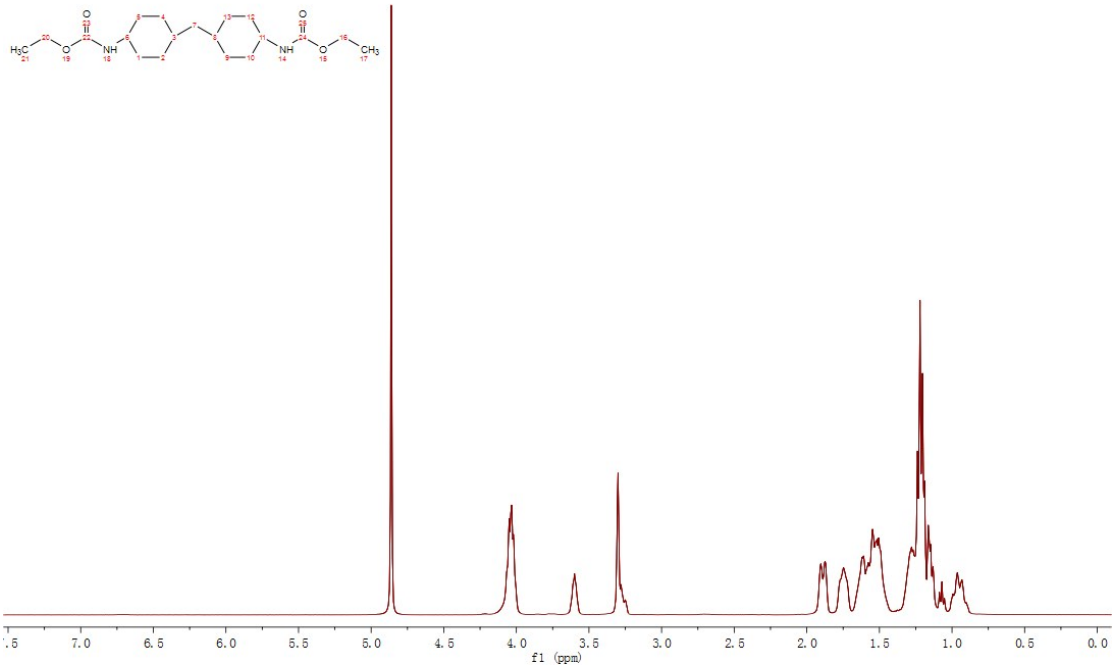
^{1}H NMR (400 MHz, CD_3OD): δ 4.86 (s, 1H), 4.00 (t, 2H), 3.06 (t, 2H), 1.58 (m, 2H), 1.47 (m, 2H), 1.38(m, 2H), 1.34 (m, 2H), 0.93 (t, 3H).



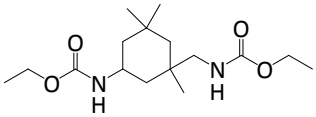
4) Diethyl-4, 4'-methylenebis (cyclohexane-4, 1-diyl) dicarbamate



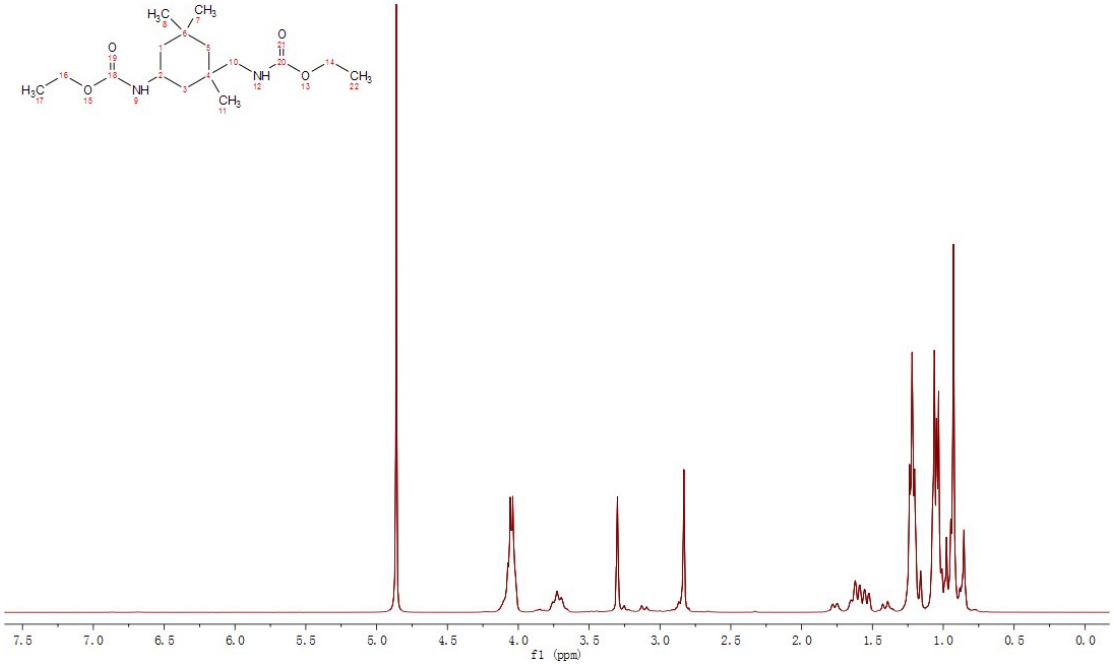
^{1}H NMR (400 MHz, CD_3OD): δ 4.86 (s, 1H), 4.03 (q, 2H), 3.60 (m, 2H), 1.89 (m, 1H), 1.72 (m, 1H), 1.56 (m, 1H), 1.23 (m, 1H), 1.15 (t, 3H), 1.07 (m, 1H), 0.95 (dd, 2H).



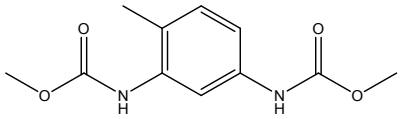
5) 3-(aminomethyl)-3, 5, 5-trimethylcyclohexyldicarbamate



^{1}H NMR (400 MHz, CD_3OD): δ 4.86 (s, 1H), 4.05 (q, 2H), 3.75 (m, 1H), 2.83 (d, 1H), 1.59 (d, 1H), 1.22 (dd, 1H), 1.16 (dd, 1H), 1.03 (d, 1H), 1.00 (t, 3H), 0.98 (d, 1H), 0.94 (s, 3H), 0.87 (s, 3H).



6) Dimethyl 2-methyl-1, 4-phenylenedicarbamate



^{1}H NMR (400 MHz, CD_3OD): δ 7.52 (s, 1H), 7.16 (s, 1H), 7.07 (d, 1H), 4.86 (d, 1H), 3.72 (s, 3H), 2.12 (s, 3H).

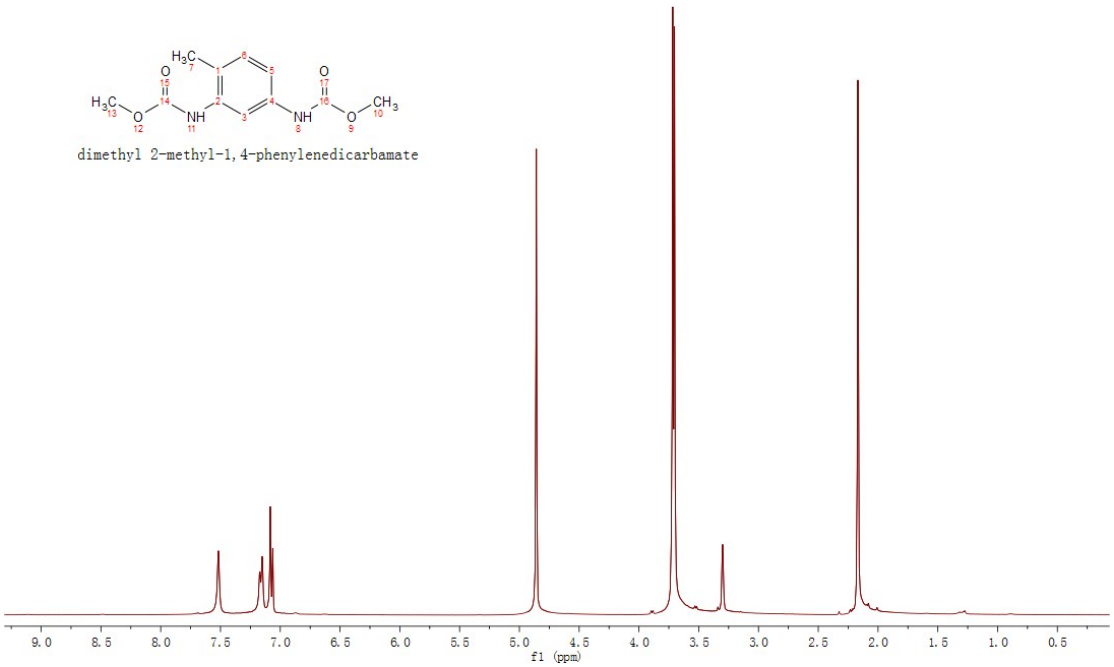


Figure S1. ^{1}H NMR copies of the carbamate products

II. TGA Characterization results of product

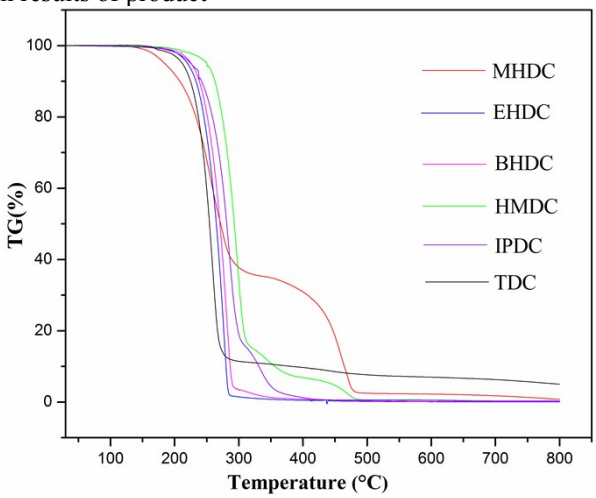


Figure S2. TGA copy of the carbamate products

III. N_2 adsorption-desorption analysis of as-prepared catalyst

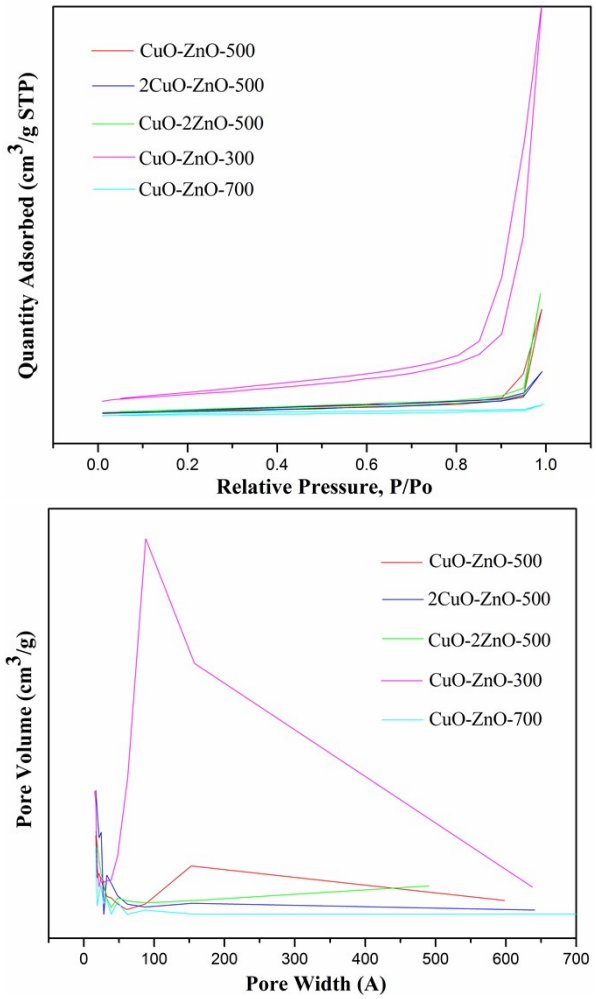


Figure S3. N_2 adsorption-desorption analysis result of various catalysts.

IV. TGA analysis of $Cu(Im)_2$

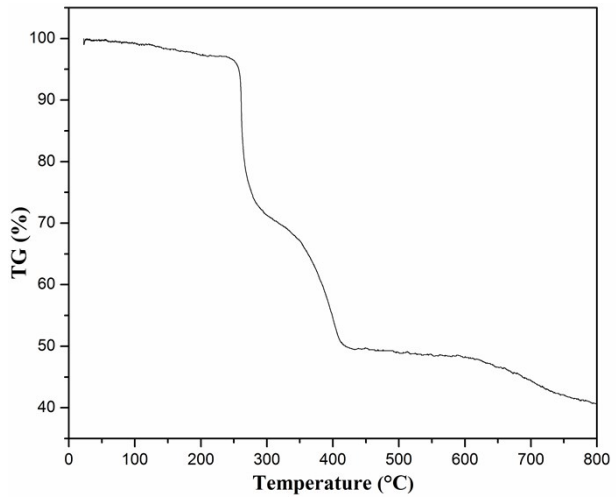
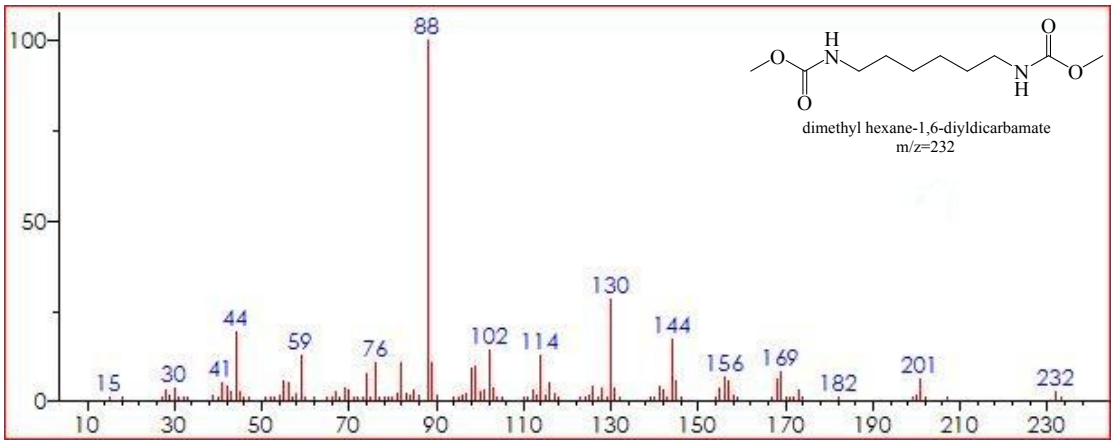
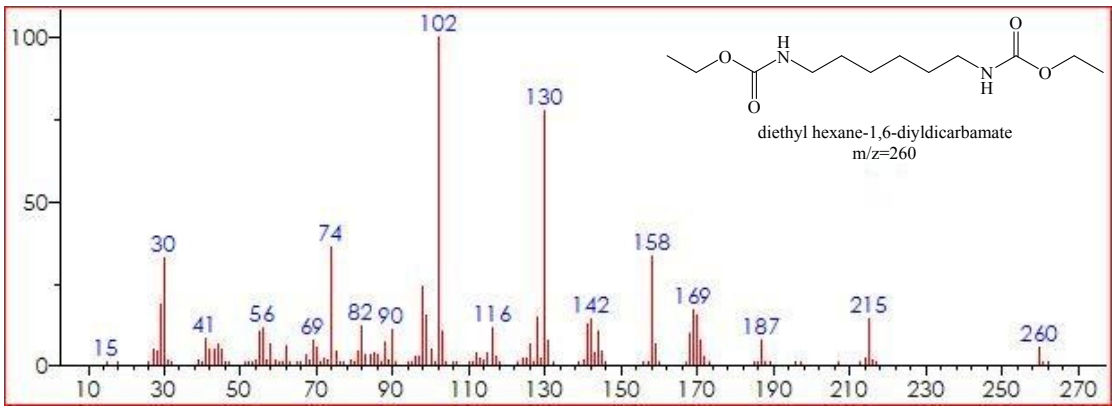


Figure S4. TGA analysis of $Cu(Im)_2$

V. GC-MS copies of carbamate products





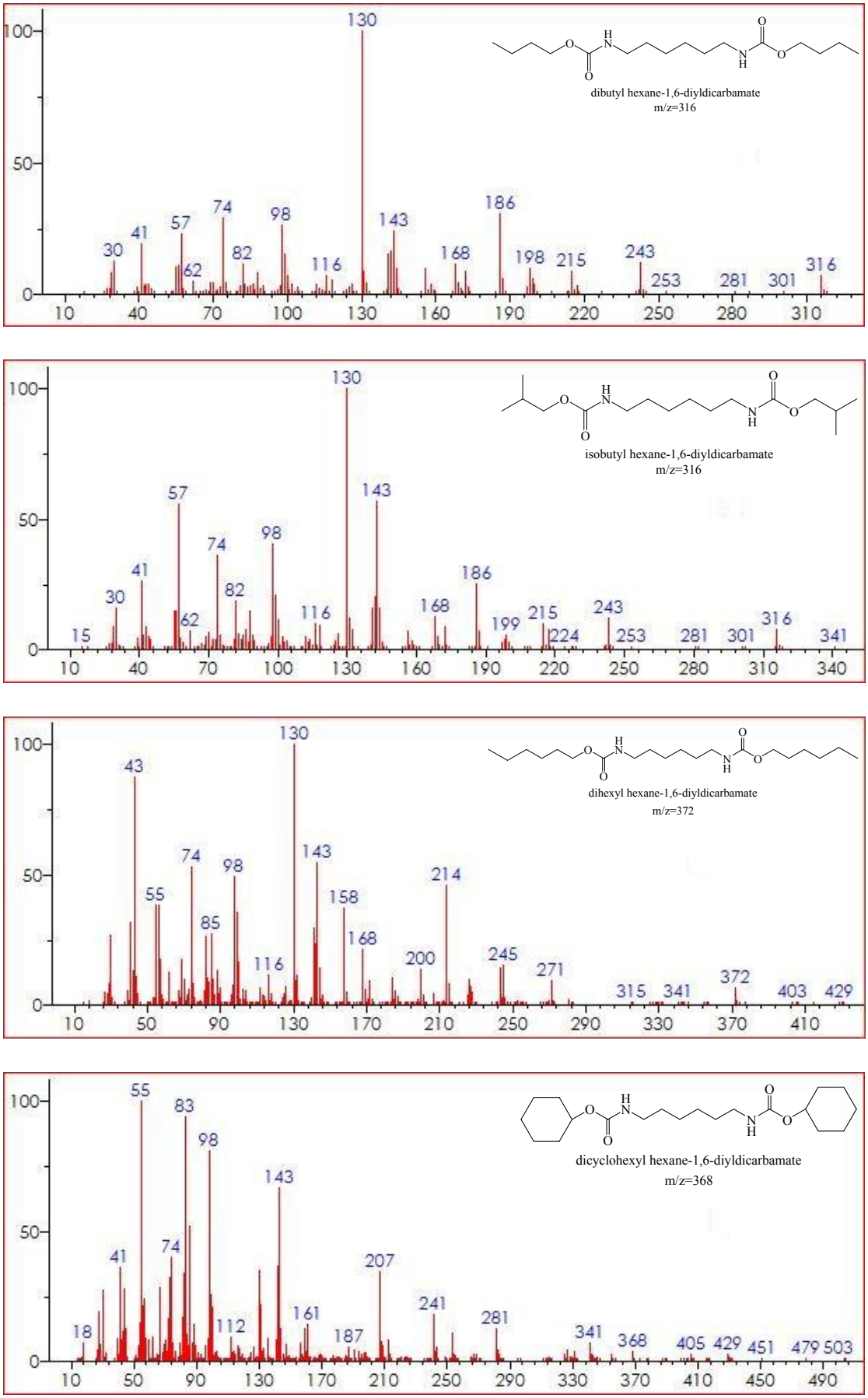


Figure S5. GC-MS copies of carbamate products

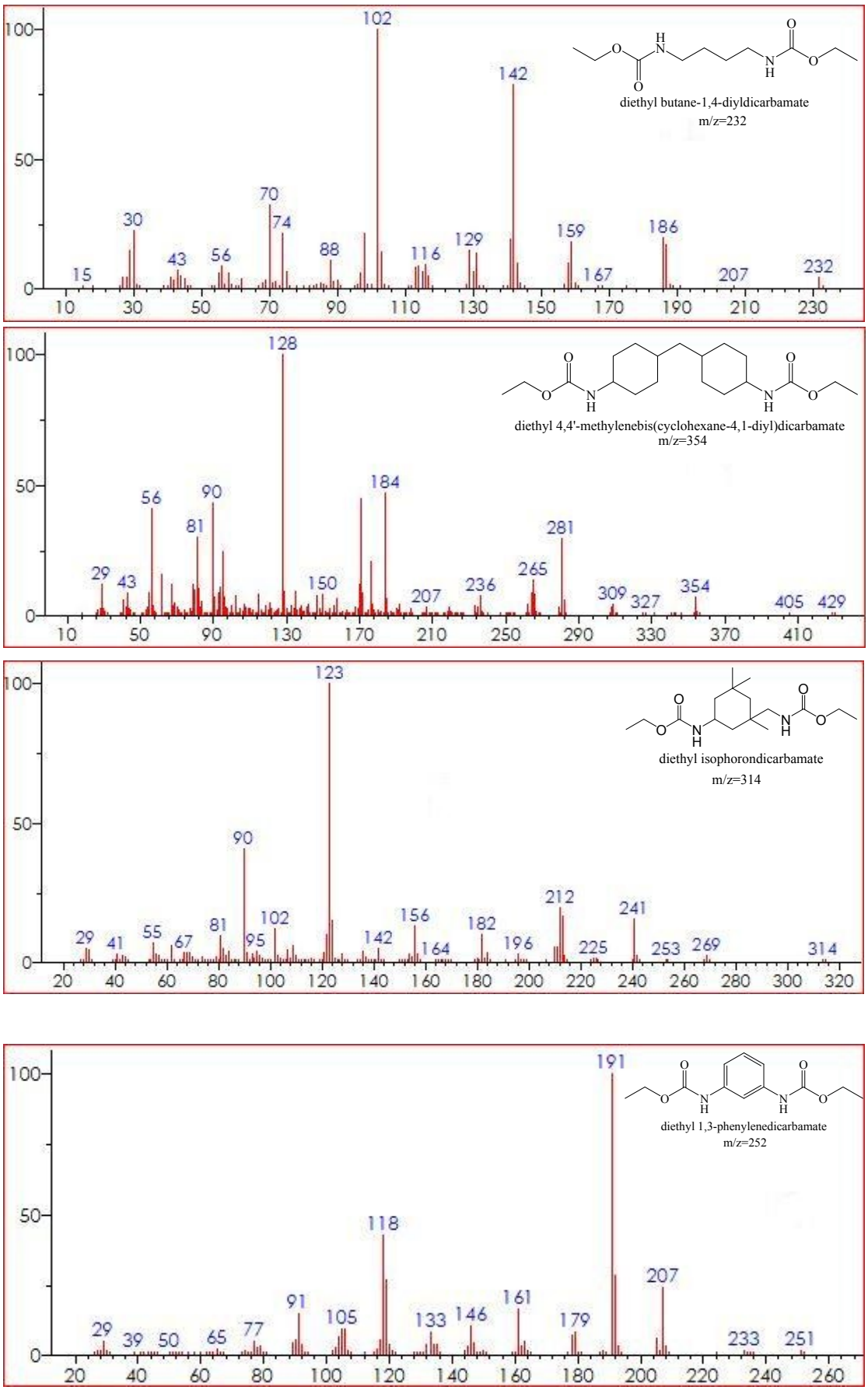


Figure S6. GC-MS copies of carbamate products

VI. TGA, XPS, SEM, AFM and FT-IR characterization results of catalysts

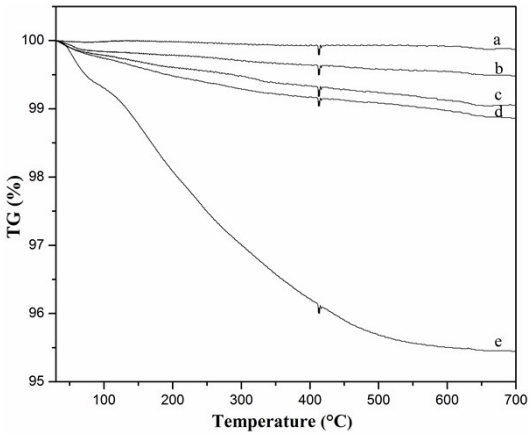


Figure S7. TGA analysis of CuO-ZnO catalysts, (a) CuO-ZnO-700, (b) CuO-ZnO-500, (c) 2CuO-ZnO-500, (d) CuO-2ZnO-500, and (e) CuO-ZnO-300.

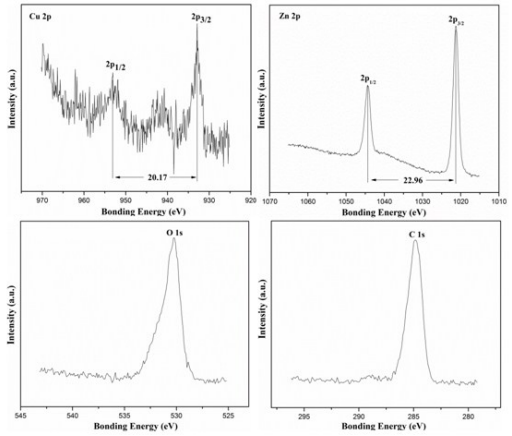


Figure S8. X-ray photoelectron spectroscopy (XPS) characterization of CuO-ZnO-500.

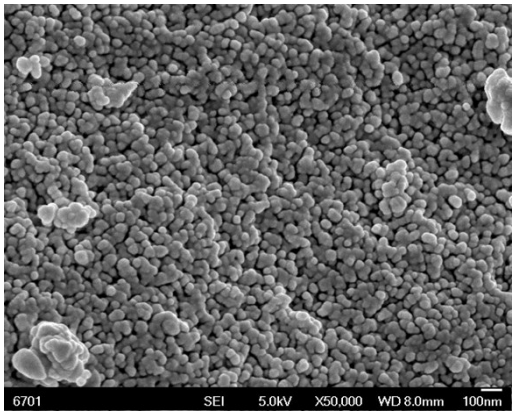


Figure S9. Scanning electron microscope (SEM) characterization of CuO-ZnO-500

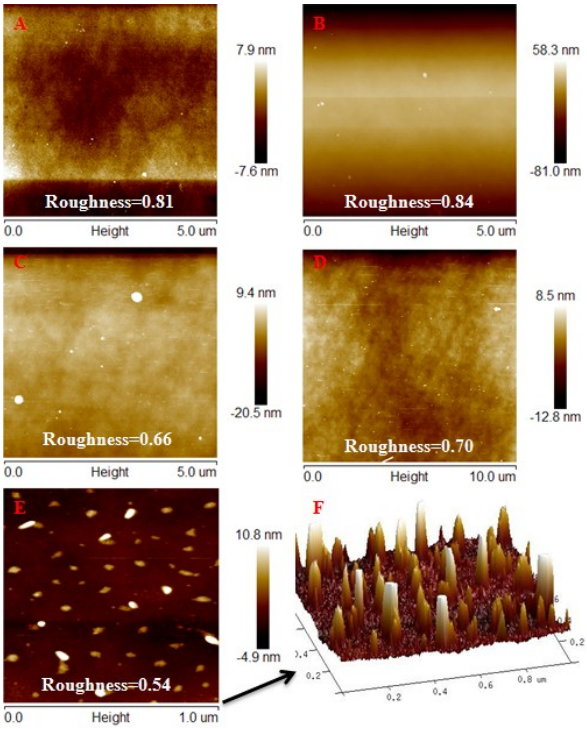


Figure S10. Atomic force microscope (AFM) characterization of CuO-ZnO catalysts, (A) CuO-ZnO-300, (B) CuO-ZnO-700, (C) 2CuO-ZnO-500, (D) CuO-2ZnO-500, (E) CuO-ZnO-500, (F) 3D analysis of CuO-ZnO-500. Insert: Roughness analysis of the corresponding samples.

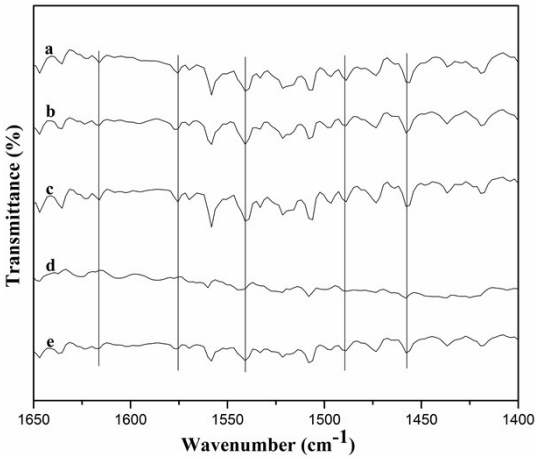


Figure S11. Fourier transform infrared spectroscopy (FT-IR) characterization conducted with pyridine as the alkaline adsorbate. (a) CuO-ZnO-300, (b) CuO-ZnO-500, (c) CuO-ZnO-700, (d) 2CuO-ZnO-500 and (e) CuO-2ZnO-500. Full reference lines shown for Lewis acid sites (1616 cm^{-1}, 1457 cm^{-1}), Lewis or Brønsted acid sites (1575 cm^{-1}, 1490 cm^{-1}), Brønsted acid sites (1540 cm^{-1}).

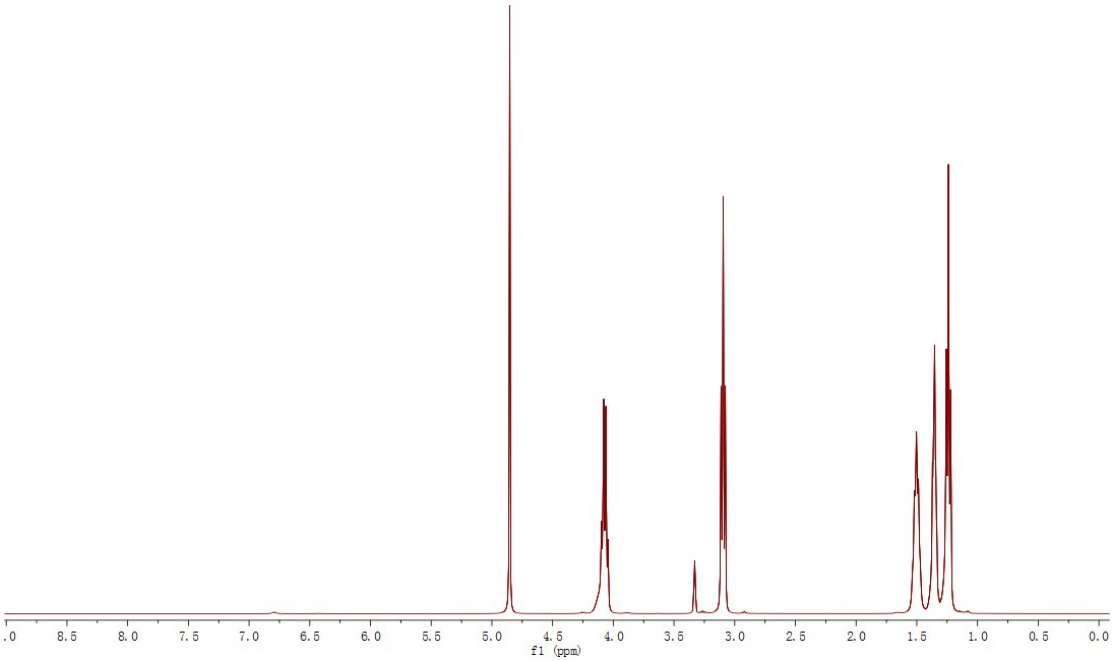


Figure 12 a) ^{1}H NMR (400 MHz, CD_3OD) of EHDC obtained from the degradation of PU-HDA for 2 h: δ 4.85 (s, 1H), 4.07 (q, 2H), 3.09 (t, 2H), 1.47 (m, 2H), 1.34 (m, 2H), 1.24 (t, 3H).

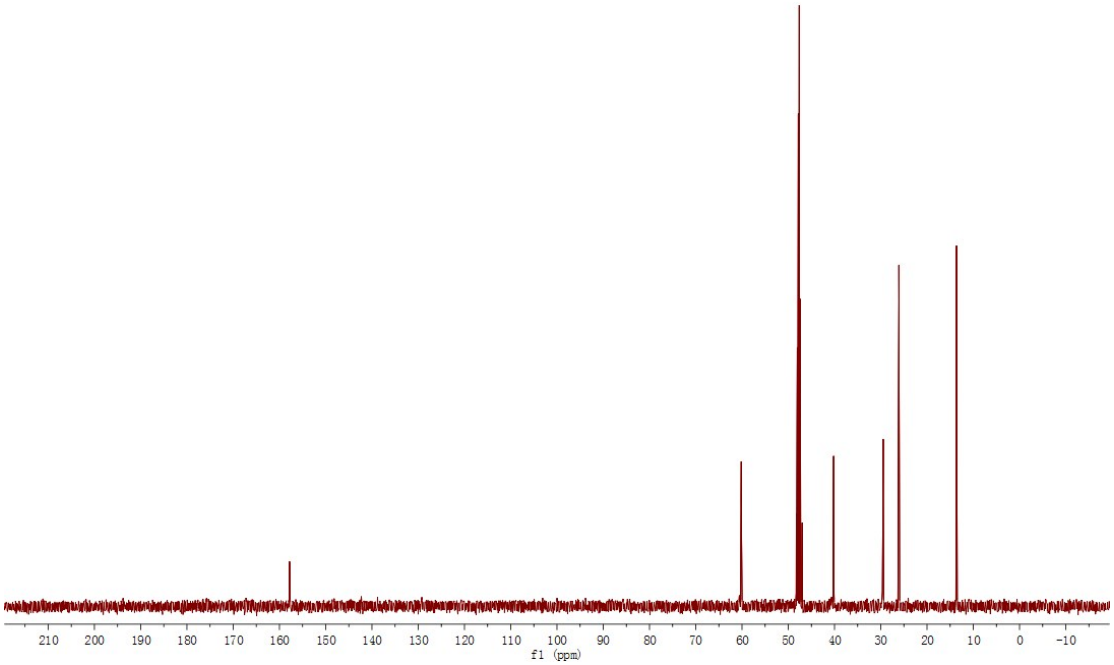


Figure 12 b) ^{13}C NMR (101 MHz, CD_3OD) of EHDC obtained from the degradation of PU-HDA for 2 h: δ 157.81, 60.16, 40.19, 29.47, 26.09, 13.63 ppm.

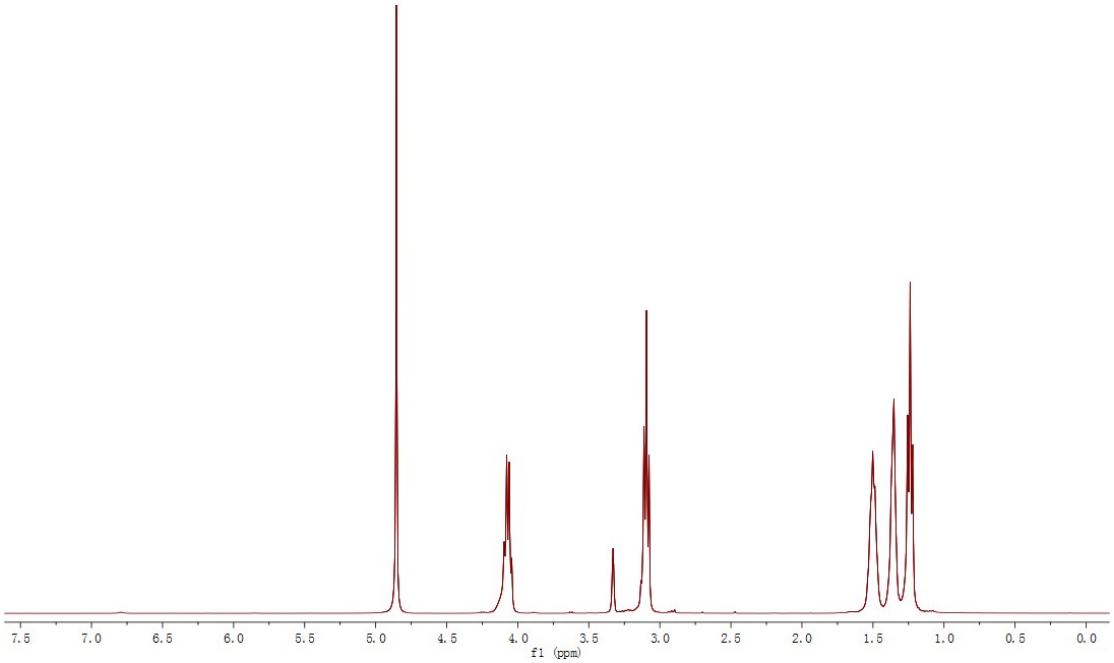


Figure 12 c) ^{1}H NMR (400 MHz, CD_3OD) of EHDC obtained from the degradation of PU-HDA for 18 h: δ 4.85 (s, 1H), 4.07 (q, 2H), 3.08 (t, 2H), 1.49 (m, 2H), 1.38 (m, 2H), 1.24(t, 3H).

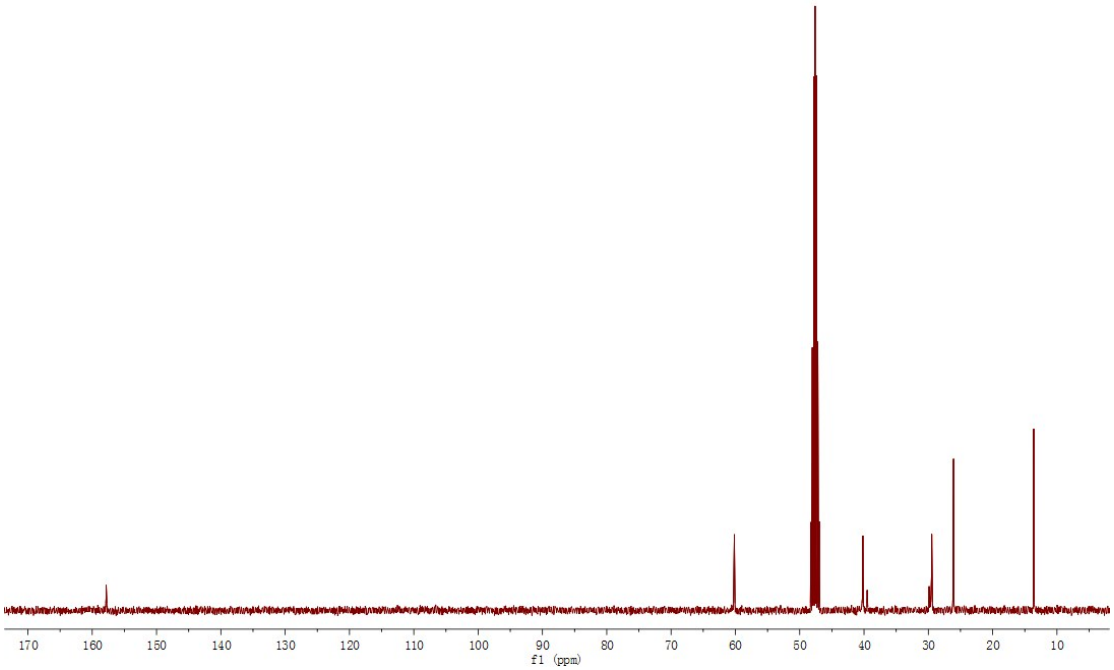


Figure 12 d) ^{13}C NMR (101 MHz, CD_3OD) of EHDC obtained from the degradation of PU-HDA for 18 h: δ 157.82, 60.16, 40.19, 29.67, 26.08, 13.62 ppm. The peaks at 29.99 and 39.50 ppm might be assigned to the PU-HDA.

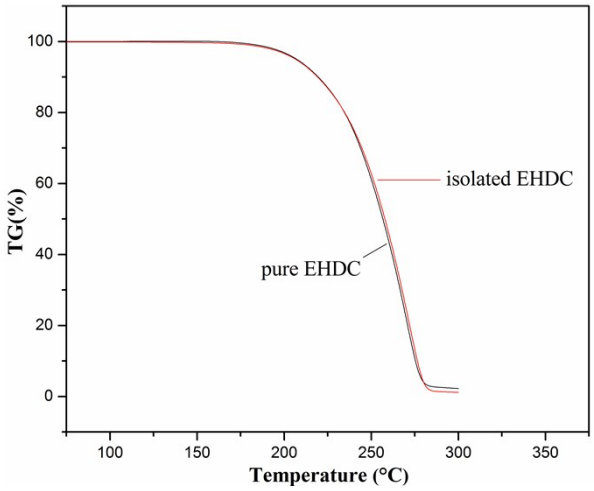


Figure S13. The thermal properties of the isolated and pure EHDC