

# Room Temperature Nanographene Production via CO<sub>2</sub> Electrochemical Reduction on the Electrodeposited Bi on Sn Substrate

Piriya Pinthong <sup>1</sup>, Sarita Phupaichitkun <sup>1</sup>, Suthasinee Watmanee <sup>1</sup>, Rungkiat Nganglumpoon <sup>1,2</sup>, Duangamol N. Tungasmita <sup>3</sup>, Sukkaneste Tungasmita <sup>2,4</sup>, Yuttanant Boonyongmaneerat <sup>5</sup>, Nadtinan Promphet <sup>5</sup>, Nadnudda Rodthongkum <sup>5</sup>, and Joongjai Panpranot <sup>1,2,6,\*</sup>

<sup>1</sup> Center of Excellence on Catalysis and Catalytic Reaction Engineering, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand

<sup>2</sup> Graphene Electronics Research Unit, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

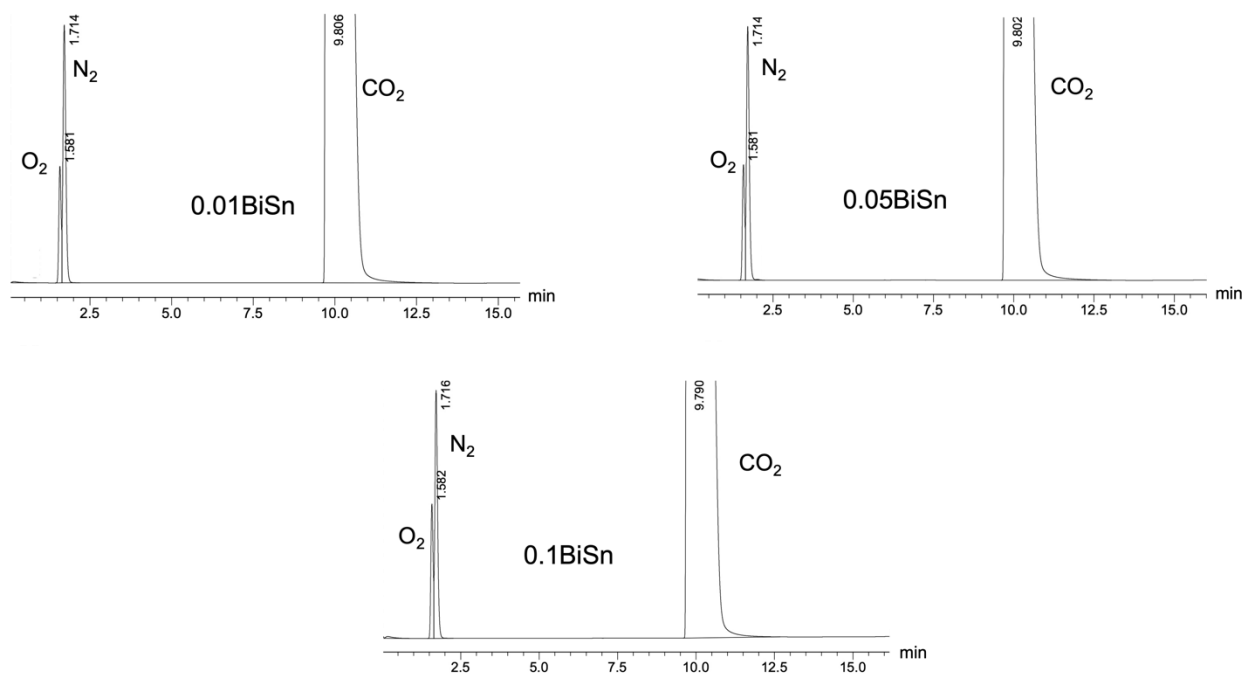
<sup>3</sup> Department of Chemistry, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

<sup>4</sup> Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.

<sup>5</sup> Metallurgy and Materials Science Research Institute (MMRI), Chulalongkorn University, Bangkok 10330, Thailand

<sup>6</sup> Bio-Circular-Green-economy Technology & Engineering Center, BCGeTEC, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand

\* Correspondence: joongjai.p@chula.ac.th



**Figure S1** GC-TCD results of 0.01Bi/Sn, 0.05Bi/Sn, and 0.1Bi/Sn after  $CO_2RR$  at -1.1 V vs. Ag/AgCl for 70 min

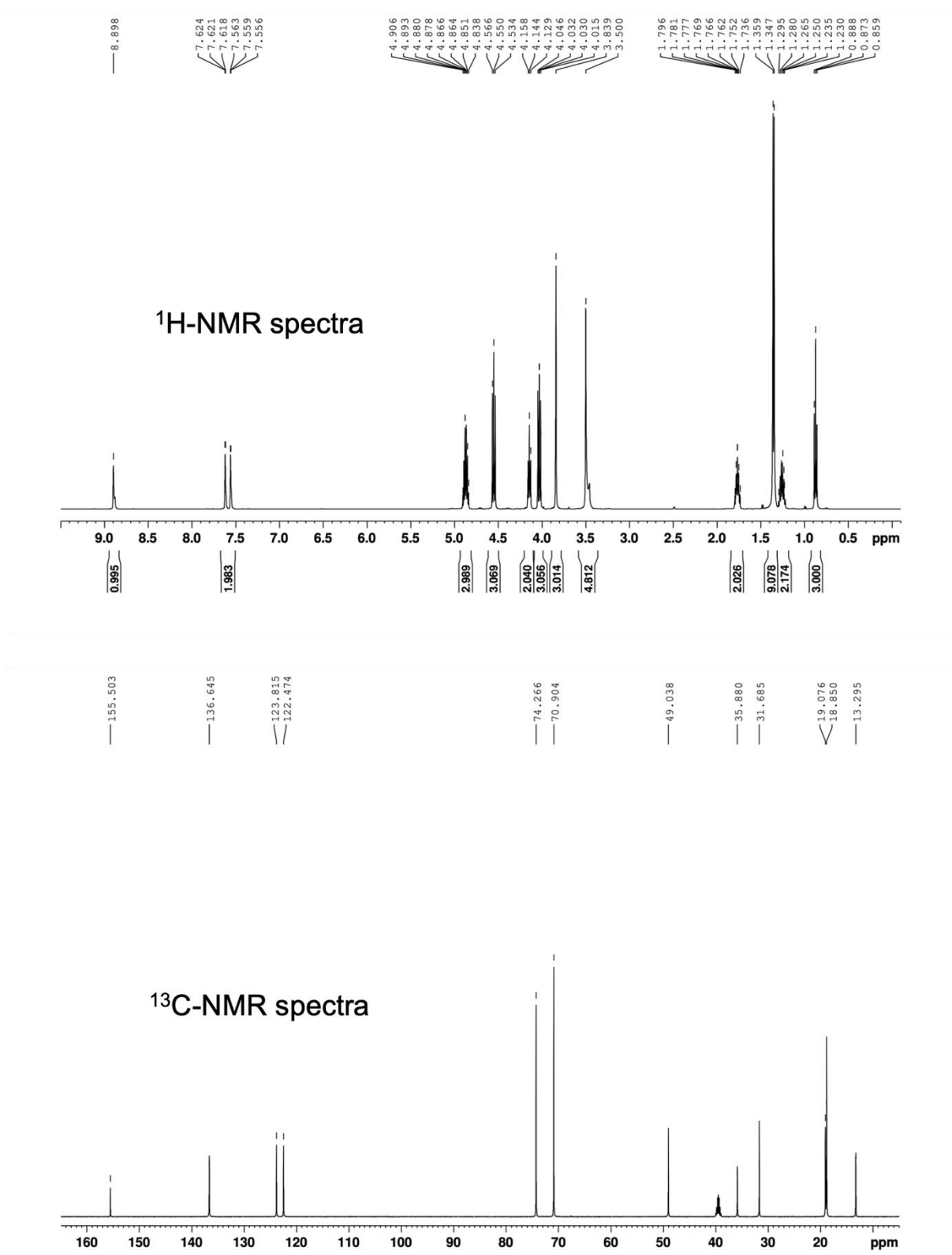


Figure S2 NMR spectra of catholyte results of 0.01Bi/Sn after CO<sub>2</sub>RR at -1.1 V vs. Ag/AgCl for 70 min

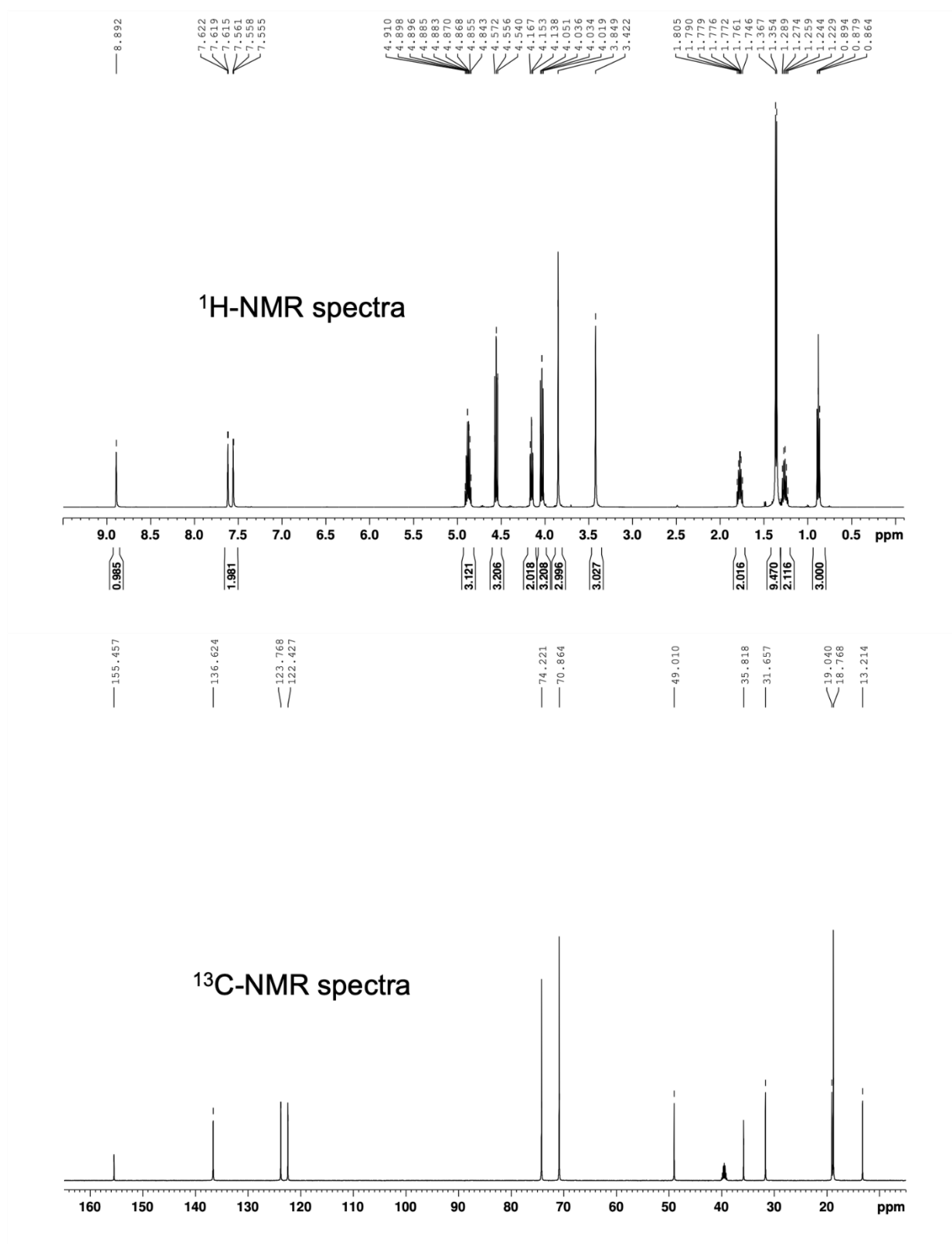


Figure S3 NMR spectra of catholyte results of 0.05Bi/Sn after CO<sub>2</sub>RR at -1.1 V vs. Ag/AgCl for 70 min

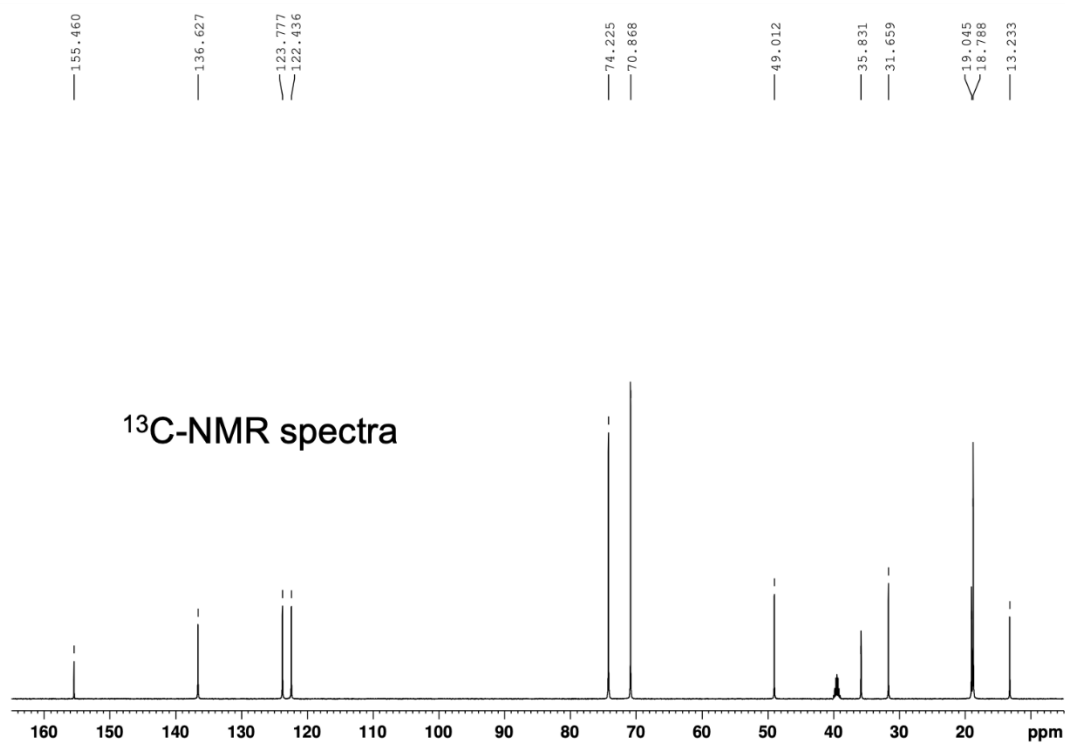
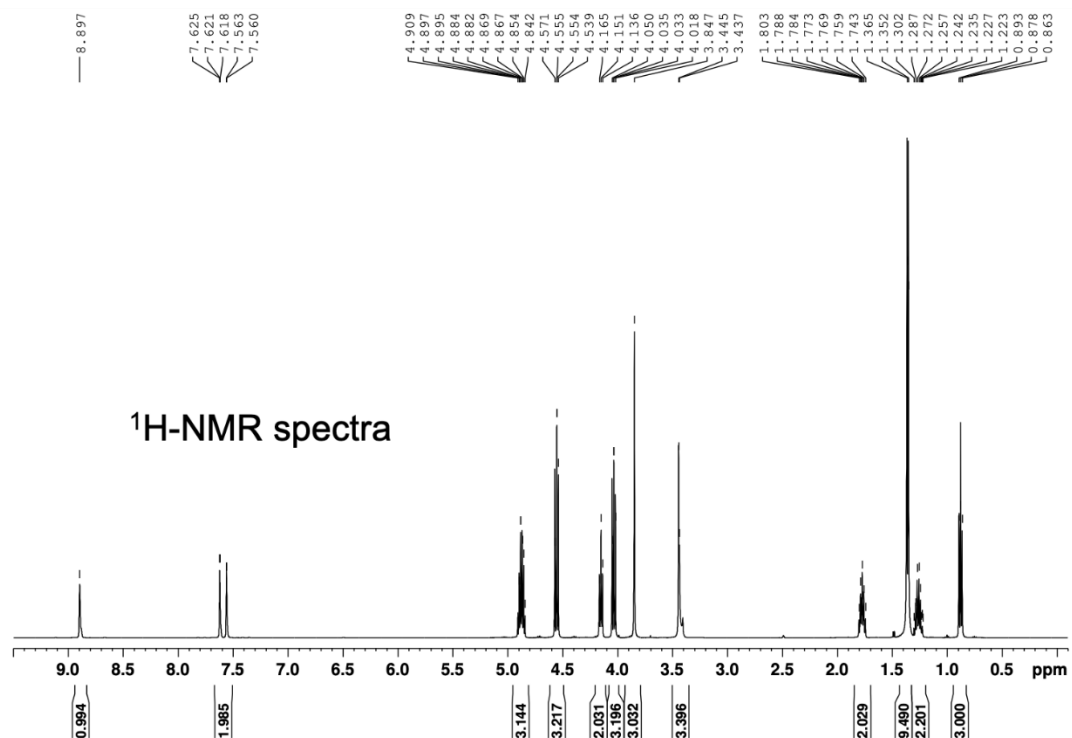


Figure S4 NMR spectra of catholyte results of 0.1Bi/Sn after CO<sub>2</sub>RR at -1.1 V vs. Ag/AgCl for 70 min

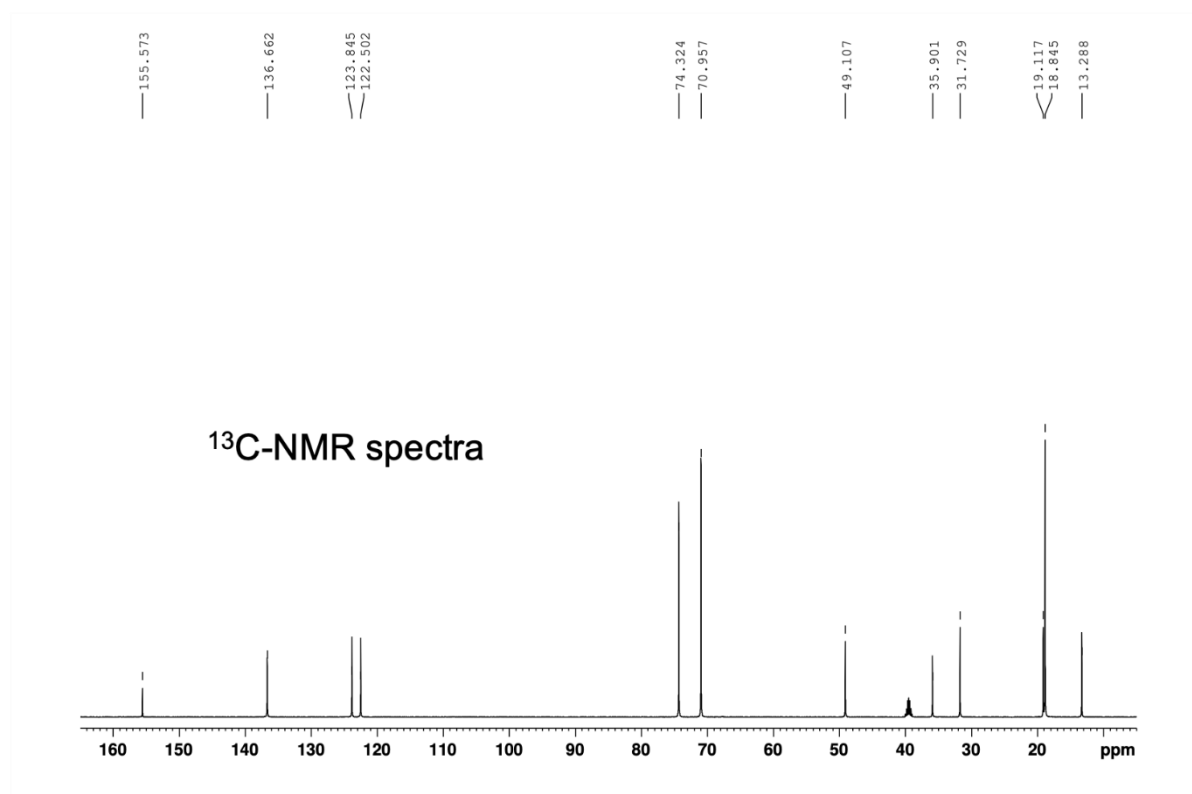
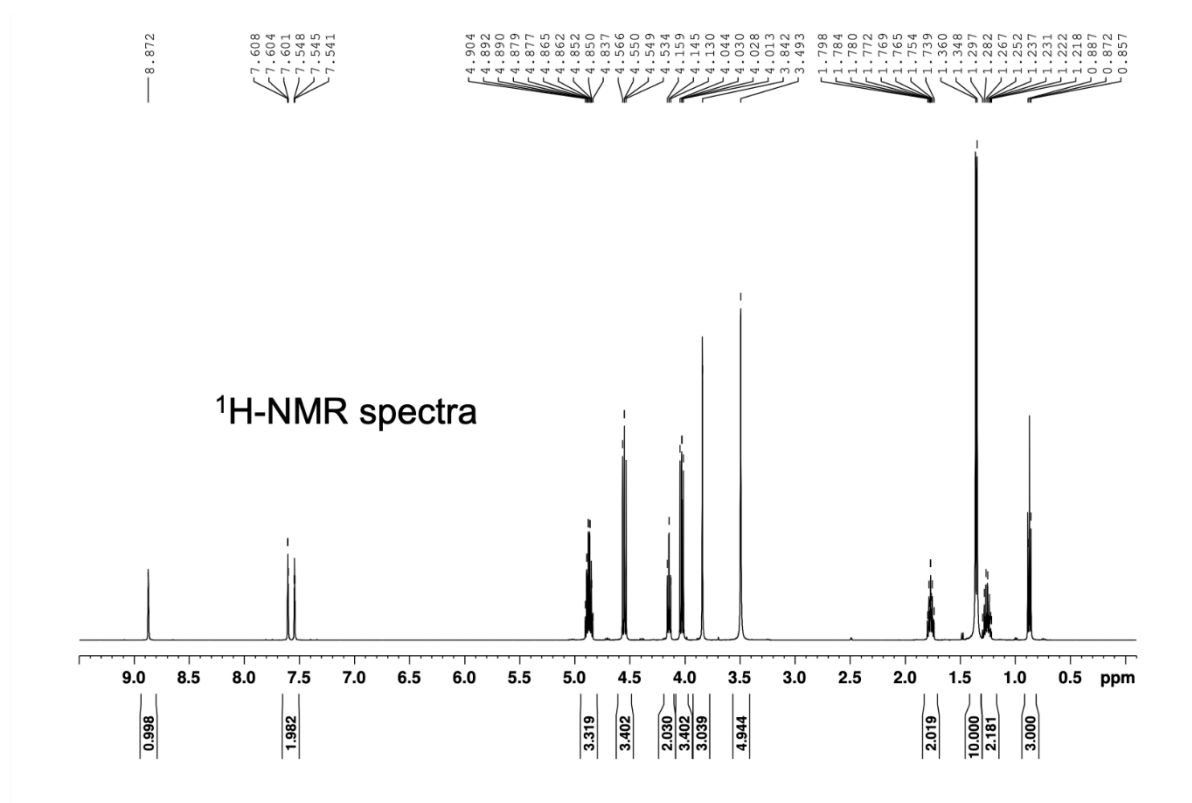
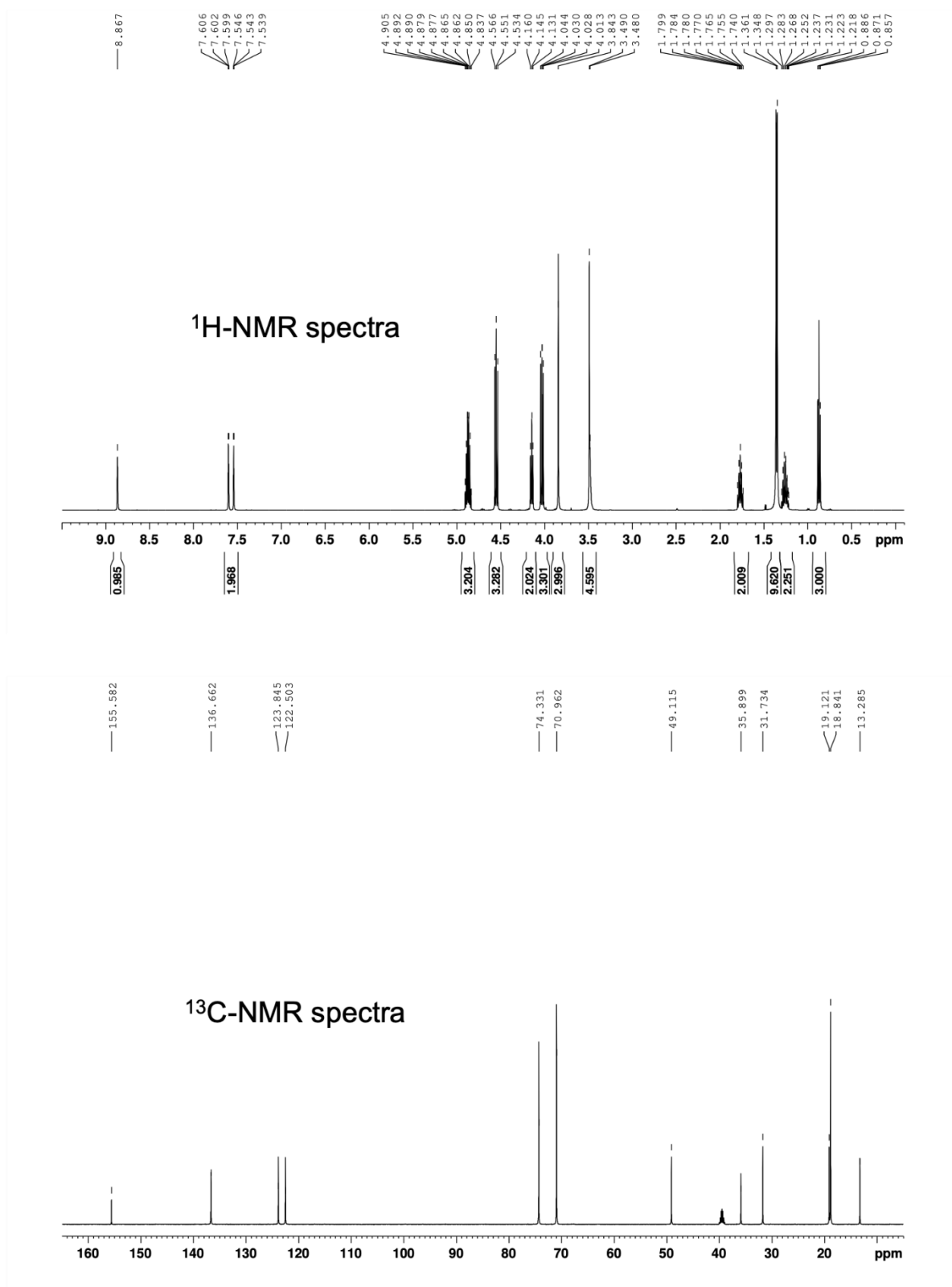


Figure S5 NMR spectra of catholyte results of 0.05Bi/Sn after CO<sub>2</sub>RR at -1.3 V vs. Ag/AgCl for 70 min



**Figure S6** NMR spectra of catholyte results of 0.05Bi/Sn after  $\text{CO}_2\text{RR}$  at -1.5 V vs. Ag/AgCl for 70 min

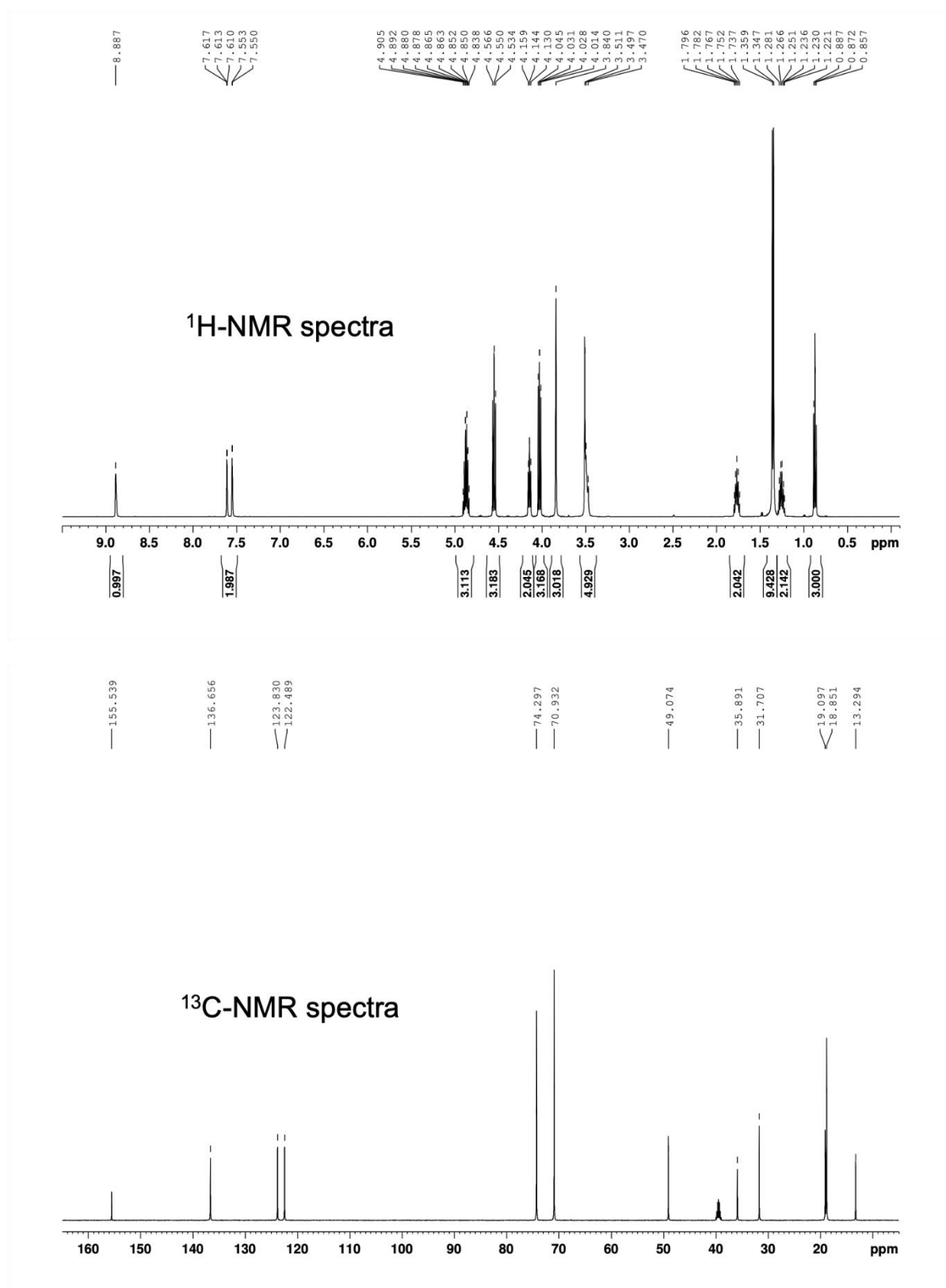


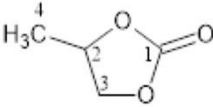
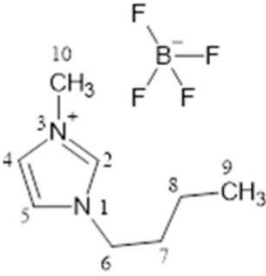
Figure S7 NMR spectra of catholyte results of 0.05Bi/Sn after CO<sub>2</sub>RR at -1.7 V vs. Ag/AgCl for 70 min

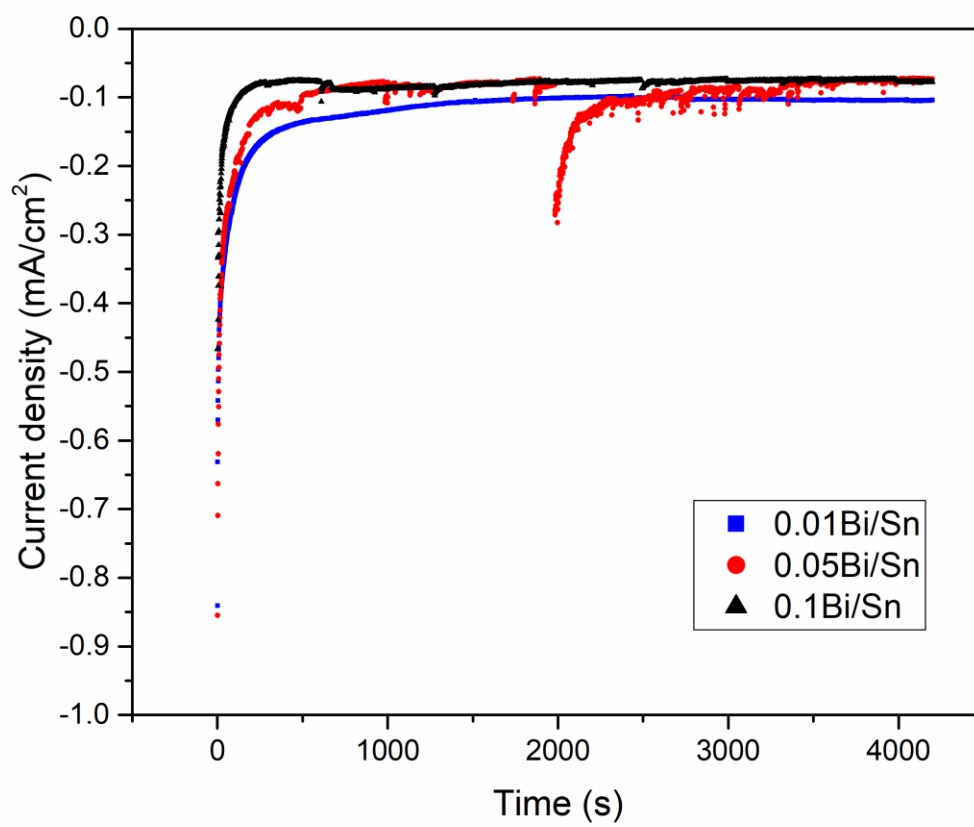


(i) Analysis of  $^1\text{H}$ -NMR spectra of cathodic electrolytes  $[\text{BMIM}]^+[\text{BF}_4]^-$  and propylene carbonate before  $\text{CO}_2\text{RR}$

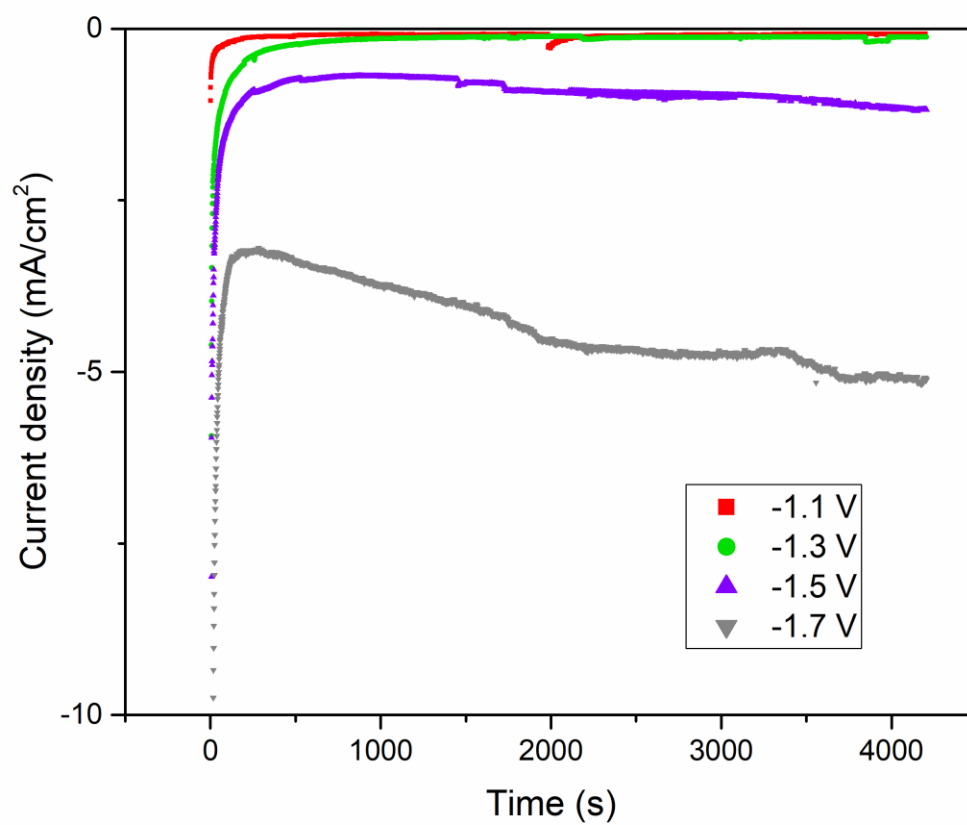
Compounds	Molecular Structure	Chemical Shift ( $\delta$ ppm)	
		Before Reaction (0 mins)	After Reaction (70 mins)
Propylene carbonate		(H2a, 1H, t) 4.88	(H2a, 1H, t) 4.84
		(H3b, 1H, dd) 4.54, $J=8$ Hz	(H3b, 1H, dd) 4.52, $J=8$ Hz
		(H3c, 1H, dd) 4.04, $J=8$ Hz	(H3c, 1H, dd) 4.01, $J=8$ Hz
		(H4, 3H, s) 1.38	(H4, 3H, s) 1.35
1-Butyl-3-methylimidazolium tetrafluoroborate		(H2, 1H, t) 8.96	(H2, 1H, t) 8.76
		(H5, 1H, t) 7.68	(H5, 1H, t) 7.53
		(H4, 1H, t) 7.61	(H4, 1H, t) 7.50
		(H6, 2H, t) 4.14	(H6, 2H, t) 4.09
		(H7, 2H, m) 1.72	(H7, 2H, m) 1.72
		(H8, 2H, m) 1.24	(H8, 2H, m) 1.29
		(H9, 3H, t) 0.87	(H9, 3H, t) 0.83
		(H10, 3H, s) 3.84	(H10, 3H, s) 3.84

(ii) Analysis of  $^{13}\text{C}$ -NMR spectra of cathodic electrolytes  $[\text{BMIM}]^+[\text{BF}_4]^-$  and propylene carbonate before  $\text{CO}_2\text{RR}$

Compounds	Molecular Structure	Chemical Shift (ppm)	
		Before Reaction (0 mins)	After Reaction (70 mins)
Propylene carbonate		(C1) 155.37	(C1) 155.64
		(C2) 74.16	(C2) 74.33
		(C3) 70.88	(C3) 70.91
		(C4) 18.95	(C4) 18.80
1-Butyl-3-methylimidazolium tetrafluoroborate		(C2) 136.80	(C2) 136.60
		(C4) 122.52	(C4) 122.30
		(C5) 123.84	(C5) 123.66
		(C6) 48.96	(C6) 49.09
		(C7) 31.73	(C7) 31.61
		(C8) 19.28	(C8) 19.07
		(C9) 13.43	(C9) 13.24
		(C10) 35.92	(C10) 35.70



**Figure S8** Current density of Bi/Sn during CO<sub>2</sub>RR at -1.1 V vs. Ag/AgCl for 70 min



**Figure S9** Current density of 0.05Bi/Sn during CO<sub>2</sub>RR at various applied potentials vs. Ag/AgCl for 70 min