

Phosphate Functionalized Nonisocyanate Polyurethanes with Bio-origin, Water Solubility and Biodegradability

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Supporting Information

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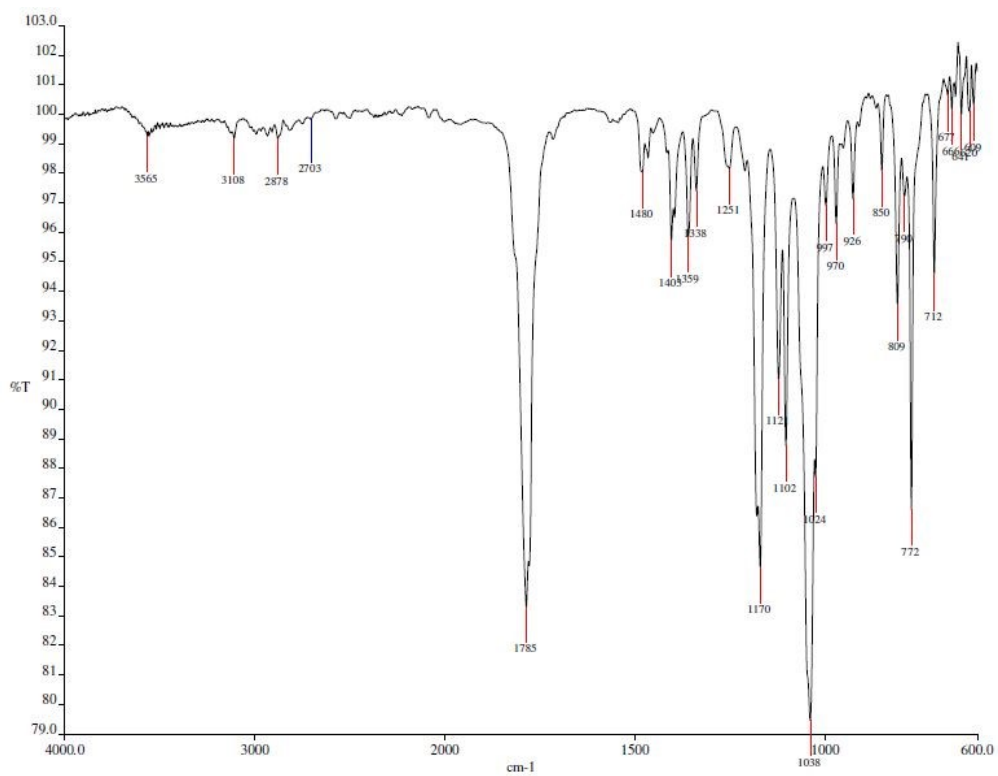


Figure S1: FTIR spectrum of FuBCC monomer

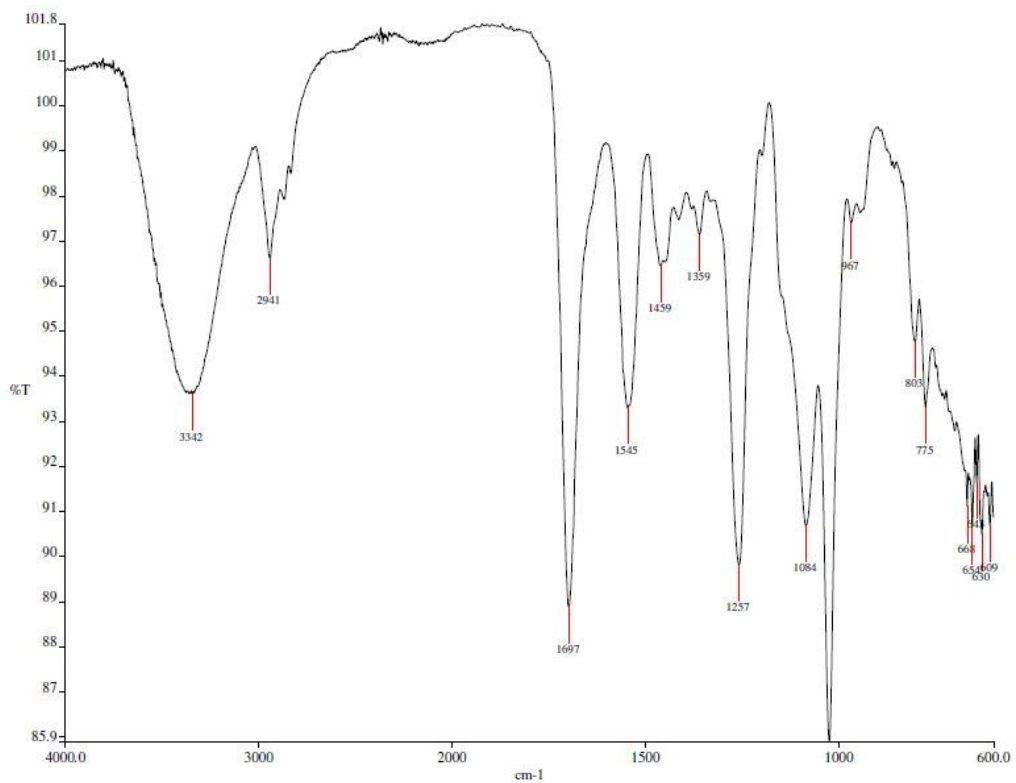


Figure S2: FTIR spectrum of Poly(FuCa)

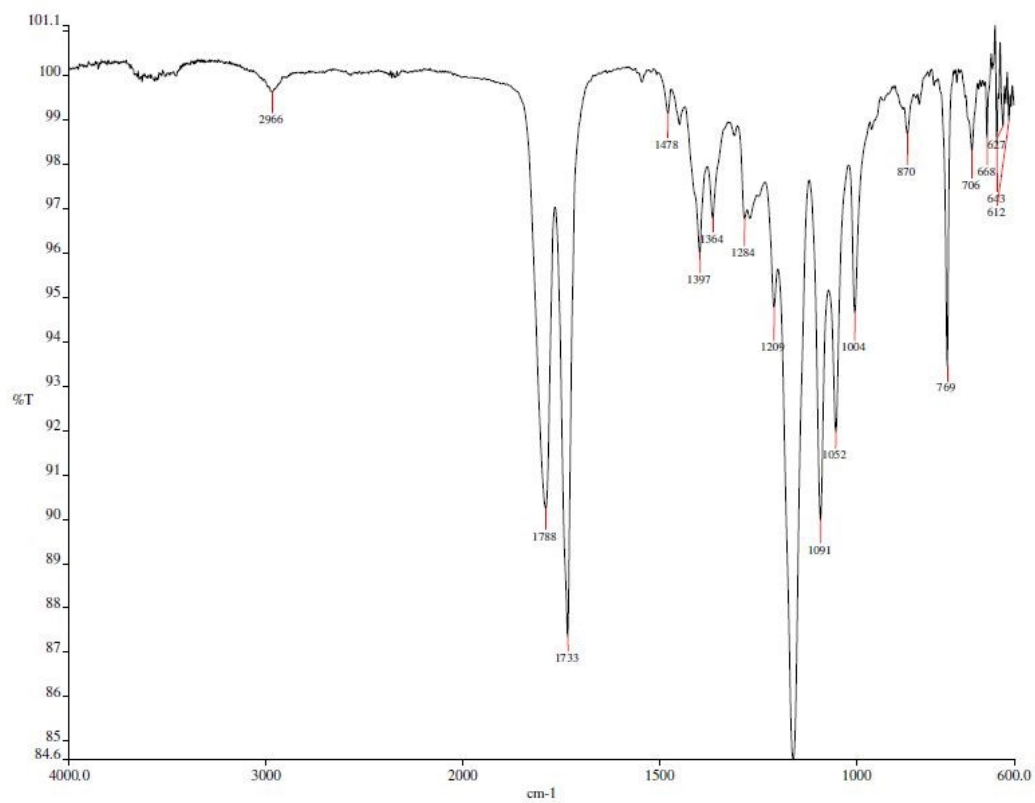


Figure S3: FTIR spectrum of SuBCC monomer

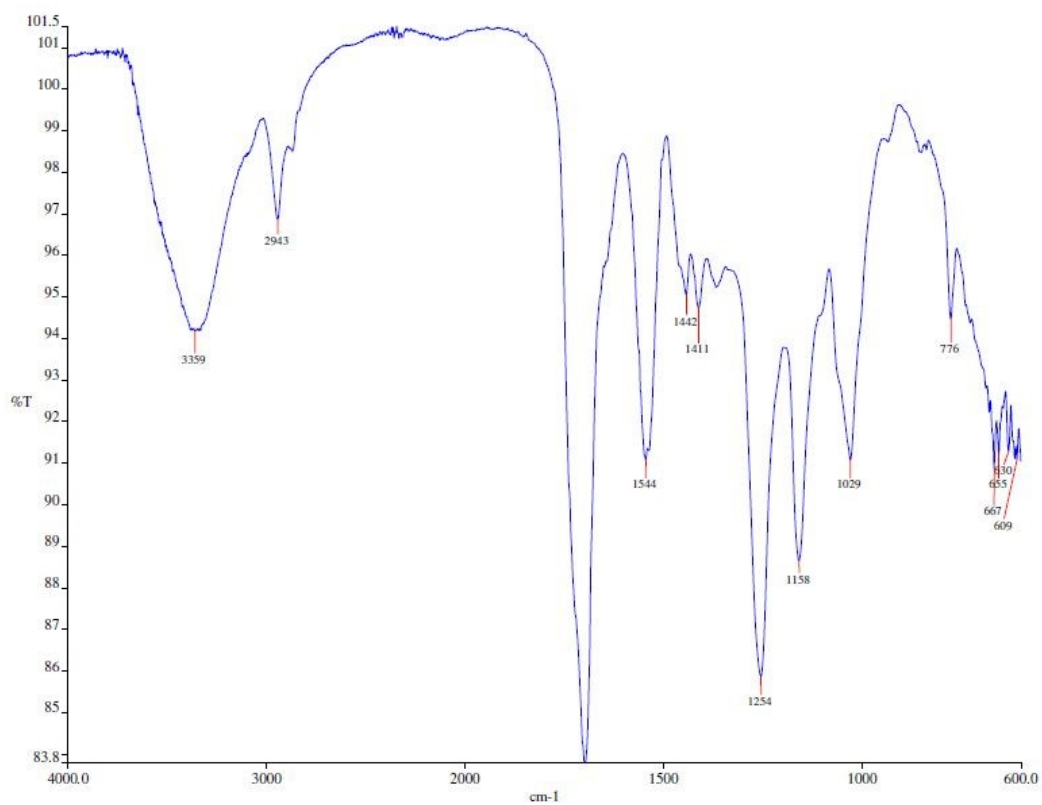


Figure S4: FTIR spectrum of Poly(SuCa)

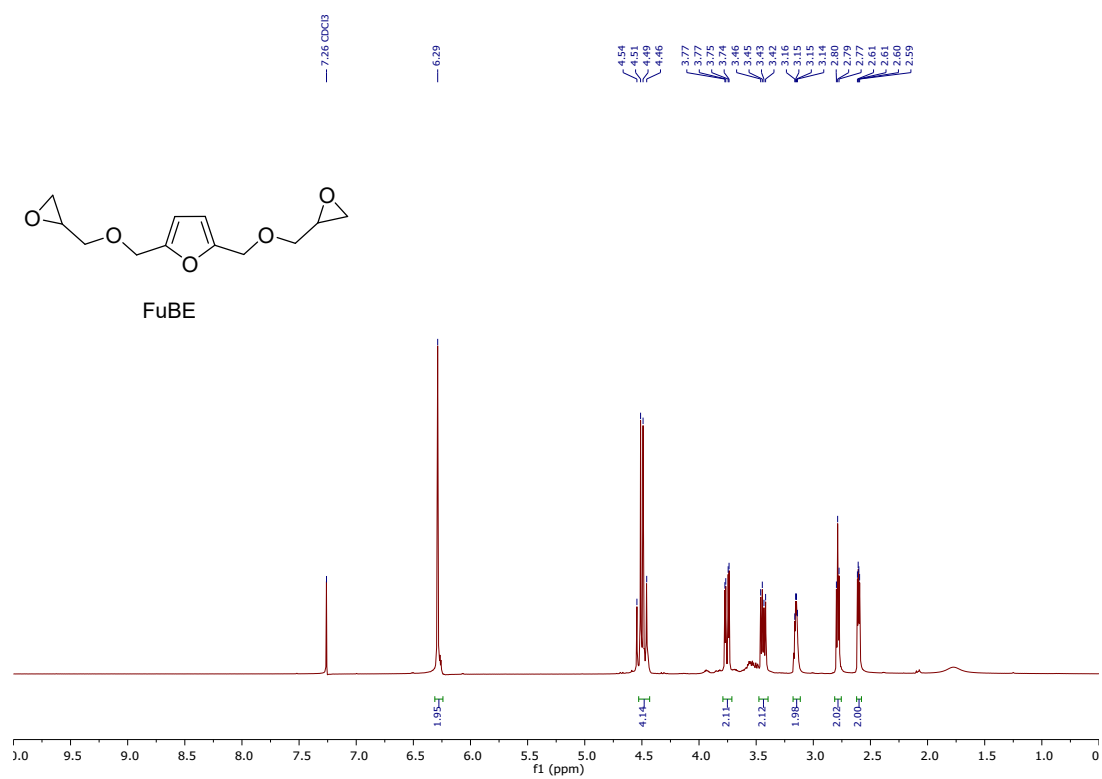


Figure S5: ¹H NMR spectrum of FuBE in CDCl₃

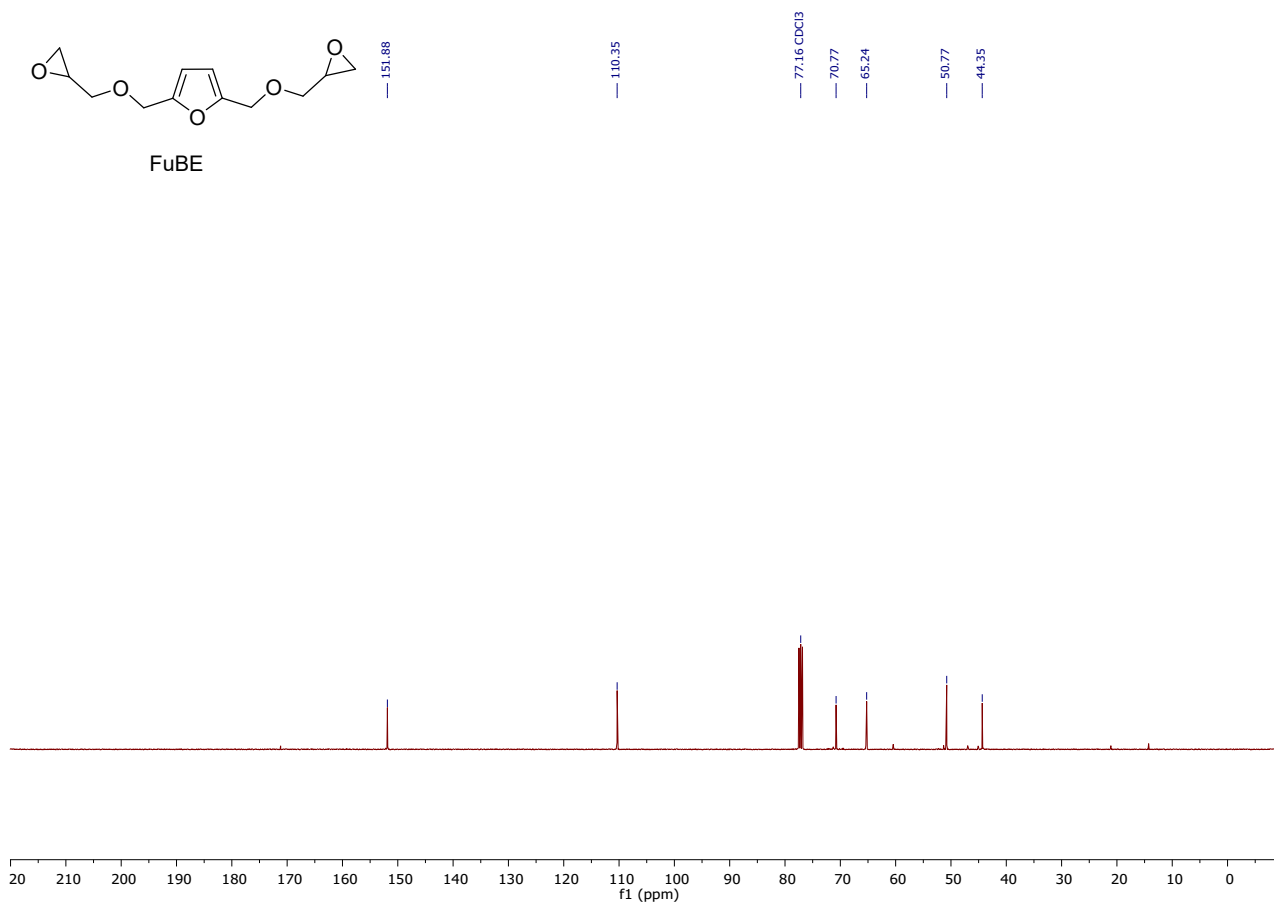


Figure S6: ^{13}C NMR spectrum of FuBE in CDCl_3

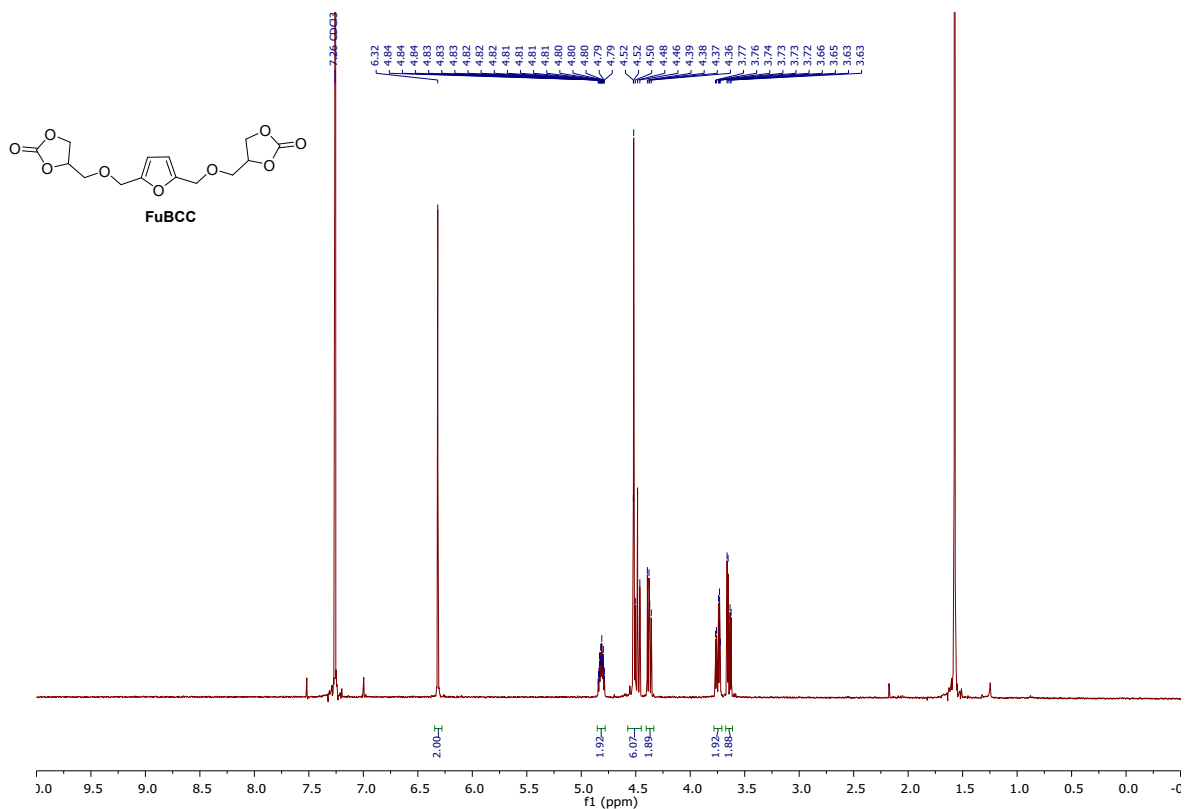


Figure S7: ^1H NMR spectrum of FuBCC monomer in CDCl_3

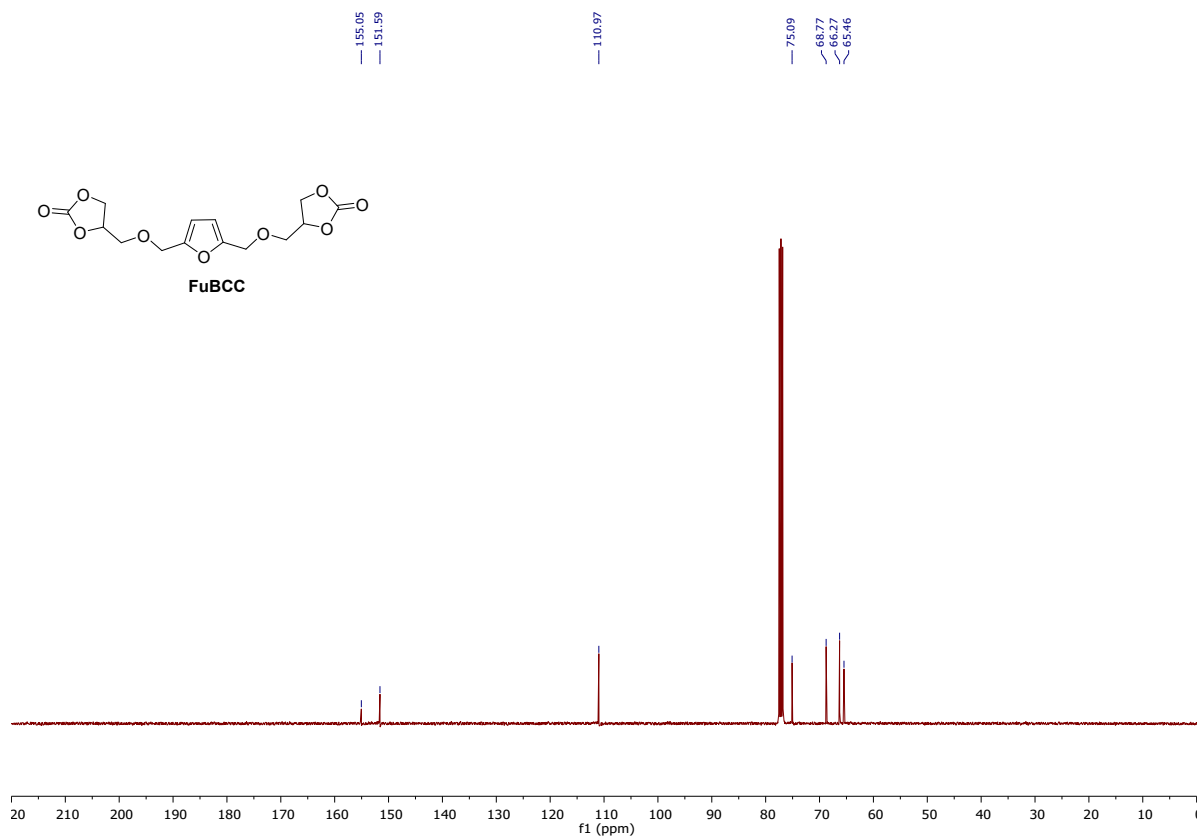


Figure S8: ^{13}C NMR spectrum of FuBCC monomer in CDCl_3

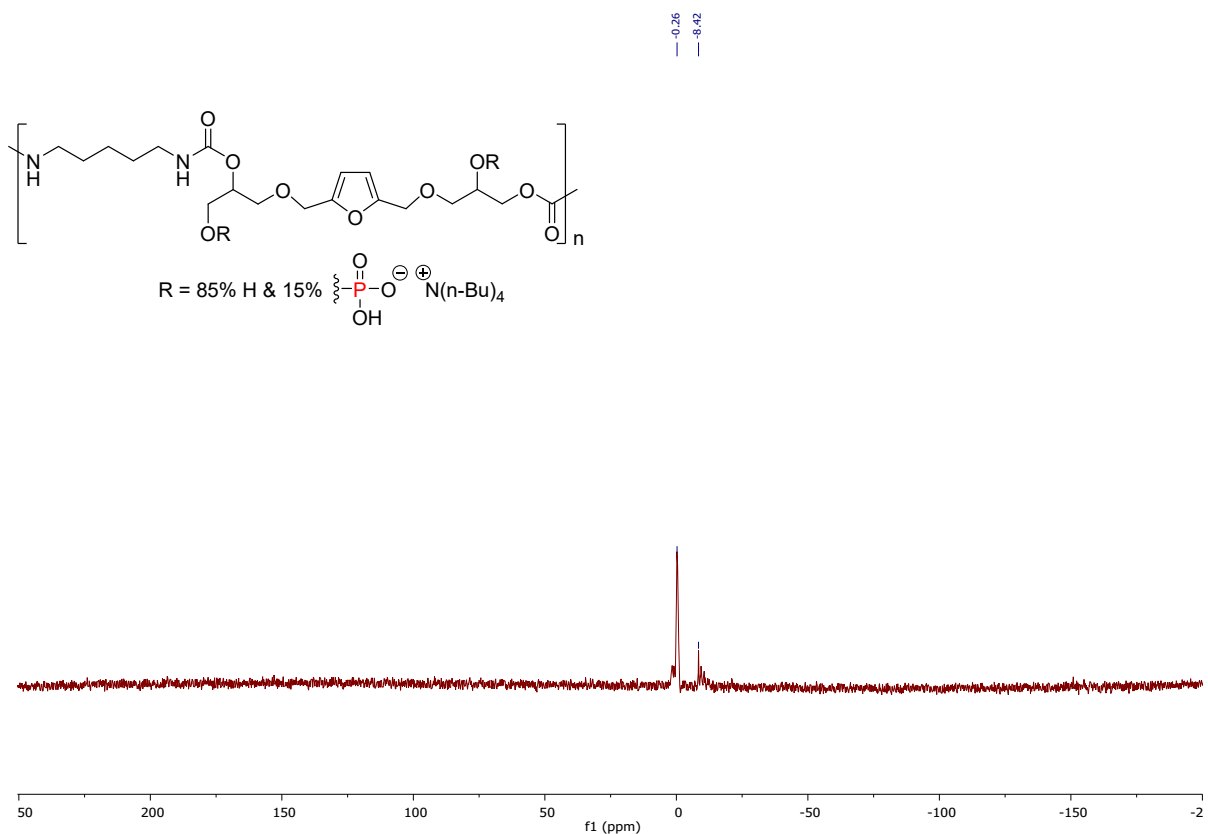


Figure S9: ^{31}P NMR spectrum of Poly(FuCa)-P15 in DMSO-d_6

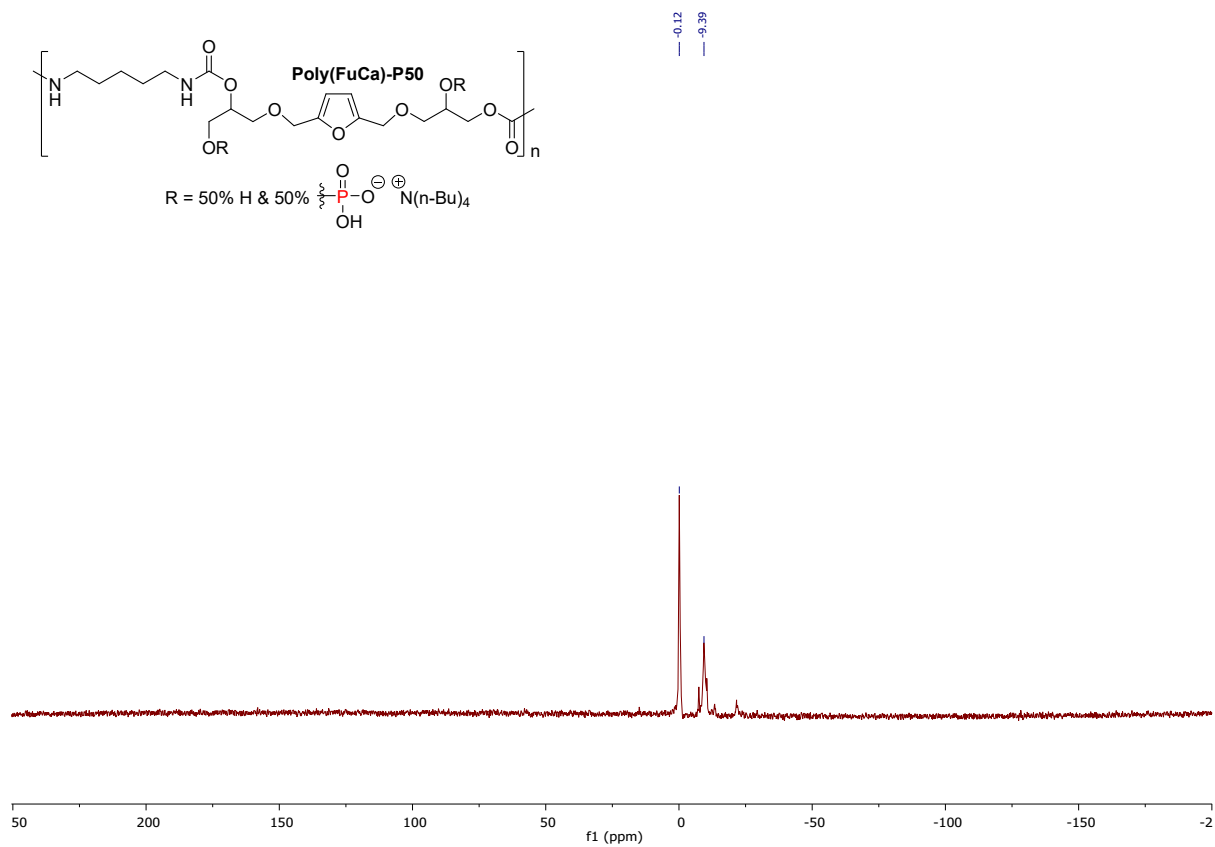


Figure S10: ^{31}P NMR spectrum of Poly(FuCa)-P50 in DMSO-d_6

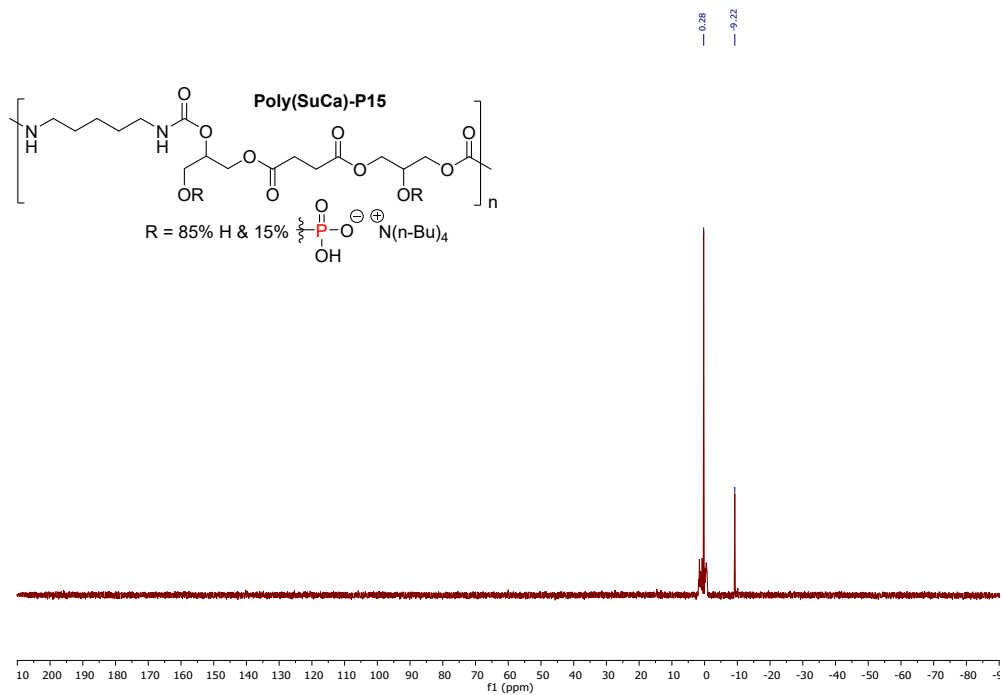


Figure S11: ^{31}P NMR spectrum of Poly(SuCa)-P15 in $\text{DMSO-}d_6$

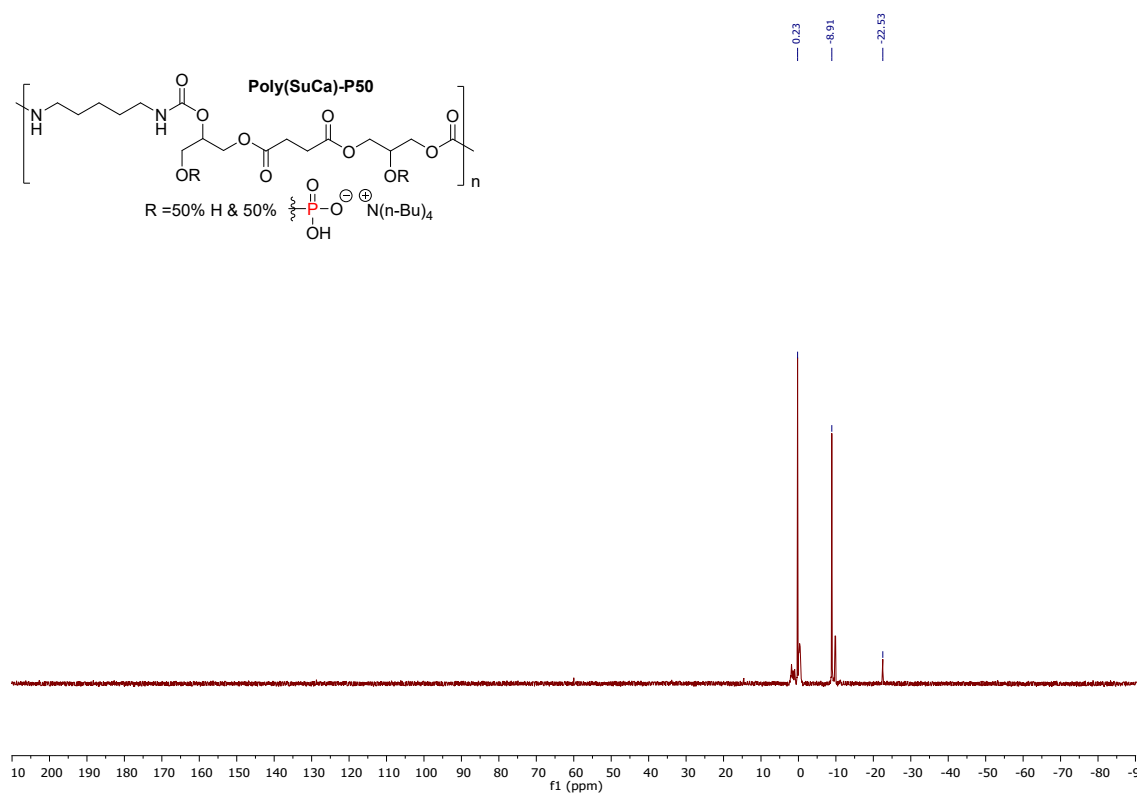


Figure S12: ^{31}P NMR spectrum of Poly(SuCa)-P50 in $\text{DMSO-}d_6$

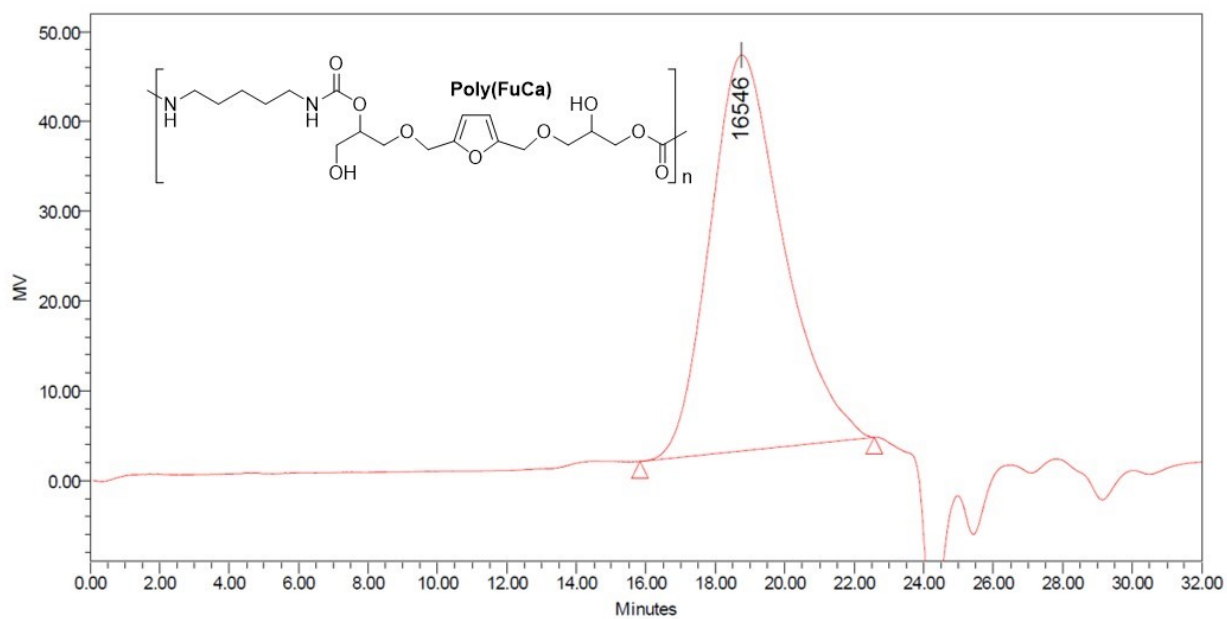


Figure S13: GPC chromatogram of Poly(FuCa)

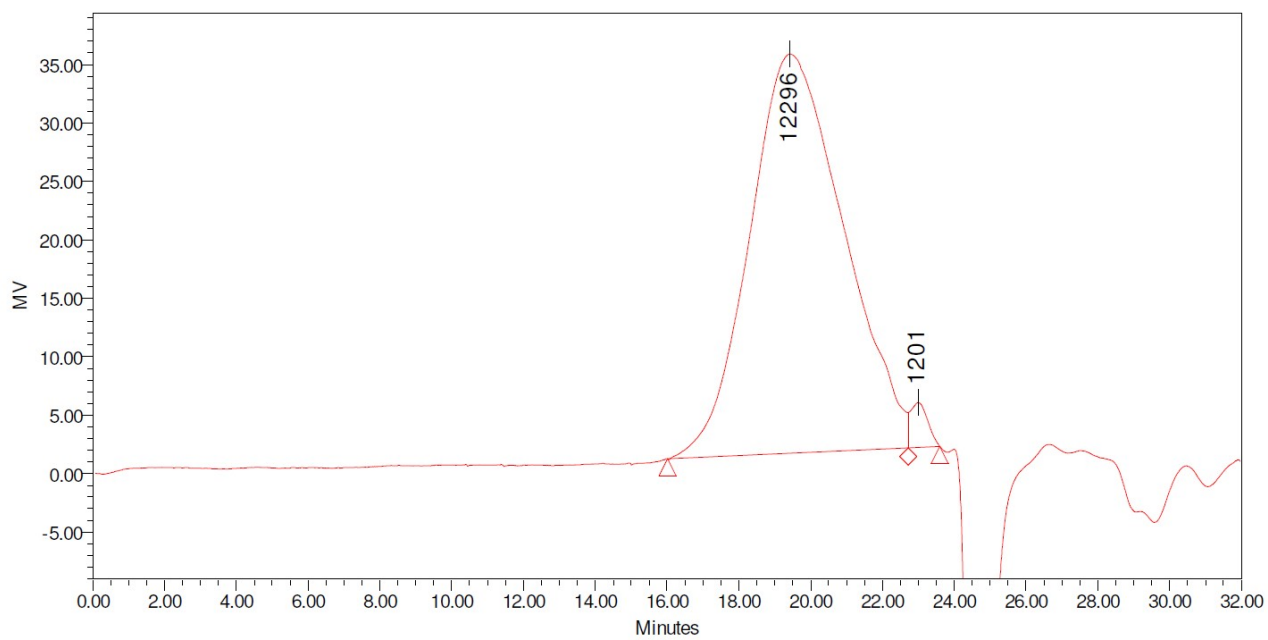


Figure S14: GPC chromatogram of Poly(SuCa)

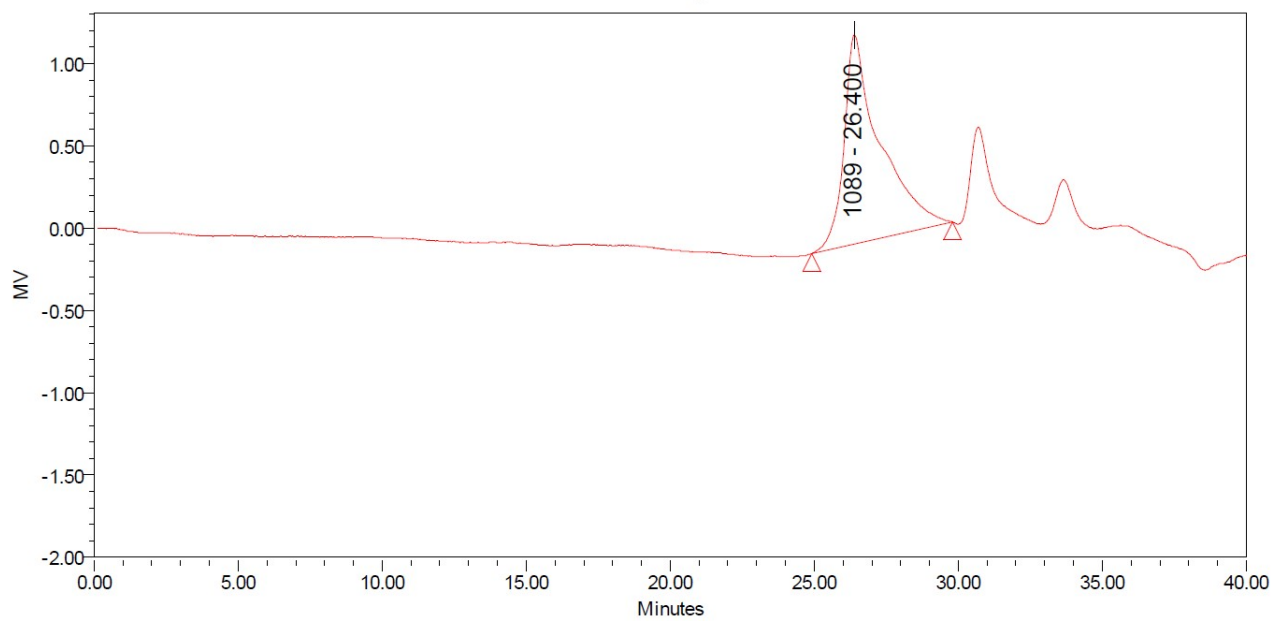


Figure S15: GPC chromatogram of Poly(FuCa)-P15

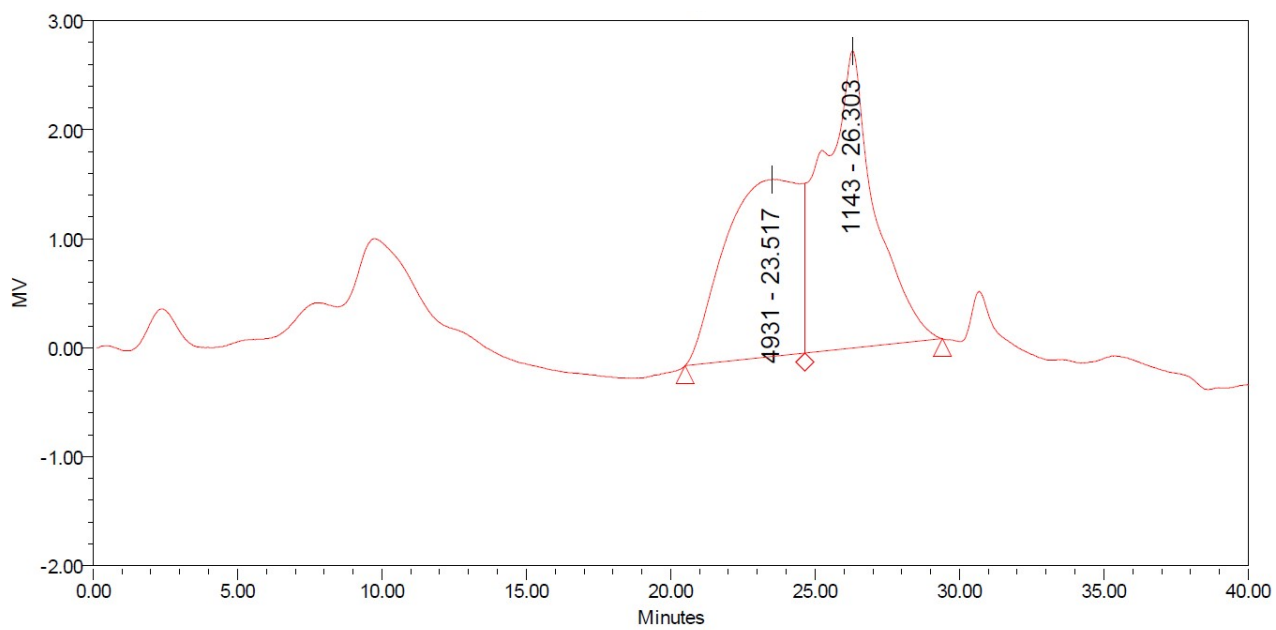


Figure S16: GPC spectrum of Poly(FuCa)-P50

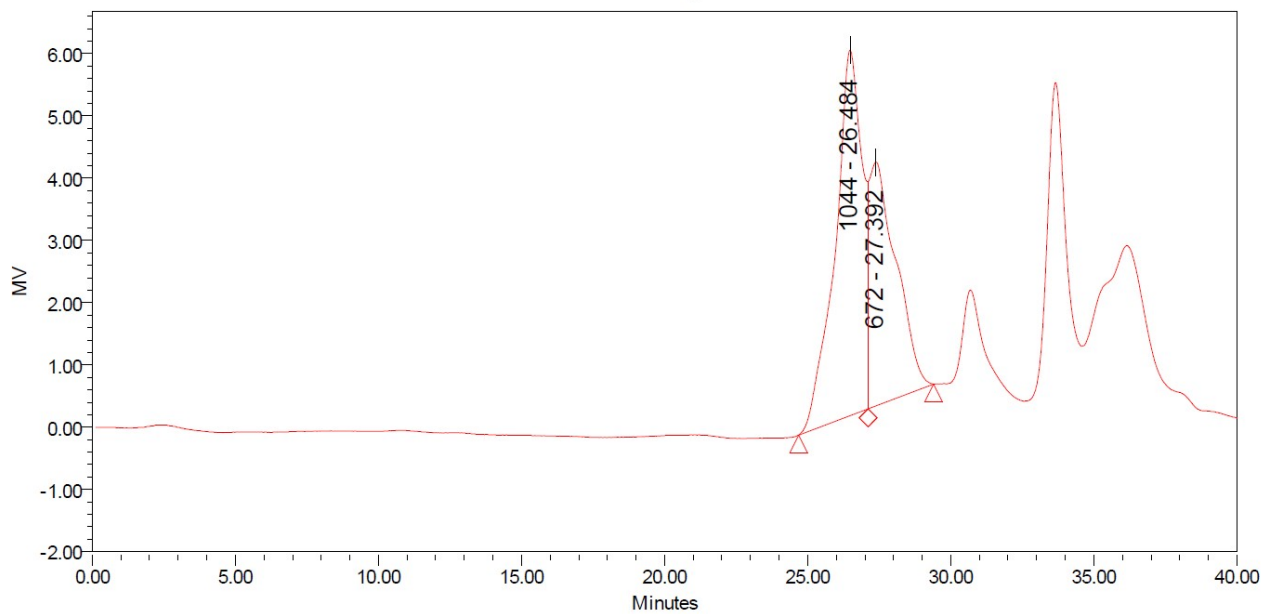


Figure S17: GPC spectrum of Poly(SuCa)-P15

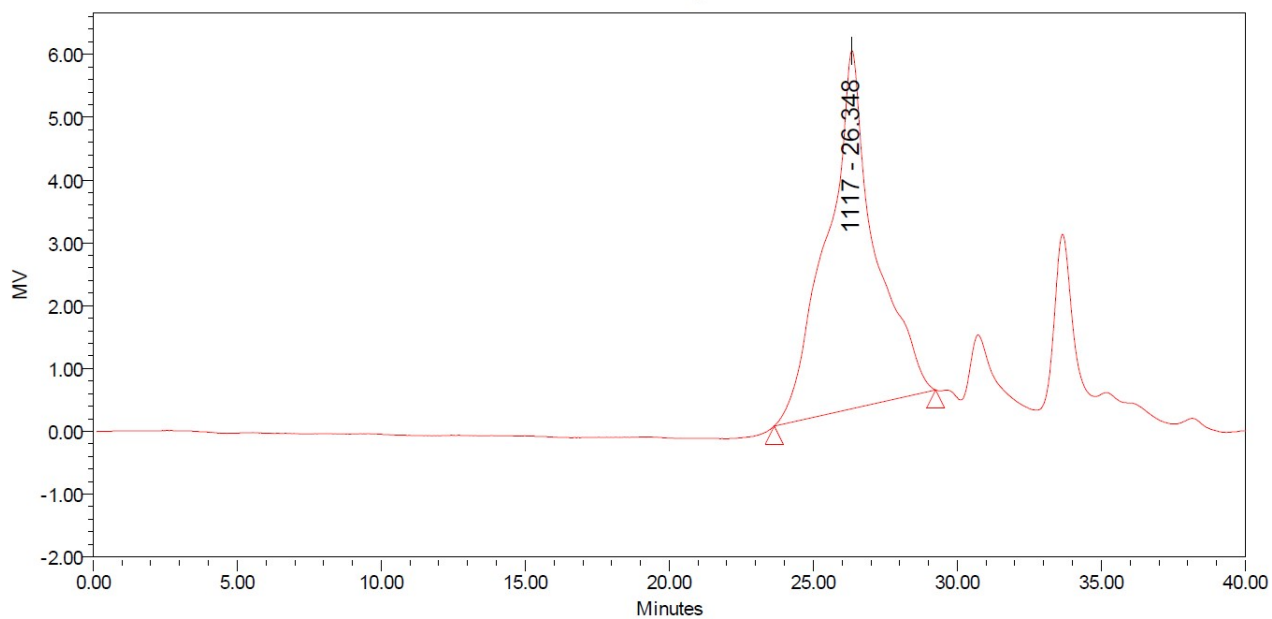


Figure S18: GPC spectrum of Poly(SuCa)-P50

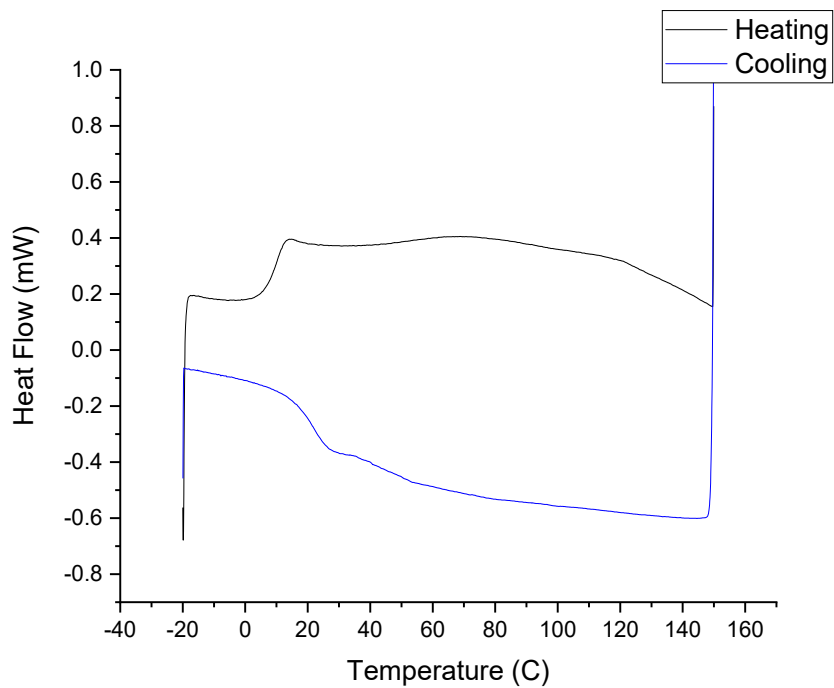


Figure S19: DSC thermogram of Poly(FuCa)

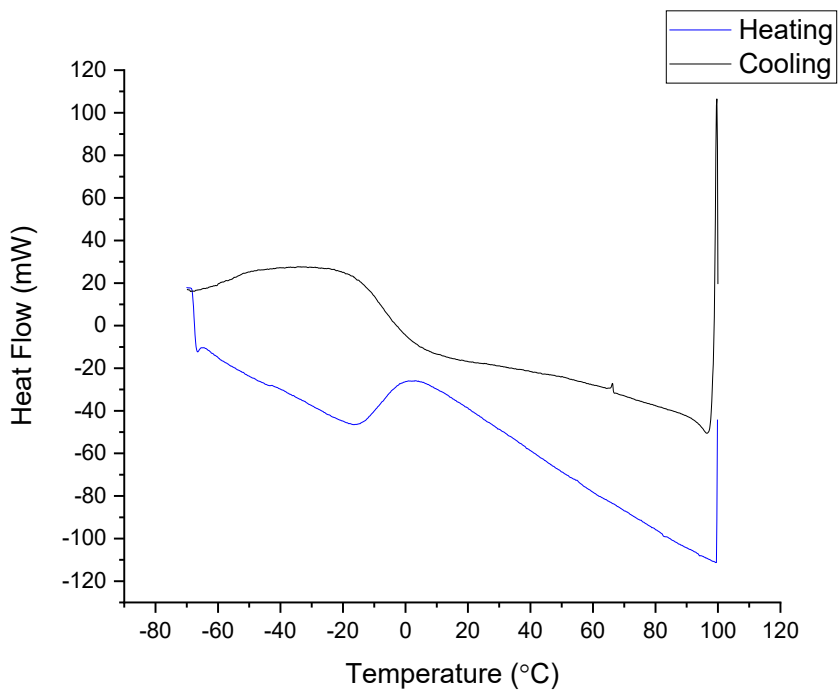


Figure S20: DSC thermogram of Poly(SuCa)

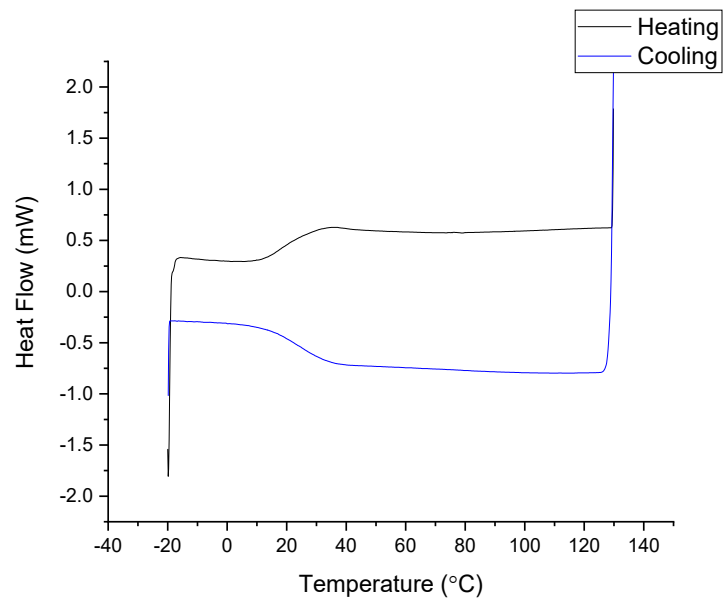


Figure S21: DSC thermogram of Poly(FuCa)-P15

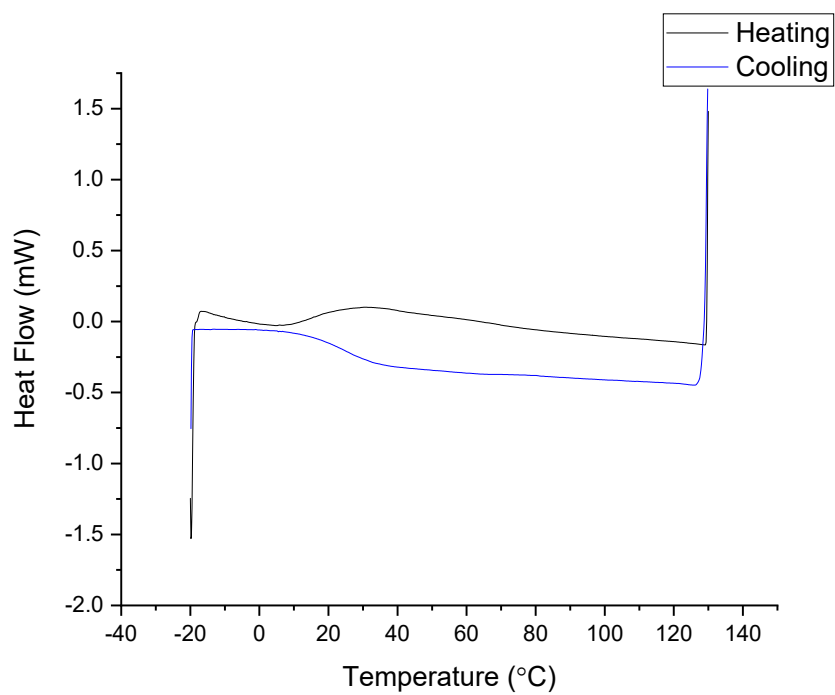


Figure S22: DSC thermogram of Poly(FuCa)-P50

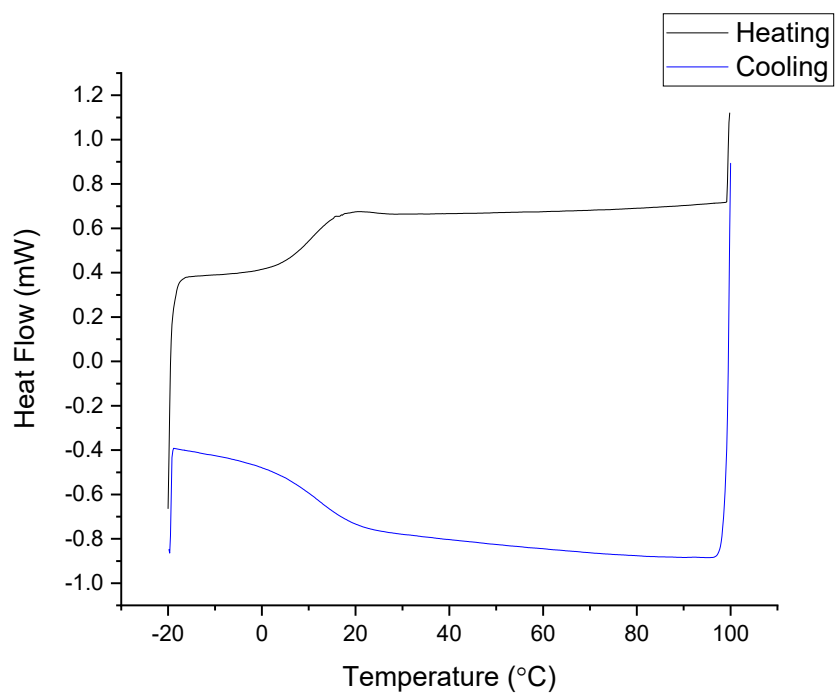


Figure S23: DSC thermogram of Poly(SuCa)-P15

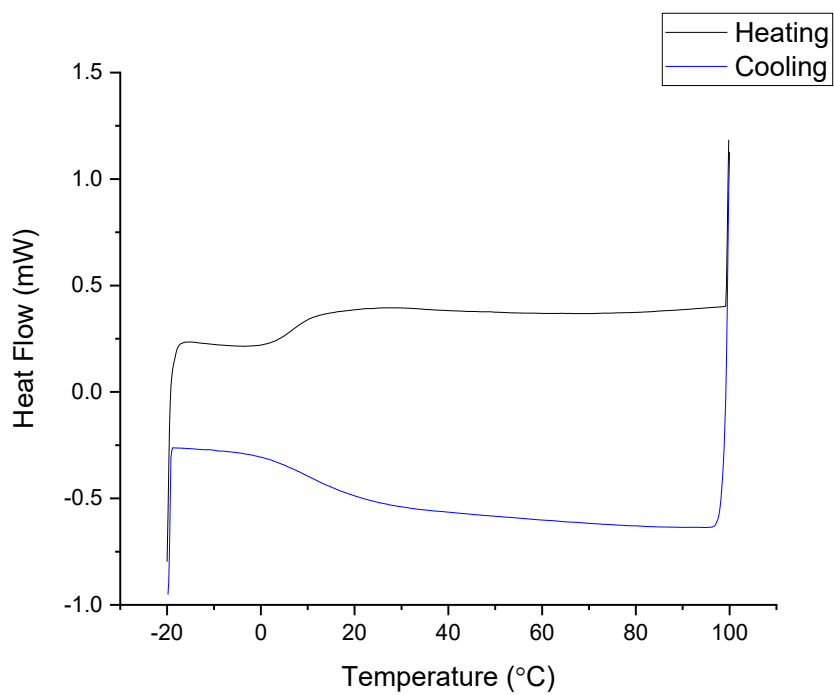


Figure S24: DSC thermogram of Poly(SuCa)-P50

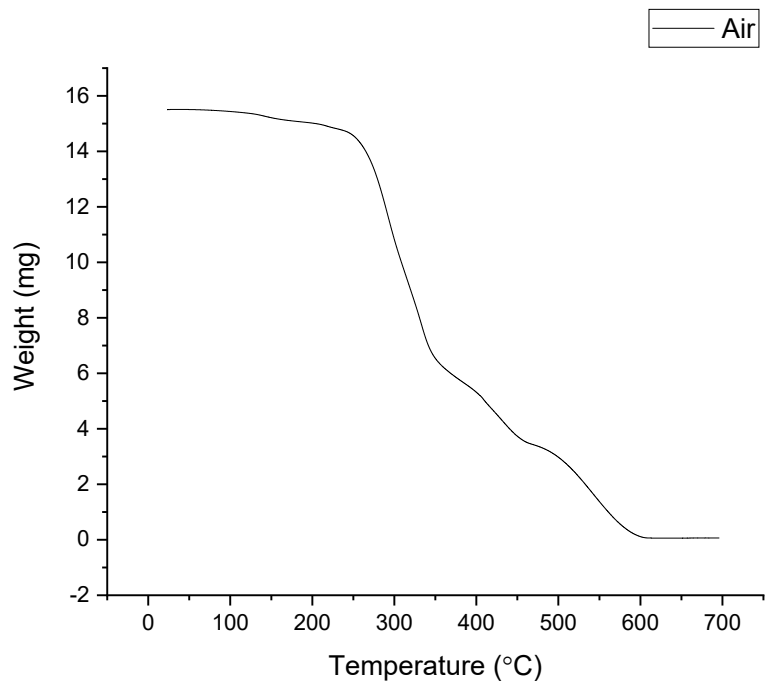


Figure S25: TGA in Air trace of Poly(FuCa)

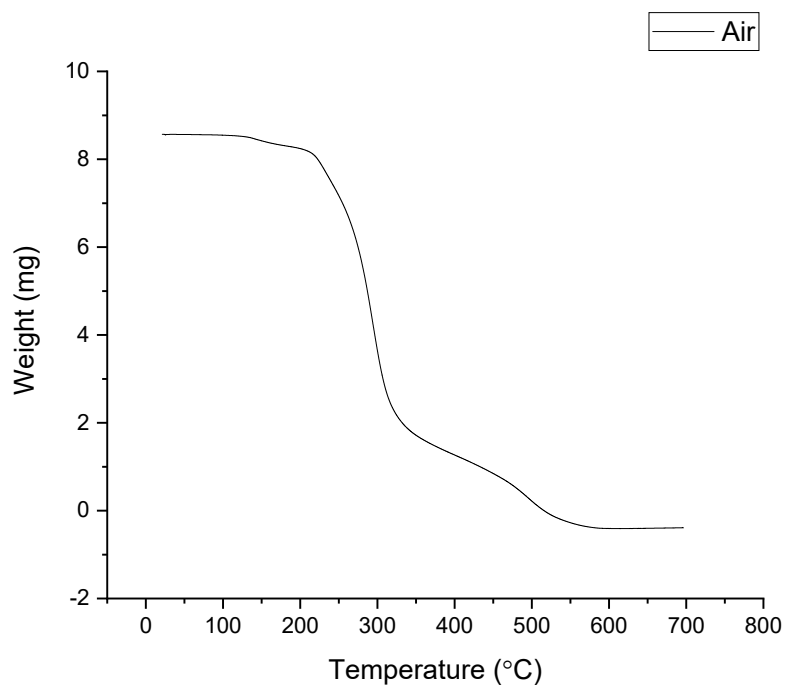


Figure S26: TGA in Air trace of Poly(SuCa)

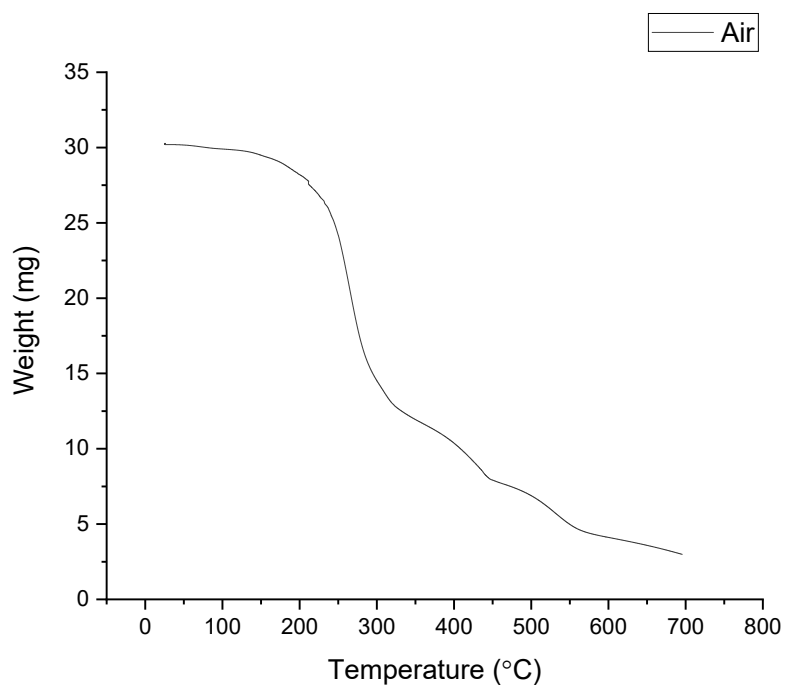


Figure S27: TGA in Air trace of Poly(FuCa)-P15

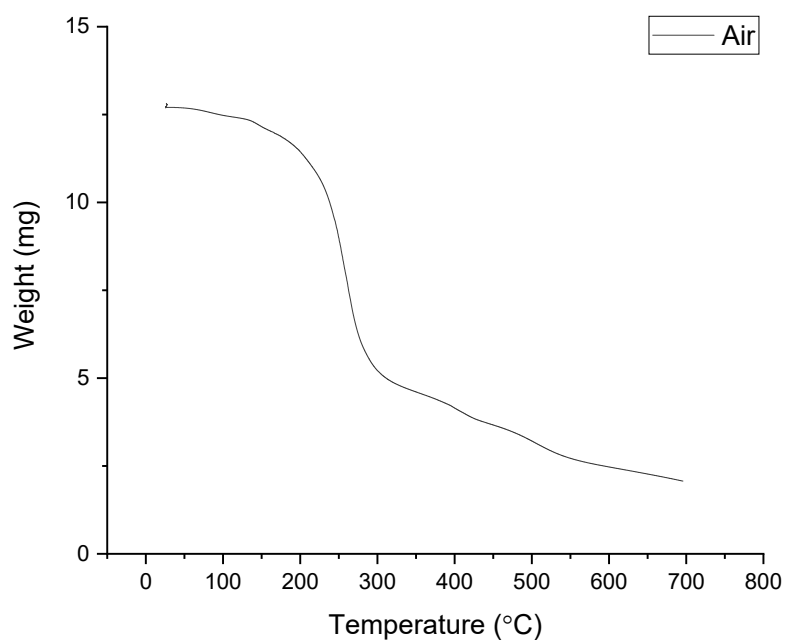


Figure S28: TGA in Air trace of Poly(FuCa)-P50

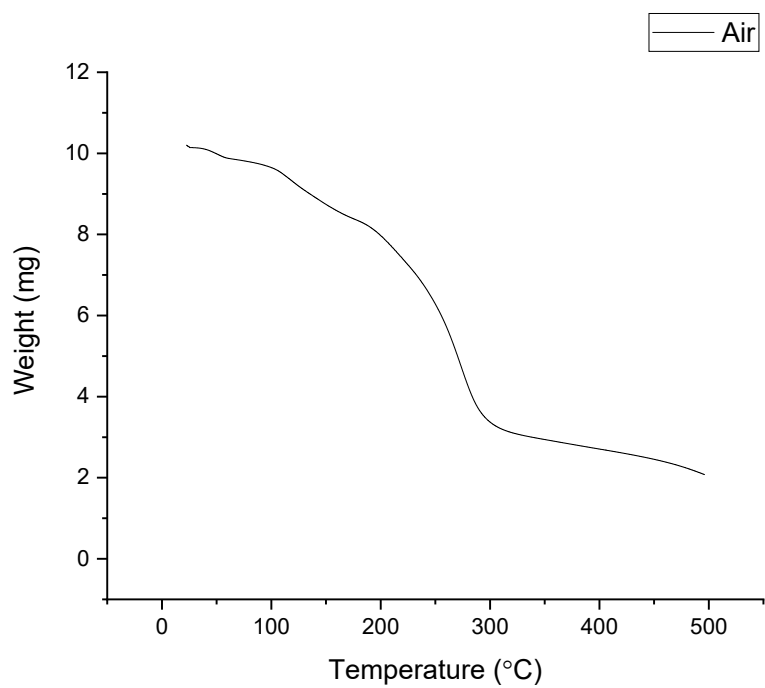


Figure S29: TGA in Air trace of Poly(SuCa)-P15

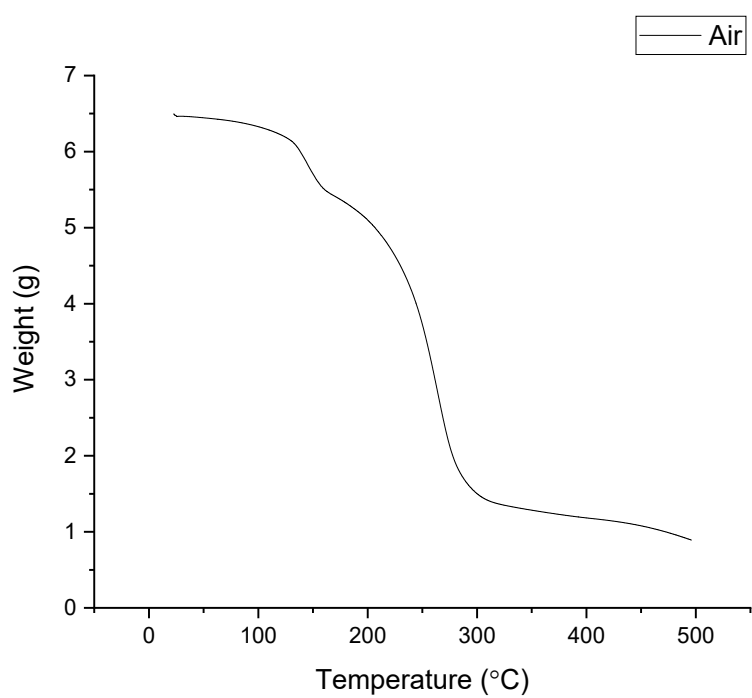
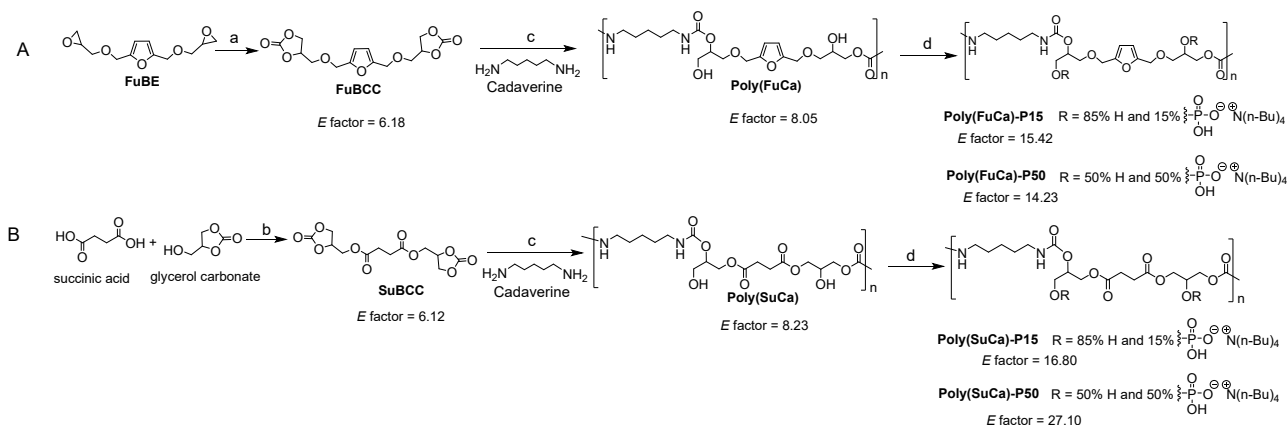


Figure S30: TGA in Air trace of Poly(SuCa)-P50

E factor calculation



Step A-a

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
FuBE	10.80	FuBCC	12.7
Catalyst (TBAP)	0.44		
CO ₂ (approx. based on 20 bar in 160 mL reactor)	6.28		
Ethyl Acetate, 60 mL	54.12		
Pet-ether, 30 mL	19.59		
Σ R (g)	91.23	Σ P (g)	12.7
Waste (g), W = ΣR - ΣP	78.53		
E-Factor = W/ΣP	6.18		

Step A-c

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
FuBCC	10.30	Poly(FuCa)	12.16
Cadaverine	3.22		
Anisole, 30 mL	29.85		
Methanol, 3x10 mL	23.94		
Diethyl ether, 3x20 mL	42.78		
Σ R (g)	110.09	Σ P (g)	12.16
Waste (g), W = ΣR - ΣP	97.93		
E-Factor = W/ΣP	8.05		

Step A-d-(15%)

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
Poly(FuCa)	10.80	Poly(FuCa)-P15	11.047
GVL (solvent), 25 mL	26.25		
TCAN, 1.5 mL	2.16		
TBAP	3.40		
Acetonitrile, 10 mL	7.86		
Methanol, 3x10 mL	23.94		
Diethyl ether, 3x50 mL	106.95		
ΣR (g)	181.36	ΣP (g)	11.047
Waste (g), $W = \Sigma R - \Sigma P$	170.31		
E-Factor = $W/\Sigma P$	15.42		

Step A-d-(50%)

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
Poly(FuCa)	10.80	Poly(FuCa)-P50	15.4
GVL (solvent), 25 mL	26.25		
TCAN, 6 mL	8.64		
TBAP	18.70		
Acetonitrile, 50 mL	39.30		
Methanol, 3x10 mL	23.94		
Diethyl ether, 3x0 mL	106.95		
ΣR (g)	234.58	ΣP (g)	15.4
Waste (g), $W = \Sigma R - \Sigma P$	219.18		
E-Factor = $W/\Sigma P$	14.23		

Step B-b

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
Succinic acid	98.00	SuBCC	211
Glycerol carbonate	200.00		
Toluene, 750 mL	650.25		
Catalyst (p-TSA)	2.00		
Acetone, 200 mL	156.80		
Ethanol, 500 mL	394.50		
ΣR (g)	1501.55	ΣP (g)	211
Waste (g), $W = \Sigma R - \Sigma P$	1290.55		
E-Factor = $W/\Sigma P$	6.12		

Step B-e

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
SuBCC	10.00	Poly(SuCa)	11.89
Cadavarine	3.22		
Anisol, 30 mL	29.85		
Methanol, 3x10 mL	23.94		
Diethyl ether, 3x20 mL	42.78		
ΣR (g)	109.79	ΣP (g)	11.89
Waste (g), $W = \Sigma R - \Sigma P$	97.9		
E-Factor = $W/\Sigma P$	8.23		

Step B-f-(15%)

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
		Poly(SuCa)-P-	
Poly(SuCa)	15.00	15	15.71
GVL-(solvent), 50 mL	52.50		
TCAN, 2.2 mL	3.17		
TBAP	4.75		
Methanol, 3x15 mL	35.91		
Ether, 3x75 mL	160.43		
Acetonitrile, 10 mL	7.86		
ΣR (g)	279.61	ΣP (g)	15.71
Waste (g), $W = \Sigma R - \Sigma P$	263.90		
E-Factor = $W/\Sigma P$	16.80		

Step B-f-(50%)

Reactants, catalyst and solvent, R	Amount of R, g	Product, P	Amount of P, g
Poly(SuCa)	1.05	Poly(SuCa)-P50	0.9157
GVL-(solvent), 2.5 mL	2.63		
TCAN, 0.6 mL	3.17		
TBAP	1.87		
Methanol, 3x1 mL	2.39		
Ether, 3x5 mL	10.70		
Acetonitrile, 5 mL	3.93		
ΣR (g)	25.73	ΣP (g)	0.9157
Waste (g), $W = \Sigma R - \Sigma P$	24.82		
E-Factor = $W/\Sigma P$	27.10		



Figure S31: Microscopic image of olive oil in water emulsions without the use of any additive taken after leaving the emulsions for 24 h.