

Supporting information

CO₂ Derived Hydrogen Bonding Spacer: Enhanced Toughness, Transparency, Elongation and Non-covalent Interactions in Epoxy-Hydroxyurethane Networks

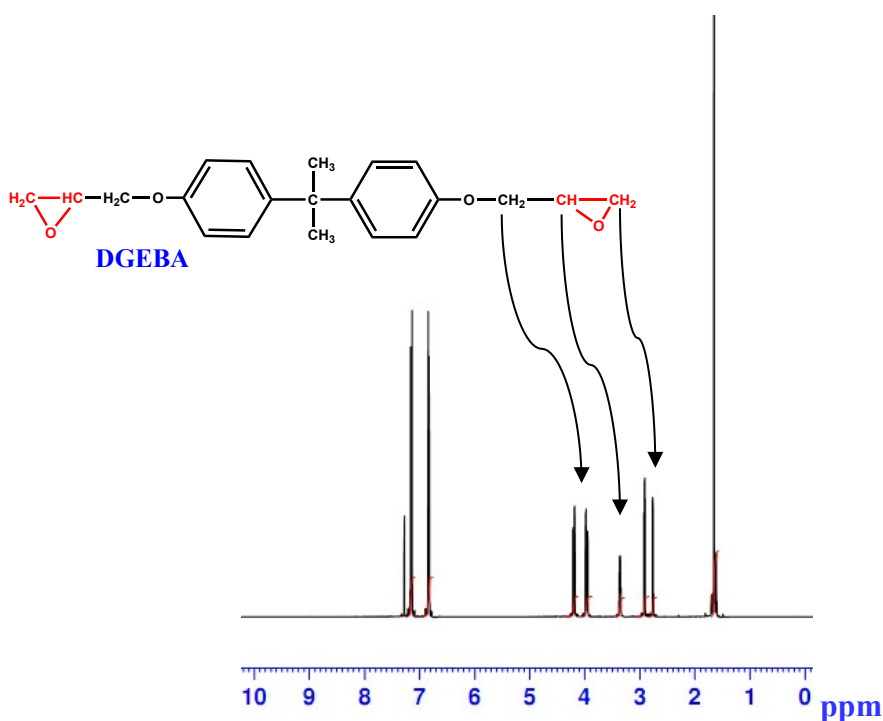
S. Anitha ^a, K.P. Vijayalakshmi ^b, G Unnikrishnan ^c, K.S. Santhosh Kumar ^{*a},

^a Polymers and Special Chemicals Group, Vikram Sarabhai Space Centre
Thiruvananthapuram – 695022, India

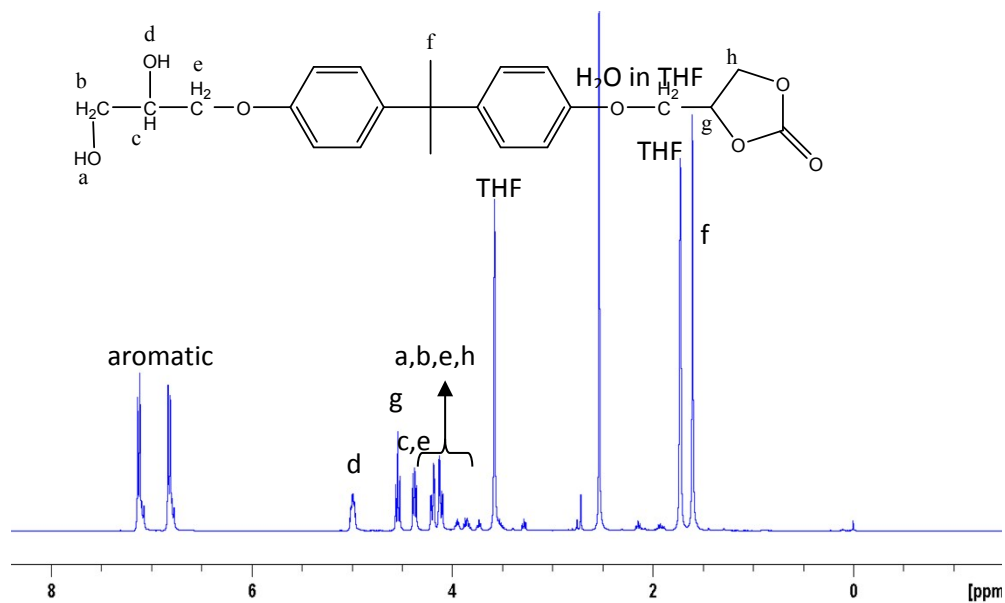
^b Analytical, Spectroscopy and Ceramics Group, Vikram Sarabhai Space Centre
Thiruvananthapuram – 695022, India

^c Department of chemistry, National Institute of Technology, Calicut-673601

Email: santhoshkshankar@yahoo.com



(a)



(b)

SI 1 ^1H NMR of (a) DGEBA and (b) MCC.

SI 2 Theoretical hydroxyl number of MCC

Theoretical -OH number = (functionality of MCC x 56100)/ molecular weight of MCC

Theoretical -OH number = $(2 \times 56100)/388 = 290 \text{ mg KOH/g}$

-OH number experimentally determined by titration = 322 kg KOH/g.

i.e. number of functional groups ~ 2.1

This closely matches with the MCC structure containing two hydroxyl groups.

SI 3 Determination of CC content via proton NMR

$$EW_{CC} = \frac{3 \times I_{CC} \times W_{\text{standard}}}{300 \times MW_{\text{standard}} \times W_{CC}}$$

where, I_{CC} is the Integration peak of $-\text{CH}$ of MCC.

W_{standrad} and W_{cc} are the weight of toluene (standard) and MCC respectively introduced into the NMR tube.

300 is the integral value of $-\text{CH}_3$ of toluene.

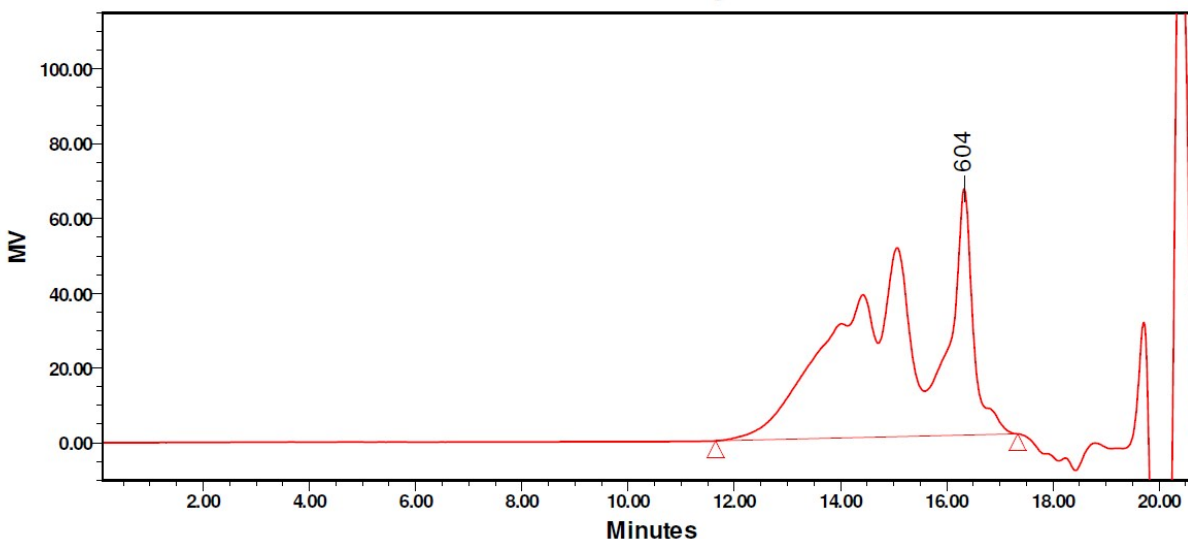
W_{CC} is the molecular weight of toluene.

Calculation: $(3 \times 28.09 \times 7.00 \text{ mg}) / (300 \times 92 \times 10.2 \text{ mg}) = 0.0021 \text{ mol/g} = 0.00210 \text{ eq/g}$

$= 2.10 \text{ meq./g}$

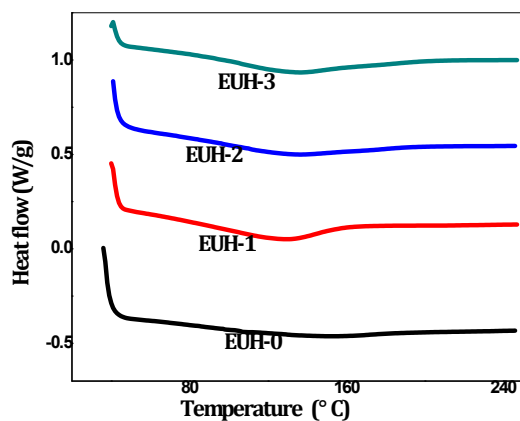
No. CC ring equivalents in 1 kg of completely functionalized molecule (theoretical) = 4.6 eq/kg
 $= 4.67 \text{ meq./g.}$

% CC ring in MCC = $2.10/4.67 = 45 \%$



$M_n = 1100 \text{ g/mol}$

SI 4 Gel permeation chromatography of MCC-Jeffamine adduct



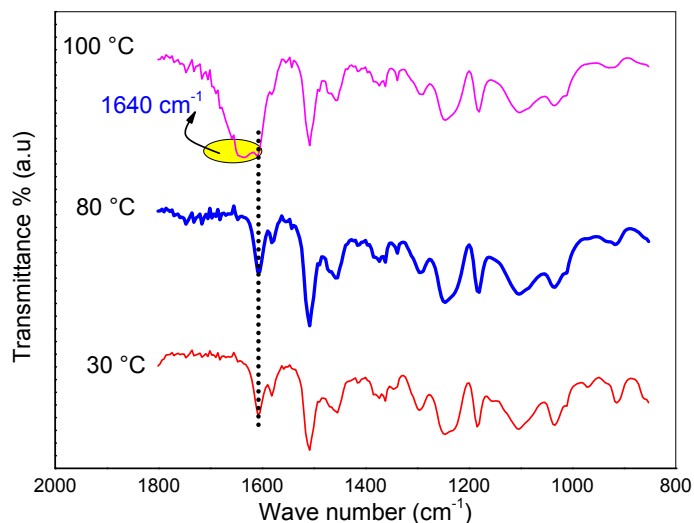
SI 5 DSC traces show complete curing of EUH networks by heating at 100°C/2h (absence of exotherm)

SI 6 Swelling property of EUH networks

Networks	Swelling index (%)		
	Methanol	IPA	Acetone
EUH-0	13.5	17.0	0.8
EUH-1	11.2	15.2	0.9
EUH-2	11.2	14.9	1.3
EUH-3	11.4	14.2	2.0

SI 7 Gel content of EUH networks

EUH networks	Gel content (wt. %)
EUH-0	98
EUH-1	96
EUH-2	96
EUH-3	95



SI 8 Formation of urethane linkages in DGEBA-MCC-Jeffmaine crosslinked network at enhanced temperature regime.

SI 9 Supporting information of DFT calculations

1. Model compound 1

E(RB3LYP) = -4517.99950681 A.U.

XYZ coordinates:

6	2.241375000	-3.199133000	-1.438438000
6	0.698567000	-3.167862000	-1.492641000
6	2.673894000	-4.569751000	-0.876003000
6	2.726863000	-2.965781000	-2.893656000
8	0.151788000	-3.398832000	-0.195887000
6	-1.203429000	-3.021478000	-0.042582000
6	-2.201599000	-4.053276000	-0.611657000
6	-2.036018000	-5.429532000	0.031955000
7	-3.567352000	-3.568533000	-0.434166000
8	2.398891000	-0.820425000	-0.968760000
6	2.555587000	0.183704000	0.025659000
6	2.486098000	1.587450000	-0.601451000
6	1.826447000	2.529659000	0.417517000
7	3.834159000	2.064631000	-0.992635000
6	4.577074000	1.149529000	-1.873177000
6	3.895144000	3.455209000	-1.449885000
6	6.097413000	1.281072000	-1.677980000
8	6.449955000	1.200200000	-0.298800000
6	6.876350000	0.171587000	-2.377695000
8	6.598250000	0.256519000	-3.770221000

6	8.131810000	-1.603334000	-4.208671000
6	8.701052000	-2.450479000	-5.166068000
6	8.381189000	-2.356176000	-6.521371000
6	7.453799000	-1.371257000	-6.901394000
6	6.876417000	-0.520182000	-5.968623000
6	7.213866000	-0.629822000	-4.611339000
6	9.007321000	-3.271303000	-7.548395000
6	4.472115000	4.401604000	-0.388995000
8	5.781960000	3.938215000	-0.053952000
6	4.560075000	5.839300000	-0.889280000
8	5.163638000	6.584450000	0.166576000
6	5.133039000	8.624130000	-1.192741000
6	5.450989000	9.984810000	-1.271835000
6	6.058189000	10.664320000	-0.214642000
6	6.345603000	9.930571000	0.948729000
6	6.039413000	8.579847000	1.048681000
6	5.429999000	7.917977000	-0.025887000
6	6.392026000	12.135325000	-0.306484000
6	4.238325000	-3.006574000	-3.146460000
6	5.870607000	-5.186425000	0.906118000
7	5.863632000	-3.943674000	1.711541000
6	6.833065000	-5.131781000	-0.291763000
6	5.079421000	-4.059646000	2.944565000
6	4.660457000	-2.694011000	3.538404000
8	4.079129000	-1.857908000	2.565936000
6	3.638627000	-2.917891000	4.645089000
8	3.544324000	-1.727189000	5.417189000
6	7.178103000	-3.336098000	1.950792000
6	1.792026000	-2.729756000	6.806851000
6	0.905122000	-2.557986000	7.876101000
6	0.833934000	-1.363141000	8.593255000
6	1.693224000	-0.321572000	8.202552000
6	2.579977000	-0.469983000	7.145408000
6	2.637860000	-1.680089000	6.435468000
6	-0.126293000	-1.186525000	9.747037000
6	7.464192000	-2.118147000	1.057993000
8	6.513946000	-1.112322000	1.377161000
6	8.886002000	-1.610393000	1.298620000
6	11.296846000	-0.043146000	1.388417000
6	12.352770000	0.863426000	1.533493000
6	12.294203000	2.153678000	1.003227000
6	11.123117000	2.523160000	0.320054000
6	10.060374000	1.641663000	0.168928000
6	10.147638000	0.345756000	0.696767000
6	13.444449000	3.122733000	1.152343000
8	9.068524000	-0.468236000	0.471073000
8	4.055663000	-4.551604000	-0.549896000

6	4.470023000	-5.538713000	0.366736000
6	2.742452000	-2.114369000	-0.469842000
1	0.377809000	-2.183877000	-1.859869000
1	0.337560000	-3.929253000	-2.202359000
1	2.085635000	-4.786225000	0.026771000
1	2.459413000	-5.363184000	-1.613664000
1	2.342649000	-1.991445000	-3.217709000
1	2.243909000	-3.717374000	-3.535345000
1	-1.369451000	-2.915987000	1.037321000
1	-1.391651000	-2.045780000	-0.515215000
1	-2.051457000	-4.128358000	-1.692438000
1	-2.698217000	-6.165008000	-0.435588000
1	-1.000928000	-5.766364000	-0.070123000
1	-2.266136000	-5.391410000	1.105359000
1	-4.013274000	-3.659467000	0.468652000
1	1.762459000	0.066642000	0.779033000
1	3.515601000	0.074341000	0.550640000
1	1.823592000	1.516646000	-1.485047000
1	1.713607000	3.550813000	0.043028000
1	0.823211000	2.161859000	0.656217000
1	2.407130000	2.565513000	1.346696000
1	4.282869000	0.128075000	-1.634982000
1	4.335212000	1.303833000	-2.938434000
1	2.907958000	3.827750000	-1.765202000
1	4.539764000	3.516606000	-2.335314000
1	6.444753000	2.244358000	-2.076366000
1	6.044486000	1.991013000	0.112991000
1	7.948093000	0.297540000	-2.181365000
1	6.569214000	-0.807643000	-1.982396000
1	8.411273000	-1.711391000	-3.166886000
1	9.414336000	-3.203403000	-4.837568000
1	7.178782000	-1.270734000	-7.949463000
1	6.159319000	0.239201000	-6.265526000
1	9.655043000	-4.016200000	-7.074750000
1	8.246849000	-3.811991000	-8.125928000
1	9.618993000	-2.712803000	-8.268921000
1	3.839617000	4.386701000	0.508303000
1	6.172649000	4.612126000	0.527422000
1	5.183196000	5.890009000	-1.793028000
1	3.562847000	6.239124000	-1.121396000
1	4.660738000	8.137803000	-2.038794000
1	5.215128000	10.522721000	-2.187246000
1	6.818981000	10.428042000	1.792592000
1	6.262556000	8.017269000	1.950291000
1	6.162169000	12.534428000	-1.299546000
1	5.825050000	12.724061000	0.426088000
1	7.455696000	12.320301000	-0.111722000

1	4.449579000	-2.777325000	-4.196967000
1	4.664878000	-3.985889000	-2.915455000
1	4.766271000	-2.265683000	-2.537895000
1	6.174452000	-6.048134000	1.537832000
1	6.769917000	-6.078390000	-0.839354000
1	7.877036000	-5.001944000	0.004034000
1	6.552962000	-4.328363000	-0.976866000
1	4.159087000	-4.601220000	2.715500000
1	5.611750000	-4.645809000	3.721860000
1	5.532704000	-2.201378000	3.996837000
1	4.809066000	-1.617135000	1.956257000
1	2.667540000	-3.157301000	4.190004000
1	3.943296000	-3.758032000	5.287674000
1	7.996471000	-4.064447000	1.851569000
1	7.222195000	-2.984030000	2.986993000
1	1.811006000	-3.676248000	6.278617000
1	0.253836000	-3.384961000	8.151711000
1	1.664563000	0.625064000	8.738811000
1	3.241112000	0.337012000	6.844530000
1	-0.726631000	-2.088264000	9.906510000
1	0.402009000	-0.971239000	10.684890000
1	-0.819827000	-0.353756000	9.572980000
1	7.373509000	-2.404837000	0.000693000
1	6.614986000	-0.345495000	0.768581000
1	9.013478000	-1.332443000	2.354157000
1	9.619277000	-2.392820000	1.049771000
1	11.384520000	-1.039569000	1.808102000
1	13.242845000	0.547962000	2.073690000
1	11.039704000	3.526732000	-0.092650000
1	9.139416000	1.934492000	-0.325282000
1	14.226681000	2.716021000	1.801577000
1	13.906924000	3.353196000	0.183616000
1	13.116214000	4.076219000	1.584665000
1	3.731566000	-5.636458000	1.175139000
1	4.535520000	-6.528813000	-0.118292000
1	2.289316000	-2.270587000	0.516797000
1	3.827271000	-2.188019000	-0.338328000
6	-4.208865000	-2.820062000	-1.372899000
8	-3.778540000	-2.547369000	-2.480282000
8	-5.426116000	-2.425565000	-0.889792000
6	-6.254665000	-1.657438000	-1.787731000
6	-6.966648000	-0.594605000	-0.958092000
6	-7.181616000	-2.625451000	-2.537468000
8	-8.061406000	-1.938588000	-3.416047000
8	-7.848276000	-1.153034000	0.019049000
6	-9.928985000	-0.552988000	-1.160604000
6	-11.302420000	-0.774967000	-1.288370000

6	-11.985959000	-1.716397000	-0.507447000
6	-11.226615000	-2.430695000	0.431136000
6	-9.855632000	-2.229018000	0.571198000
6	-9.187507000	-1.292956000	-0.226253000
6	-13.488100000	-1.967420000	-0.746993000
6	-13.621249000	-2.747379000	-2.077825000
6	-14.119921000	-2.837892000	0.366611000
6	-15.159745000	-0.286079000	-1.790978000
6	-15.875009000	0.908460000	-1.757539000
6	-15.702285000	1.802873000	-0.697688000
6	-14.797825000	1.490738000	0.322929000
6	-14.090064000	0.289743000	0.269068000
6	-14.250743000	-0.627480000	-0.778579000
8	-16.448038000	2.953035000	-0.749553000
6	-16.358784000	3.887589000	0.327727000
6	-17.398310000	4.966467000	0.038055000
8	-18.677643000	4.369898000	-0.164253000
6	-17.569796000	5.929734000	1.212744000
8	-18.044616000	5.254739000	2.364962000
1	-5.611392000	-1.148374000	-2.512280000
1	-6.222886000	-0.026648000	-0.392376000
1	-7.481000000	0.095364000	-1.631360000
1	-6.556743000	-3.284223000	-3.148459000
1	-7.722554000	-3.247029000	-1.812407000
1	-8.879915000	-1.750442000	-2.928385000
1	-9.466684000	0.221038000	-1.764081000
1	-11.855715000	-0.177412000	-2.008035000
1	-11.699729000	-3.168473000	1.070329000
1	-9.279799000	-2.791188000	1.299875000
1	-14.661367000	-3.030661000	-2.275769000
1	-13.253736000	-2.165961000	-2.929774000
1	-13.030750000	-3.667826000	-2.023853000
1	-15.194184000	-2.942474000	0.183585000
1	-13.993483000	-2.388456000	1.356898000
1	-13.686581000	-3.844491000	0.386044000
1	-15.323351000	-0.954725000	-2.629216000
1	-16.572762000	1.163131000	-2.549749000
1	-14.634268000	2.168364000	1.153273000
1	-13.382978000	0.071519000	1.065058000
1	-16.588451000	3.399529000	1.281806000
1	-15.350425000	4.320961000	0.378809000
1	-17.090430000	5.529341000	-0.858077000
1	-18.524543000	3.578853000	-0.708317000
1	-16.611384000	6.389316000	1.477696000
1	-18.257522000	6.732720000	0.905297000
1	-18.812092000	4.742406000	2.055923000

2. Model compound 2 (double chain)

E(RB3LYP) = -9036.01918729 A.U.

XYZ coordinates:

6	0.152236000	2.319522000	-0.129942000
8	0.090519000	2.569808000	-1.329268000
8	0.032976000	3.254565000	0.855872000
6	-0.074368000	4.657329000	0.509440000
6	-1.344601000	4.945860000	-0.310393000
6	1.202990000	5.211592000	-0.142170000
8	1.239889000	6.625874000	-0.044051000
8	-1.657337000	6.342329000	-0.280989000
6	-2.842957000	6.113826000	1.863830000
6	-3.713820000	6.692994000	2.785600000
6	-4.242436000	7.978864000	2.610007000
6	-3.839715000	8.681546000	1.465105000
6	-2.971615000	8.119675000	0.529917000
6	-2.477338000	6.827125000	0.717624000
6	-5.194462000	8.562761000	3.674395000
6	-4.338183000	8.970782000	4.897239000
6	-5.928274000	9.828987000	3.170832000
6	-6.602496000	7.174103000	5.354744000
6	-7.568621000	6.209796000	5.637417000
6	-8.226350000	5.546041000	4.598510000
6	-7.921725000	5.879305000	3.273665000
6	-6.955515000	6.849194000	3.012870000
6	-6.261948000	7.509324000	4.036415000
8	-9.142865000	4.592087000	4.962290000
6	-9.645666000	3.716390000	3.946820000
6	-10.641532000	2.785377000	4.628975000
8	-11.618197000	3.550798000	5.337667000
6	-11.427713000	1.947682000	3.619777000
8	-12.213963000	2.786231000	2.778856000
1	-0.169846000	5.138803000	1.485919000
1	-1.184125000	4.703196000	-1.361352000
1	-2.187501000	4.350660000	0.057774000
1	2.072208000	4.836677000	0.407978000
1	1.280381000	4.865006000	-1.181707000
1	0.403798000	6.962920000	-0.408673000
1	-2.475269000	5.112687000	2.055405000
1	-4.002651000	6.108313000	3.654141000
1	-4.214643000	9.681727000	1.275105000
1	-2.685564000	8.666157000	-0.363770000
1	-4.944242000	9.462697000	5.666785000
1	-3.839517000	8.107329000	5.349509000
1	-3.562914000	9.677141000	4.582776000

1	-6.634097000	10.171211000	3.934711000
1	-6.496686000	9.632960000	2.255682000
1	-5.228772000	10.649604000	2.973777000
1	-6.101923000	7.653792000	6.189207000
1	-7.808929000	5.945405000	6.662862000
1	-8.417840000	5.388142000	2.444713000
1	-6.718713000	7.076624000	1.976999000
1	-10.165651000	4.289272000	3.170579000
1	-8.819695000	3.151197000	3.497470000
1	-10.101393000	2.119367000	5.320078000
1	-11.133141000	4.275128000	5.768302000
1	-10.765169000	1.372779000	2.966587000
1	-12.063891000	1.241221000	4.173152000
1	-12.672584000	3.390579000	3.389448000
6	-6.235361000	0.560849000	-4.249042000
6	-4.703563000	0.525279000	-4.448253000
6	-6.693204000	2.035526000	-4.321045000
6	-6.842505000	-0.303100000	-5.386104000
8	-4.063134000	1.347014000	-3.475815000
6	-2.671977000	1.130908000	-3.325754000
6	-1.815496000	1.774645000	-4.432920000
6	-2.090716000	3.274838000	-4.581818000
7	-0.412370000	1.500812000	-4.133128000
8	-6.334197000	-1.382763000	-2.779131000
6	-6.283811000	-1.841228000	-1.430816000
6	-6.520435000	-3.359019000	-1.351867000
6	-5.696208000	-3.901845000	-0.172780000
7	-7.959556000	-3.684710000	-1.194338000
6	-8.839083000	-3.068445000	-2.200403000
6	-8.234490000	-5.114537000	-1.016448000
6	-10.296051000	-2.957935000	-1.720285000
8	-10.381335000	-2.284518000	-0.468236000
6	-11.165437000	-2.158421000	-2.686583000
8	-11.204630000	-2.857415000	-3.924316000
6	-12.801503000	-1.227325000	-4.818832000
6	-13.546607000	-0.805332000	-5.925761000
6	-13.486082000	-1.465005000	-7.154281000
6	-12.642771000	-2.585013000	-7.247495000
6	-11.894611000	-3.021798000	-6.162501000
6	-11.969529000	-2.343932000	-4.936700000
6	-14.288681000	-0.995415000	-8.345709000
6	-8.607794000	-5.468400000	0.428612000
8	-9.781908000	-4.730640000	0.774992000
6	-8.885716000	-6.958314000	0.600631000
8	-9.299685000	-7.125947000	1.955634000
6	-9.704486000	-9.515500000	1.588050000
6	-10.149890000	-10.726087000	2.131186000

6	-10.605140000	-10.822102000	3.447070000
6	-10.600217000	-9.650515000	4.222800000
6	-10.163202000	-8.438882000	3.704095000
6	-9.713613000	-8.365425000	2.378779000
6	-11.090817000	-12.131796000	4.023606000
6	-8.369399000	-0.428919000	-5.439231000
6	-9.761527000	3.397991000	-2.747258000
7	-9.601066000	2.680769000	-1.462184000
6	-10.864043000	2.767677000	-3.614818000
6	-8.426129000	3.084851000	-0.689621000
6	-8.087963000	2.150689000	0.494484000
8	-8.020025000	0.797214000	0.113449000
6	-6.724798000	2.529956000	1.063390000
8	-6.623068000	1.987738000	2.379313000
6	-10.848561000	2.630948000	-0.680238000
6	-4.205286000	2.396183000	2.415542000
6	-3.003073000	2.250703000	3.118857000
6	-2.951816000	1.652796000	4.379199000
6	-4.161813000	1.192385000	4.926038000
6	-5.362779000	1.318968000	4.241656000
6	-5.395958000	1.921350000	2.974078000
6	-1.650130000	1.499105000	5.131908000
6	-11.488291000	1.232508000	-0.681676000
8	-10.718342000	0.396683000	0.182143000
6	-12.942381000	1.258808000	-0.222516000
6	-15.583857000	0.580493000	0.614571000
6	-16.858014000	0.171448000	1.023958000
6	-17.290278000	-1.148735000	0.888795000
6	-16.392006000	-2.069266000	0.322938000
6	-15.122841000	-1.685633000	-0.088737000
6	-14.708459000	-0.352543000	0.052466000
6	-18.669039000	-1.580689000	1.332216000
8	-13.447286000	-0.067526000	-0.393788000
8	-8.027905000	2.150930000	-3.850686000
6	-8.467633000	3.462005000	-3.577342000
6	-6.577547000	0.023503000	-2.847337000
1	-4.359568000	-0.513369000	-4.341618000
1	-4.450348000	0.864810000	-5.464971000
1	-6.029573000	2.653374000	-3.699404000
1	-6.613296000	2.400005000	-5.360224000
1	-6.410940000	-1.307693000	-5.305280000
1	-6.490347000	0.110200000	-6.342726000
1	-2.402334000	1.578014000	-2.361132000
1	-2.448880000	0.053704000	-3.277801000
1	-2.018374000	1.277320000	-5.385436000
1	-1.506074000	3.688833000	-5.409479000
1	-3.152645000	3.454131000	-4.776386000

1	-1.818217000	3.810857000	-3.664240000
1	-0.040566000	1.818057000	-3.240400000
1	-5.290938000	-1.604277000	-1.017372000
1	-7.022685000	-1.321451000	-0.807088000
1	-6.121733000	-3.800633000	-2.285596000
1	-5.779704000	-4.985870000	-0.056217000
1	-4.636596000	-3.676610000	-0.332568000
1	-6.009684000	-3.430953000	0.766354000
1	-8.476373000	-2.061482000	-2.400181000
1	-8.820643000	-3.609444000	-3.162579000
1	-7.379691000	-5.734481000	-1.327895000
1	-9.071782000	-5.411406000	-1.659558000
1	-10.741815000	-3.957081000	-1.620757000
1	-9.969268000	-2.889587000	0.181176000
1	-12.169625000	-2.054477000	-2.256491000
1	-10.746745000	-1.151492000	-2.830252000
1	-12.888287000	-0.688767000	-3.881888000
1	-14.192284000	0.063525000	-5.817915000
1	-12.571247000	-3.124652000	-8.189793000
1	-11.244057000	-3.887896000	-6.237973000
1	-14.959037000	-0.173205000	-8.074655000
1	-13.639900000	-0.638253000	-9.156289000
1	-14.904680000	-1.802619000	-8.761468000
1	-7.788718000	-5.187134000	1.103761000
1	-10.078626000	-5.073029000	1.635053000
1	-9.686054000	-7.277532000	-0.081293000
1	-7.985023000	-7.554069000	0.396337000
1	-9.357326000	-9.488175000	0.561337000
1	-10.138633000	-11.614423000	1.503720000
1	-10.946499000	-9.689059000	5.253458000
1	-10.160664000	-7.536231000	4.307775000
1	-10.986173000	-12.947928000	3.301647000
1	-10.528210000	-12.409921000	4.923581000
1	-12.148654000	-12.077888000	4.311039000
1	-8.662303000	-1.065009000	-6.282519000
1	-8.855996000	0.542023000	-5.558435000
1	-8.766540000	-0.891869000	-4.530993000
1	-10.041014000	4.457397000	-2.560236000
1	-10.962847000	3.332189000	-4.548755000
1	-11.842357000	2.779824000	-3.126979000
1	-10.608112000	1.734540000	-3.863684000
1	-7.561645000	3.054514000	-1.355455000
1	-8.508964000	4.124148000	-0.304216000
1	-8.832858000	2.283042000	1.293454000
1	-8.952453000	0.512670000	-0.017290000
1	-5.954874000	2.098956000	0.411713000
1	-6.588873000	3.620399000	1.104137000

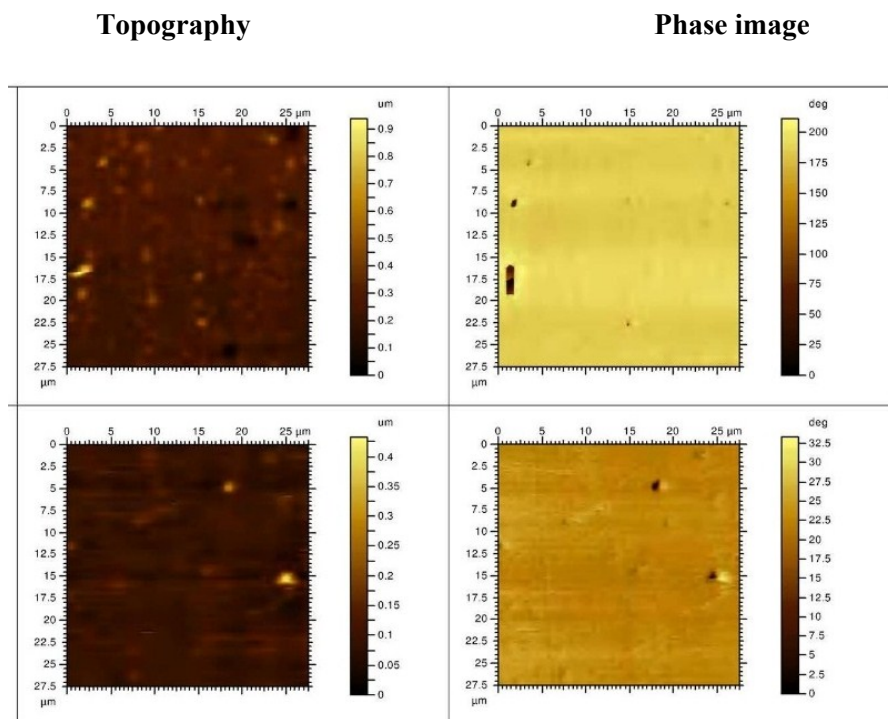
1	-11.574348000	3.366361000	-1.055997000
1	-10.665376000	2.908736000	0.362928000
1	-4.199433000	2.878281000	1.444760000
1	-2.083311000	2.610628000	2.660665000
1	-4.160627000	0.722123000	5.907381000
1	-6.293245000	0.953886000	4.665700000
1	-0.817495000	1.955282000	4.585589000
1	-1.694643000	1.975840000	6.119217000
1	-1.398821000	0.443741000	5.299853000
1	-11.456794000	0.836479000	-1.704298000
1	-10.864870000	-0.549943000	-0.038394000
1	-13.000002000	1.567137000	0.827833000
1	-13.528903000	1.961378000	-0.834355000
1	-15.289642000	1.615957000	0.741268000
1	-17.527534000	0.909816000	1.460229000
1	-16.693884000	-3.108001000	0.203882000
1	-14.430725000	-2.402780000	-0.519923000
1	-19.233045000	-0.741314000	1.751937000
1	-19.253804000	-1.987750000	0.497273000
1	-18.620707000	-2.363589000	2.100026000
1	-7.681751000	4.035143000	-3.063321000
1	-8.691454000	4.008053000	-4.509707000
1	-5.954066000	0.547416000	-2.110398000
1	-7.620267000	0.233446000	-2.593051000
7	0.346873000	1.101670000	0.425683000
1	0.291692000	1.055296000	1.435033000
6	4.030359000	-3.035480000	-1.124009000
6	2.764750000	-2.211271000	-1.468128000
6	3.580752000	-4.485470000	-0.850020000
6	4.969435000	-2.909666000	-2.351716000
8	1.814841000	-2.188168000	-0.401376000
6	1.642400000	-0.944517000	0.252950000
6	0.452879000	-0.151174000	-0.323897000
6	-0.849992000	-0.954115000	-0.278450000
8	5.021136000	-1.133775000	0.033561000
6	5.439593000	-0.575942000	1.275272000
6	6.091555000	0.802529000	1.063364000
6	5.731424000	1.686584000	2.267569000
7	7.557200000	0.669650000	0.901168000
6	7.976367000	-0.255133000	-0.162617000
6	8.310725000	1.924830000	0.885665000
6	9.311688000	-0.936519000	0.181285000
8	9.271810000	-1.506494000	1.486979000
6	9.658467000	-2.074938000	-0.772925000
8	9.814348000	-1.517636000	-2.075355000
6	10.427147000	-3.721445000	-2.956354000
6	10.775279000	-4.477245000	-4.081711000

6	10.862181000	-3.912226000	-5.355260000
6	10.586447000	-2.539650000	-5.475438000
6	10.238096000	-1.769136000	-4.373641000
6	10.156281000	-2.357975000	-3.102432000
6	11.231762000	-4.739120000	-6.565248000
6	9.033397000	2.198473000	2.211462000
8	9.895360000	1.090033000	2.474343000
6	9.858417000	3.479799000	2.157492000
8	10.530801000	3.566107000	3.412142000
6	11.671387000	5.619083000	2.709570000
6	12.581613000	6.627929000	3.044920000
6	13.235041000	6.652994000	4.278072000
6	12.948954000	5.619223000	5.185548000
6	12.049757000	4.608058000	4.873530000
6	11.405117000	4.603542000	3.629258000
6	14.209589000	7.751300000	4.635356000
6	6.242918000	-3.763580000	-2.352270000
6	5.457422000	-6.947089000	1.218477000
7	5.998692000	-6.023253000	2.242292000
6	6.476776000	-7.374220000	0.150991000
6	5.127552000	-5.910496000	3.413719000
6	5.306942000	-4.580899000	4.184710000
8	5.287710000	-3.470227000	3.316963000
6	4.177508000	-4.421645000	5.192351000
8	4.542292000	-3.407731000	6.120395000
6	7.411418000	-6.173760000	2.607003000
6	2.391172000	-3.640192000	7.272466000
6	1.569417000	-3.199417000	8.316519000
6	1.967874000	-2.192643000	9.196673000
6	3.238841000	-1.625631000	8.998809000
6	4.069610000	-2.047026000	7.970117000
6	3.652037000	-3.062477000	7.094769000
6	1.075816000	-1.725578000	10.323809000
6	8.326659000	-5.121155000	1.962391000
8	7.964967000	-3.852844000	2.491091000
6	9.794176000	-5.441006000	2.251912000
6	12.694718000	-5.479455000	2.223151000
6	14.084706000	-5.349465000	2.310887000
6	14.730712000	-4.136711000	2.051864000
6	13.933269000	-3.031432000	1.715490000
6	12.548926000	-3.137470000	1.637360000
6	11.923782000	-4.368917000	1.868811000
6	16.233155000	-4.000096000	2.152612000
8	10.563690000	-4.392586000	1.680734000
8	4.642525000	-5.231553000	-0.271826000
6	4.235989000	-6.337645000	0.502978000
6	4.674103000	-2.512340000	0.169693000

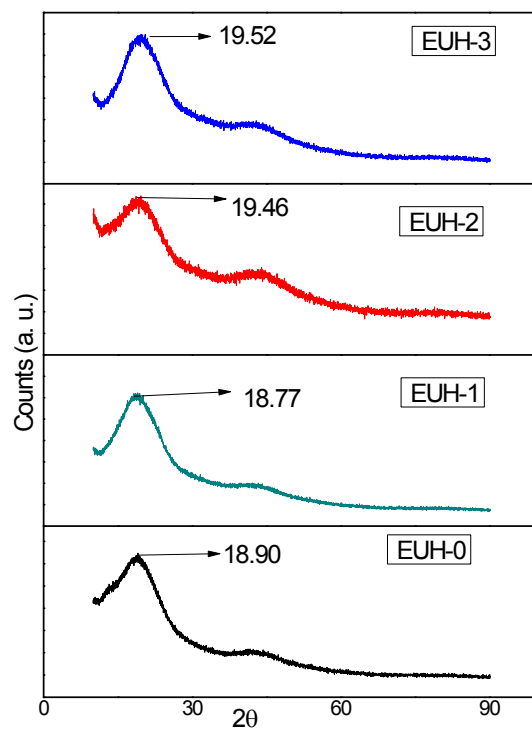
1	3.060084000	-1.192933000	-1.745929000
1	2.265335000	-2.665360000	-2.335206000
1	2.725516000	-4.459717000	-0.159377000
1	3.241074000	-4.961863000	-1.786219000
1	5.244270000	-1.852654000	-2.450589000
1	4.385099000	-3.160589000	-3.250288000
1	1.444537000	-1.170371000	1.311144000
1	2.556826000	-0.341881000	0.200015000
1	0.680403000	0.126631000	-1.357222000
1	-1.669025000	-0.397541000	-0.743776000
1	-0.719557000	-1.902767000	-0.806554000
1	-1.133300000	-1.178887000	0.757685000
1	4.566133000	-0.485095000	1.937776000
1	6.156856000	-1.237739000	1.780545000
1	5.635713000	1.247105000	0.158560000
1	6.141660000	2.697325000	2.192696000
1	4.642744000	1.785308000	2.333021000
1	6.089591000	1.237576000	3.201284000
1	7.212724000	-1.024502000	-0.272995000
1	8.058765000	0.243252000	-1.143058000
1	7.670827000	2.785876000	0.636980000
1	9.073281000	1.876351000	0.099078000
1	10.127906000	-0.201464000	0.143985000
1	9.193607000	-0.739900000	2.091070000
1	10.583521000	-2.559410000	-0.443449000
1	8.859116000	-2.828099000	-0.772607000
1	10.374604000	-4.201746000	-1.985947000
1	10.983962000	-5.537070000	-3.952759000
1	10.645603000	-2.065442000	-6.453131000
1	10.025217000	-0.709186000	-4.469661000
1	11.477653000	-5.768282000	-6.284087000
1	10.409713000	-4.782693000	-7.291457000
1	12.100099000	-4.321674000	-7.090373000
1	8.301812000	2.292839000	3.025000000
1	10.447242000	1.343536000	3.233506000
1	10.589551000	3.428537000	1.338612000
1	9.213726000	4.356872000	2.004819000
1	11.186920000	5.640005000	1.740015000
1	12.781671000	7.412323000	2.318441000
1	13.441778000	5.606529000	6.155353000
1	11.831527000	3.811509000	5.578539000
1	14.394169000	8.412683000	3.782829000
1	13.833906000	8.371675000	5.459390000
1	15.176162000	7.343691000	4.956093000
1	6.856873000	-3.525194000	-3.228045000
1	6.016873000	-4.832949000	-2.370875000
1	6.850938000	-3.576924000	-1.461389000

1	5.087032000	-7.873524000	1.703911000
1	5.971319000	-8.013166000	-0.581183000
1	7.306153000	-7.955028000	0.562535000
1	6.875843000	-6.508812000	-0.382717000
1	4.089629000	-5.952580000	3.071896000
1	5.264001000	-6.758781000	4.115117000
1	6.250937000	-4.605602000	4.751349000
1	6.123650000	-3.530490000	2.808153000
1	3.258842000	-4.139931000	4.658762000
1	3.999057000	-5.369506000	5.722407000
1	7.796126000	-7.177812000	2.381249000
1	7.510035000	-6.054791000	3.691804000
1	2.038227000	-4.425835000	6.614067000
1	0.591581000	-3.660243000	8.440689000
1	3.582732000	-0.837486000	9.665943000
1	5.050579000	-1.606691000	7.819419000
1	0.117035000	-2.254440000	10.317888000
1	1.539814000	-1.894472000	11.304221000
1	0.861926000	-0.651353000	10.252920000
1	8.185641000	-5.130104000	0.871680000
1	8.518082000	-3.147051000	2.086459000
1	9.974953000	-5.492958000	3.335301000
1	10.056971000	-6.411561000	1.804943000
1	12.232558000	-6.442118000	2.415204000
1	14.675135000	-6.223305000	2.579758000
1	14.408474000	-2.078588000	1.497001000
1	11.925604000	-2.277304000	1.416193000
1	16.744223000	-4.913966000	1.828085000
1	16.590818000	-3.168832000	1.536181000
1	16.552130000	-3.802485000	3.185411000
1	3.460946000	-6.027645000	1.219061000
1	3.786754000	-7.122141000	-0.131865000
1	3.974259000	-2.642943000	1.006426000
1	5.565810000	-3.098415000	0.417604000
6	0.470881000	1.201626000	-5.121857000
8	0.195721000	0.987134000	-6.291397000
8	1.742642000	1.149034000	-4.610592000
6	2.797648000	0.933100000	-5.567610000
6	3.879871000	0.102834000	-4.889830000
6	3.264249000	2.299873000	-6.093876000
8	4.354974000	2.178920000	-6.997007000
8	4.441730000	0.745394000	-3.739475000
6	6.602416000	1.317633000	-4.765205000
6	7.719558000	2.155301000	-4.749838000
6	7.852892000	3.211348000	-3.836136000
6	6.801419000	3.397120000	-2.927292000
6	5.672509000	2.578572000	-2.932061000

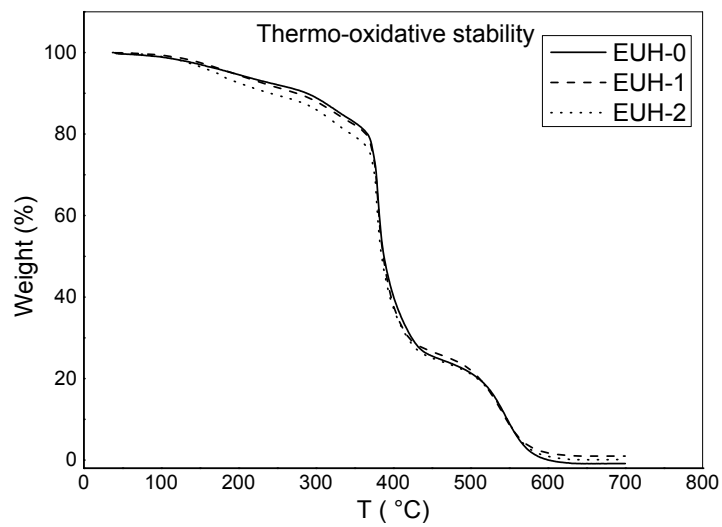
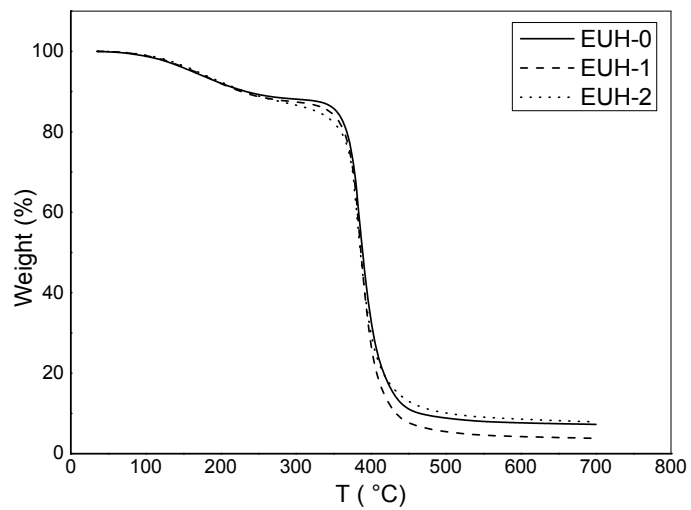
6	5.559378000	1.528925000	-3.849459000
6	9.096981000	4.119488000	-3.889039000
6	9.023475000	4.938468000	-5.202632000
6	9.128888000	5.126016000	-2.712786000
6	11.560668000	3.613635000	-4.494722000
6	12.735543000	2.881531000	-4.343348000
6	12.771408000	1.775649000	-3.487531000
6	11.616865000	1.413509000	-2.788424000
6	10.450746000	2.163058000	-2.953312000
6	10.386204000	3.274399000	-3.803623000
8	13.964118000	1.103183000	-3.409785000
6	14.072052000	-0.011436000	-2.518973000
6	15.512876000	-0.501590000	-2.632858000
8	16.420040000	0.581948000	-2.432953000
6	15.864136000	-1.536323000	-1.562418000
8	15.842381000	-0.956419000	-0.266143000
1	2.403667000	0.348354000	-6.405022000
1	3.442643000	-0.826409000	-4.516796000
1	4.642824000	-0.150382000	-5.630668000
1	2.433210000	2.748257000	-6.646602000
1	3.500582000	2.955573000	-5.245952000
1	5.174613000	2.236836000	-6.479528000
1	6.578617000	0.483166000	-5.458543000
1	8.521803000	1.956920000	-5.455848000
1	6.843922000	4.199645000	-2.198635000
1	4.861481000	2.739082000	-2.228525000
1	9.813783000	5.695557000	-5.251812000
1	9.108389000	4.297920000	-6.086348000
1	8.063099000	5.461471000	-5.257183000
1	10.045583000	5.722130000	-2.766460000
1	9.122161000	4.613954000	-1.744421000
1	8.278341000	5.817029000	-2.747352000
1	11.573326000	4.462480000	-5.170529000
1	13.633957000	3.150971000	-4.890857000
1	11.594000000	0.542593000	-2.144764000
1	9.561661000	1.848149000	-2.415652000
1	13.861824000	0.301524000	-1.489149000
1	13.368891000	-0.803575000	-2.807211000
1	15.659550000	-0.943889000	-3.631103000
1	16.035594000	1.344870000	-2.897169000
1	15.142208000	-2.359190000	-1.561285000
1	16.856959000	-1.951837000	-1.791970000
1	16.344491000	-0.126804000	-0.355073000



SI 10 Topography and phase images of EUH-1 and EUH-2 hybrids. The AFM images show the existence of single phase as there is no color variation in the mapped area.



SI 11 Wide angle X-ray diffractograms of EUH-0, EUH-1, EUH-2 and EUH-3 hybrids.



SI 12 TGA profiles of EUH networks under nitrogen (top) and oxidative environments (bottom).