Supporting Information

Self-assembled Cationic Organic Nanosheet: Role of Positional Isomers in Guanidium-Core for Efficient Lithium-Ion Conduction

Ananta Dey,^{a,b} Vishwakarma Ravikumar Ramlal,^{a,b} Selvasundarasekar Sam Sankar,^c Subrata Kundu, ^{*,c} Amal Kumar Mandal, ^{*,a,b} and Amitava Das^{*,b,d}

 [a] Analytical and Environmental Science Division and Centralized Instrument Facility, CSIR-Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat-364002, India. Email: <u>akmandal@csmcri.res.in</u>

> ^[b] Academy of Scientific and Innovative Research (AcSIR), CSIR- Human Resource Development Centre, (CSIR-HRDC) Campus, Sector 19, Kamla Nehru Nagar, Ghaziabad, Uttar Pradesh-201 002, India

^[c] Electrochemical Process Engineering (EPE) Division, CSIR-Central Electrochemical Research Institute (CECRI), Karaikudi, Tamil Nadu, 630003, India. Email: <u>skundu@cecri.res.in</u>

 ^[d] Department of Chemical Sciences
 Indian Institute of Science Education and Research Kolkata, Mohanpur, 741 246, West Bengal, India. Email: <u>a.das@csmcri.res.in</u>

No	Table of Contents	Page No
1.	Materials and Characterization	3
2.	Synthesis of AM-2 & AM-3	3
3.	¹ H NMR & ¹³ C NMR and HRMS spectra of AM-2	4
4.	¹ H NMR & ¹³ C NMR and HRMS spectra of AM-3	6
5.	Methods of sample preparation for FE-SEM, TEM, AFM	7
6.	Determination of the degree of aggregation (α_{agg})	7
7.	Temperature dependent UV-Vis data for AM-2	8
8.	Crystal structure of AM-3 with interplanar distance	9
<mark>9.</mark>	PXRD pattern of bulk-powder of AM-2 and AM-3	9
<mark>10.</mark>	TGA profile of the nanoflower morphology of AM-2 and AM-3	9
11.	Sample preparation for Li-ion conductivity	10
12.	SEM and TEM images in presence of LiClO ₄	10
13.	Details of conductivity measurement	11
14.	Admittance plots	11
15.	Conductivity data	12
16.	Comparable table of Conductivity data	14
<mark>17.</mark>	Calculation of Li-ion transference number (t_{Li+})	<mark>1</mark> 4
<mark>18.</mark>	Electrochemical stability of SONs of AM-2 and AM-3	15
19.	AFM instrumental details	16
20.	Reference	16

1. Materials and Characterization:

Materials: The chemicals like 4-formylbenzoic acid, 3-formylbenzoic acid, Guanidium hydrochloride, Hydrazine hydrate used for synthesis were purchased from commercial suppliers and used directly without further purification. Solvents such as isopropanol, ethanol, DMF were purchased from Spectrochem Chemical company. A Barnstead System, U.S., was employed to get high purity nanopure water for making all the aqueous solutions.

Characterization: ¹H NMR and ¹³C NMR were recorded using Geol resonance ECZ600R spectrometer at 25 °C. TMS was used as an internal reference during NMR spectroscopic study. Parkin Elmer 883 spectrometer was used to record the FT-IR data using the KBr pellet. UV-Vis absorption spectra were recorded using Shimadzu corp 80109 UV- Vis spectrophotometer. Using a Zetasizer Nano-ZS90 (Malvern) instrument with a 632.8 nm He-Ne laser DLS, experiments were carried out at 298 K. Transmission electron microscopy images were collected using a JEOL JEM-2100 electron microscope working at 200 kV accelerating voltage. The samples were prepared on the surface of lacey-carbon-supported copper TEM grids. The AFM data were collected with the help of tapping mode with an NT-MDT Ntegra Aura atomic force microscope. JEOL JSM-7100F instrument working at 18 kV accelerating voltage was used to record the FE-SEM data. Before taking the FE-SEM images, the thin coating of Au (~ 4 nm) was coated using a vacuum evaporator. Using a Q-of-micro quadrupole mass spectrophotometer (Micromass), ESI-MS was done. Powder X-ray diffraction (PXRD) patterns were recorded at room temperature on a Philips X'pert X-ray powder diffractometer using Cu-Ka radiation (λ =1.5418 A) in the 20 range of 5–50°. X-ray photoelectron spectra (XPS) were obtained from a Thermo Fischer Scientific ESCALAB XI⁺ using an Al Kα (hv = 1486.6 eV) X-ray source with a base vacuum-operated at 300 W. Thermo-gravimetric analysis (TGA) was conducted using an Auto TGA 2950 apparatus under a nitrogen flow of 100 mL min⁻¹ while heating from room temperature. The conductivity study has been done using the electrochemical work station (VSP Biologic, France).

2. Synthesis of AM-2 and AM-3:



Figure S1: Synthesis route of AM-2 and AM-3.

Synthesis of L: Triaminoguanidinium chloride was prepared by the literature method.^[1]

Synthesis of AM-2: In a (1:1 v/v) ethanol/water solvent mixture (40 mL) triaminoguanidinium chloride (0.25 gm, 1.75 mmol) and 3-formylbenzoic acid (0.75 gm, 5.30 mmol) were dissolve. The reaction mixture was stirred for 12h at 80 °C. Then the reaction mixture was cooled down to ambient temperature. After some time, a large amount of white precipitate was obtained. The white precipitate was filtered using a G4 gooch crucible under a vacuum. The desired product was washed several times with ethanol and dried under reduced pressure. Yield 0.75 gm (82%). ¹H NMR (200 MHz, DMSO- *d*₆, δ ppm): 8.61 (3H, s), 8.37 (3H, s), 8.21 (3H, d, *J* = 8.0), 8.02 (3H, d, *J* = 8.0), 7.62 (3H, t, *J* = 8.0). ¹³C NMR (125 MHz DMSO-*d*₆, δ ppm): 168.0, 152.0, 147.4, 136.0, 132.3, 132.2, 131.2, 129.9, 128.9.4. HRMS: *m/z* calculated for [M] (C₂₅H₂₁N₆O₆): 501.4785; found [M + H⁺]: 501.1610.

Synthesis of AM-3: In a (1:1 v/v) ethanol/water solvent mixture (40 mL), triaminoguanidinium chloride (0.50 gm, 3.50 mmol) and 4-formylbenzoic acid (1.50 gm, 10.60 mmol) were dissolve. The reaction mixture was stirred for four h at 90 °C. Then the reaction mixture cooled down to ambient temperature. After some time, a large amount of yellowish-white precipitate was obtained. The precipitate was filtered using a G4 gooch crucible under a vacuum. The desired product was washed several times with ethanol and dried under reduced pressure. Yield 1.5 gm (82%). ¹H NMR (600 MHz, DMSO- d_6): δ ppm 8.75 (3H, s), 8.10-8.06 (12H, m). ¹³C NMR (125 MHz, DMSO- d_6): 166.9, 150.6, 147.6, 138.0, 131.7, 129.5, 127.5. HRMS: m/z calculated for [M]⁺ (C₂₅H₂₁N₆O₆)⁺: 501.4785; found: 501.1594.



3. ¹H NMR, ¹³C NMR and HRMS spectra of AM-2:

Figure S2: ¹H NMR spectrum of AM-2 recorded in DMSO-*d*₆.



Figure S3: ¹³C NMR (125 MHz) spectrum of AM-2 recorded in DMSO-d₆.



Figure S4: HRMS spectrum of AM-2 recorded in Methanol.

4. ¹H NMR, ¹³C NMR and HRMS spectra of AM-3:



Figure S5: ¹H NMR spectrum of AM-3 recorded in DMSO-d₆.



Figure S6: ¹³C NMR spectrum of AM-3 recorded in DMSO- d_6 .



Figure S7: HRMS spectrum of AM-3 recorded in Methanol.

5. Methods of sample preparation for FE-SEM, TEM, AFM:

Sample preparation for Nanosheets morphology: To get the exfoliated nano sheet, water was used as a solvent. 1 mg/mL (total volume 5ml) water suspension of the compound AM-2 and AM-3 was initially sonicated for 10 minutes. From that solution, 20 μ L was drop cast on Si (100) wafer, and we observe the nanoplate-like morphology. Then, 0.6 mL of this suspension was exposed to 2.4 mL of water. The dispersion was sonicated for 30 minutes. From that aliquot, 20 μ L was drop cast on a TEM grid and Si (100) wafer, and we observe the nanosheet morphology. After drop-casting, all the samples were dried under a desiccator. Before taking the FE-SEM images, the ultrathin gold layer was coated on all the samples.

Sample preparation for Nanoflower morphology: First 2 mg of AM-2 and Am-3 dissolve in 2 ml of DMF. 1 ml of this DMF solution exposed to 1 ml of water to maintain a solvent ratio of 1:1 DMF/water (v/v). The mixture was shaken well for 2-3 minutes and left undisturbed for 10 minutes. After 10 minutes, 0.6 ml of this solution was exposed to 2.4 ml of (1:1, v/v) DMF/water solvent mixture. From that solution, 20 μ L was drop cast on Si (100) wafer. After drop-casting, all the samples were dried under a desiccator. Before taking the FE-SEM images, the ultrathin gold layer was coated on all the samples.

6. Determination of the degree of aggregation (α_{agg}):

The degree of aggregation (α_{agg}) was calculated from the temperature-dependent UV-Vis spectral data by using equation (1) as mentioned below.

$$\alpha(T) = \frac{\varepsilon(T) - \varepsilon_M}{\varepsilon_A - \varepsilon_M}....(1)$$

Where $\mathcal{E}(T)$ is the measured extinction coefficient at temperature *T*; \mathcal{E}_M and \mathcal{E}_A are the extinction coefficients of the monomer and fully aggregated state, respectively. The latter two values were determined from the spectral data at high and low temperatures, respectively.

The experimentally determined degree of aggregation was fitted temperature-dependent isodesmic self-assembly model accordingly with equation (2) as mentioned below, to obtain the enthalpy value ΔH .

$$\alpha(T) = \frac{1}{1 + \exp[-0.908\Delta H \frac{T - T_m}{RT_m^2}]}....(2)$$

Where α is the degree of aggregation, and T_m is the melting temperature defined as the temperature at $\alpha = 0.5$ at $T = T_m$. R is the Boltzmann constant.

From the experimentally determined degree of aggregation, the number-averaged degree of polymerization, DP_N , calculated temperature-dependent isodesmic self-assembly model accordingly with equation (3), as mentioned below.

From the number-averaged degree of polymerization, DP_N , and the known concentration of molecules, c_T , the equilibrium constant K_e was determined as a function of temperature using equation (4), as mentioned below.

$$DP_N(T) = \frac{1}{2} + \frac{1}{2}\sqrt{4K_e(T)C_T + 1} \qquad(4)$$

7. Temperature-dependent UV-Vis data for AM-2:



Figure S8: (a) Variable temperature UV-Vis spectra of AM-2 (3.7×10^{-5} M) in DMF/water. (b) Corresponding plot of change of absorbance at 360 nm with temperature. (c) Temperature-dependent degree of aggregation, calculated from UV-Vis spectral change at 316 nm and corresponding isodesmic fit. (d) Corresponding plot of the degree of polymerization, DP_N, as a function of temperature. (e) Corresponding plot of the equilibrium constant, *K_e*, as a function of temperature. (f) Corresponding Van't Hoff plot for AM-2 in DMF/water.

8. Crystal structure of AM-3 with interplanar distance:



Figure S9: (a) Single-crystal XRD structure of AM-3 with interplanar distance. (b) Crystal structure of AM-3 showing the extended length of the molecule.

9. PXRD pattern of bulk-powder of AM-2 and AM-3:



Figure S10: PXRD pattern of bulk-powder of (a) AM-2 and (b) AM-3.

10. TGA profile of the nanoflower morphology of AM-2 and AM-3



Figure S11: Thermogravimetric analysis (TGA) curves of nanoflower morphology of (a) AM-2, and (b) AM-3, respectively.

11. Sample preparation for Li-ion conductivity

(A) Methods of sample preparation for SONs morphology:

To get the exfoliated nano sheet, water was used as a solvent. 1 mg/mL (total volume 5ml) of the compound AM-2 and AM-3 dispersed in water containing 0.2, 0.5, 0.7 1.0 and 2.0 equivalents of LiClO₄. The dispersion was sonicated for 30 minutes. An aliquot of this homogeneous dispersed solution of the nanostructures drop-casted on the surface of a Whatman filter membrane separator and remove the residue solvent. The prepared samples were dried at room temperature for 60 minutes and sandwiched in between the SS electrode. Then we proceed with measuring the conductivity.

(b) Methods of sample preparation for bulk-powder:

1 mg/mL (total volume 5ml) of the compound AM-2 and AM-3 dispersed in water containing 0.2, 0.5, 0.7 1.0 and 2.0 equivalents of LiClO₄. An aliquot of this homogeneous dispersed solution of the nanostructures drop-casted on the surface of a Whatman filter membrane separator and remove the residue solvent. The prepared samples were dried at room temperature for 60 minutes and sandwiched in between the SS electrode. Then we proceed with measuring the conductivity.

(c) Methods of sample preparation for nanoflower morphology:

First, 2 mg of AM-2 and Am-3 dissolve in 2 ml of DMF. 1 ml of this DMF solution exposed to 1 ml of water containing (0.2, 0.5, 0.7 1.0, and 2.0 equivalents of LiClO₄) to maintain a solvent ratio of 1:1 DMF/water (v/v). The mixture was shaken well for 2-3 minutes and left undisturbed for 10 minutes. No sonication was done here for mixing. An aliquot of this dispersed solution of the nanostructures drop-casted on the surface of a Whatman filter membrane separator and remove the residue solvent. The prepared samples were dried at room temperature for the duration of 60 minutes and sandwiched in between the SS electrode. Then we proceed with measuring the conductivity.



12. SEM and TEM images in the presence of LiClO₄:

Figure S12: (a), (b) FE-SEM and (c), (d) TEM images of SONs of AM-2 in the presence of 2.0 equivalents of LiClO₄. (e), (f) FE-SEM and (g), (h) TEM images of SONs of AM-3 in the presence of 2.0 equivalents of LiClO₄.

13. Details of conductivity measurement:

The ionic conductivity measurements were carried out using stainless steel (SS) electrodes, unlike the comb-shaped Au electrodes, as used by Wu *et al.* to prepare their samples for ionic conductivity measurements.^[2] The use of SS electrodes is a more reliable and fast method; moreover, the drying duration is just 20-30 min which is significantly less comparing to the Au electrodes, which needs a drying time of ~ 48 hours. We have used the Whatman filter membrane separator, which had more permeability, and the thickness was 0.026 cm, which is calculated using the screw cage method. The radius of the SS electrode surface was 7 mm, and the calculated area was 1.5386 cm². Once the sample solution is ready, we drop-casted four drops over the separator, which became wet, and kept it for drying at room temperature for 50 to 60 min. After drying, the impedance study was carried out in order to know the resistance values for different samples, and subsequently, we calculate the related conductivity values using the standard equation:

Where d = Thickness (cm), R = Resistance (ohm) and A = Area (cm²).



14. Admittance plots:

Figure S13. Admittance plots of AM-2 dopped with varying equivalents of $LiClO_4$ for (a) SONs, (b) bulk-powde and (c) nanoflower. Admittance plots of AM-3 dopped with varying equivalents of $LiClO_4$ for (d) SONs, (e) bulk-powde and (f) nanoflower.

15. Conductivity data:

Table S1: Resistance and lithium ionic conductivity values of AM-2 in SONs morphology with varying LiC	$\overline{10_4}$
concentration at room temperature.	

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	135.7	1.245*10-4
0.5	1.5386	0.026	126.4	1.336*10-4
0.7	1.5386	0.026	93.1	1.815*10 ⁻⁴
1.0	1.5386	0.026	85.8	1.969*10 ⁻⁴
2.0	1.5386	0.026	49.42	3.419*10-4

Table S2: Resistance and lithium ionic conductivity values of AM-3 in SONs morphology varying $LiClO_4$ concentration at room temperature.

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	152.6	1.107*10-4
0.5	1.5386	0.026	112.7	1.499*10-4
0.7	1.5386	0.026	107.6	1.570*10-4
1.0	1.5386	0.026	94.2	1.793*10-4
2.0	1.5386	0.026	78.12	2.163*10-4

Table S3: Resistance and lithium ionic conductivity values of AM-2 in bulk-powder morphology with varying LiClO₄ concentration at room temperature.

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	170.15	9.931*10 -5
0.5	1.5386	0.026	159.31	1.060*10-4
0.7	1.5386	0.026	153.72	1.099*10 ⁻⁴
1.0	1.5386	0.026	113.5	1.488*10 ⁻⁴
2.0	1.5386	0.026	86.3	1.958*10 ⁻⁴

Table S4: Resistance and lithium ionic conductivity values of AM-3 in bulk-powder morphology with varying LiClO₄ concentration at room temperature.

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	178.52	9.465*10 ⁻⁵
0.5	1.5386	0.026	172.9	9.773*10 ⁻⁵
0.7	1.5386	0.026	165.6	1.020*10-4
1.0	1.5386	0.026	140.32	1.204*10-4
2.0	1.5386	0.026	111.8	1.511*10 ⁻⁴

Table S5: Resistance and lithium ionic conductivity values of AM-2 in nanoflower morphology with varying LiClO₄ concentration at room temperature.

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	417.63	4.046*10 ⁻⁵
0.5	1.5386	0.026	388.91	4.345*10 ⁻⁵
0.7	1.5386	0.026	367.27	4.601*10 ⁻⁵
1.0	1.5386	0.026	342.38	4.942*10 ⁻⁵
2.0	1.5386	0.026	299.83	5.631*10 ⁻⁵

Table S6: Resistance and lithium ionic conductivity values of AM-3 in nanoflower morphology with varying LiClO₄ concentration at room temperature.

Equivalents of LiClO ₄	Area A (cm²)	Thickness d (cm)	Resistance R (ohm)	Conductivity (S cm ⁻¹)
0.2	1.5386	0.026	409.43	4.127*10 ⁻⁵
0.5	1.5386	0.026	380.45	4.441*10 ⁻⁵
0.7	1.5386	0.026	360.63	4.686*10 ⁻⁵
1.0	1.5386	0.026	330.71	5.109*10 ⁻⁵
2.0	1.5386	0.026	317.92	5.315*10 ⁻⁵

16. Comparable table of Conductivity Data:

Materials	Materials Conductivity Description		Ref.
CON	(5/cm)		
SONS	3.42×10^{-4}	Self-assembled cationic organic	(Inis work)
(This work)	at 298 K	nanosheets	
Zwitterionic	$5.1 imes 10^{-5}$	Self-assembled zwitterionic organic	ACS App. Mater. &
Nano sheets	at 298 K	nanosheets	Inter., 2020, 12 ,
			58122-58131.
Supramolecular	$1.2 \times 10^{-4} \mathrm{~S~cm^{-1}}$	Supramolecular polymer electrolytes.	Nat. Commun. 2019,
polymer	at 298 K.		10, 5384.
Self-assembled	$2.4 imes10^{-7}$	Self-assembled nanosheets from	Angew. Chem. 2011,
Nano sheets	at 298 K	positively charged polycyclic	123, 2843 - 2846
		aromatic hydrocarbons	
MOF	MOF 5.5×10^{-5} Mg ₂ (dobdc)·0.35LiOiPr·0.25LiBF ₄ :		J. Am. Chem. Soc.
at 300 K		$EC \cdot DEC$ ($EC = ethylene carbonate;$	2011 , 133, 14522.
DEC = diethy		DEC = diethyl carbonate). MOF +	
		liquid	
		organic molecule (on the film)	
MOF 1.8×10 ⁻⁵ LiOtBu-grafted UiO-66 (MOF		LiOtBu-grafted UiO-66 (MOF+	Chem. Eur. J. 2013,
at 293 K.		Post-surface	19, 5533.
		Modification)	
MOF	MOF 10 ⁻⁶ MOF (10wt%)+LiTFSI+PEO		J. Mater. Chem. A
	at 295K	(MOF-loaded polymer	2014 , 2, 9948.
		Electrolytes)	
COF	$2.7 imes 10^{-5} \ \mathrm{S \ cm^{-1}}$	Lithium sulfonated COF	J. Am. Chem. Soc.
at 298 K			2019 , 141, 5880–5885
COF	COF 3.05×10^{-5} Ionic COF with spiroborate Linka		Angew. Chem. Int. Ed.
	at 298 K		2016 , 55, 1737 –1741
COF	$7.2 imes10^{-3}$	Lithium Imidazolate COF	J. Am. Chem. Soc.
	at 298 K		2019 , 141, 7518–7525
COF	5.74 x 10 ⁻⁵	Guanidium based cationic COF	J. Am. Chem. Soc.
	at 300 K		2018 , 140, 896–899

Table S7: Comparable chart for Lithium-ion conductivity values of reported materials.

17. Calculation of Li-ion transference number (*t*_{Li+}):

For the calculation of Li-ion transference number, we have used Bruce-Vincent method ^[3,4], where a symmetric cell Li/AMLi/Li used and the DC current allowed following through the cell. The steady state current obtained through potentiostatic polarization study and the related spectral curve was given as figure S14a (Li/AM-2Li/Li) and figure S14b (Li/AM-3Li/Li). The impedance study of the cell for before and after potentiostatic polarization study carried out. The measured impedance curves are given as figure S15a and figure S15b corresponding to

Li/AM-2Li/Li and Li/AM-3Li/Li respectively. The required values needed for the calculation of transference number (t_{Li+}) were tabulated in Table S8. The Li-ion transference number calculated by the following equation as:

$$t_{Li^+} = \frac{I_{SS}(\Delta V - I_0 R_0)}{I_0(\Delta V - I_{SS} R_{SS})}$$

Where, I_{SS} is the steady state current, ΔV is the applied potential, I_0 is the initial current, R_0 and R_{SS} are the interfacial resistance before and after potentiosatatic polarization study, respectively.

S.No	Material	<i>I</i> _{SS} (μΑ)	ΔV (mV)	<i>I</i> ₀ (μΑ)	R ₀ (Ω)	<i>R</i> _{SS} (Ω)	<i>t</i> _{<i>Li</i>+}
1	SONs of AM-2	10	10	12	462.3	927.5	0.49
2	SONs of AM-3	9	10	25	221.2	1461.8	0.15



Figure S14: (a) The potentiostatic polarization curves of SONs of AM-2. (b) The potentiostatic polarization curves of SONs of AM-3.



Figure S15: (a) The interfacial resistance curves of SONs of AM-2 before and after potentiostatic polarization study respectively. (b) The interfacial resistance curves of SONs of AM-3 before and after potentiostatic polarization study respectively.

18. Electrochemical stability of SONs of AM-2 and AM-3:

To investigate the electrochemical stability, we have performed the linear sweep voltammetry (LSV) measurement for SONs of AM-2 and AM-3. Linear sweep voltammetry (LSV) was carried out with Ti/AMLi/Li asymmetric cell.

The sweep rate was fixed as 0.1 mV s^{-1} with a fixed voltage window (-0.5 V to 6 V vs. Li/Li⁺) at room temperature. The electrochemical stability window of ca. 6 V were observed for both SONs of AM-2 and AM-3 (Figure S16).



Figure S16: (a) The Linear sweep voltammetry curves of SONs of AM-2. (b) The Linear sweep voltammetry curves of SONs of AM-3.

19. Cantilever details for AFM measurements:

Table S9. The table represents the cantilever used for AFM measurements, consists of the following parameters.

Cantilever	Cantilever	Cantilever	Resonance	Force
Length	width	Thickness	frequency	constant,
L ± 10 µm	W ± 5 μm	$T \pm 0.5 \ \mu m$	kHz	Nm ⁻¹
125	30	1.5 - 2.5	87 - 230	1.45 - 15.1

20. Reference:

- [1] A. Maity, M. Gangopadhyay, A. Basu, S. Aute, S. S. Babu and A. Das, *J. Am. Chem. Soc.*, 2016, **138**, 11113–11116.
- [2] D. Wu, R. Liu, W. Pisula, X. Feng and K. Müllen, Angew. Chem. Int. Ed., 2011, 50, 2791–2794.
- [3] J. Evans, C. A. Vincent and P. G. Bruce, Polymer, 1987, 28, 2324.
- [4] M. Siekierski, M. Bukat, M. Ciosek, M. Piszcz and M. Szerszen, Polymers, 2021, 13, 895.