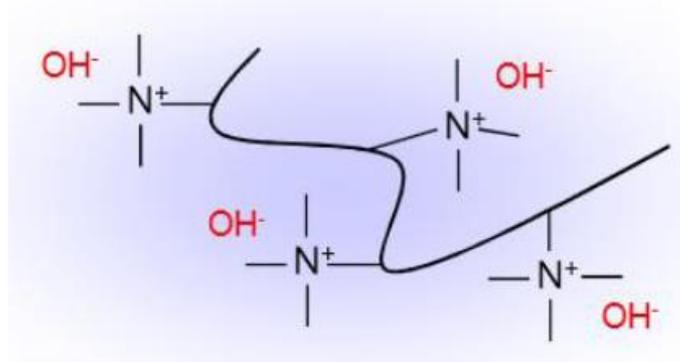


Проводящие добавки в электродных композициях

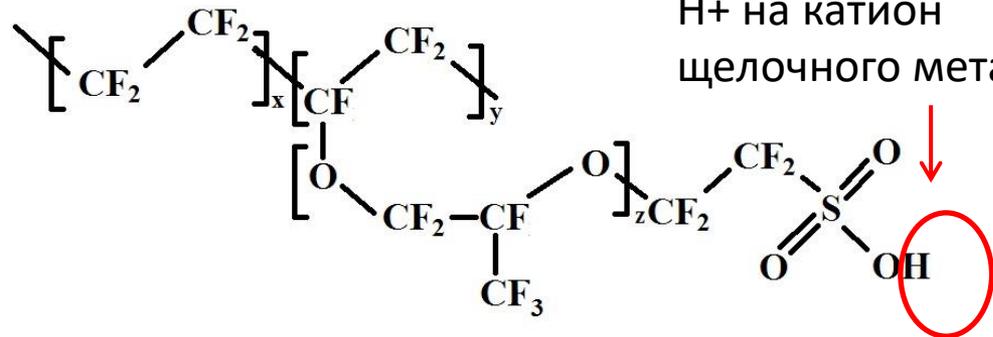
Материал	ρ , Ом м	σ , См м ⁻¹
Металлы		
Ag	$1.6 \cdot 10^{-8}$	$6.2 \cdot 10^7$
Pt	$1.1 \cdot 10^{-7}$	$9.3 \cdot 10^6$
Углеродные материалы		
C (графит, вдоль базисной грани)	$(3.9 \dots 4) \cdot 10^{-7}$	$(2.5 \dots 2.6) \cdot 10^6$
C (графитоподобные материалы)	$(2 \dots 20) \cdot 10^{-6}$	$(0.5 \dots 5) \cdot 10^5$
C (графит, по нормали к базисной грани)	$(1 \dots 15) \cdot 10^{-4}$	$(0.7 \dots 10) \cdot 10^3$
C (ацетиленовая сажа)	$(4.1 \dots 15) \cdot 10^{-4}$	$(0.7 \dots 2.4) \cdot 10^3$
C (алмаз)	$> 10^6 \dots 10^8$	$< 10^{-8} \dots 10^{-6}$
Оксиды		
IrO ₂	$(3 \dots 5) \cdot 10^{-7}$	$(2 \dots 3) \cdot 10^6$
β -MnO ₂	$\sim 10^{-3}$	$\sim 10^3$
LaMnO ₃	$1.6 \cdot 10^{-2}$	$6.2 \cdot 10^1$
LaCoO ₃	$4.2 \cdot 10^{-2}$	$2.4 \cdot 10^1$
Co ₃ O ₄	$1.7 \cdot 10^1$	$6.0 \cdot 10^{-2}$
NiO	$2.5 \cdot 10^2$	$4.0 \cdot 10^{-3}$

Углерод	Название	$S_{\text{ВЕТ}}, \text{М}^2/\text{Г}$	$S_{\text{ВЛН}}, \text{М}^2/\text{Г}$	$D_{\text{ВЛН}}, \text{А}$	Контактный угол, γ°	
					C	$\text{Mn}_2\text{O}_3/\text{C}$
Sibunit 176	S-176	6	4	160	60	38
Sibunit 152	S-152	65	52	275	50	31
Sibunit 152	S-152(2)	82	58	200	-	-
Sibunit 1519	S-1519	272	117	111	56	34
Acetylene black	AB	64	47	161	140	115
Vulcan XC-72	VU	221	50	219	85	0
Ketjenblack 300J	KB	858	262	115	58	46
Multiwall carbon nanotubes	CNT	98	67	142	150	135
CFC-1	CFC	175	66	131	0	0

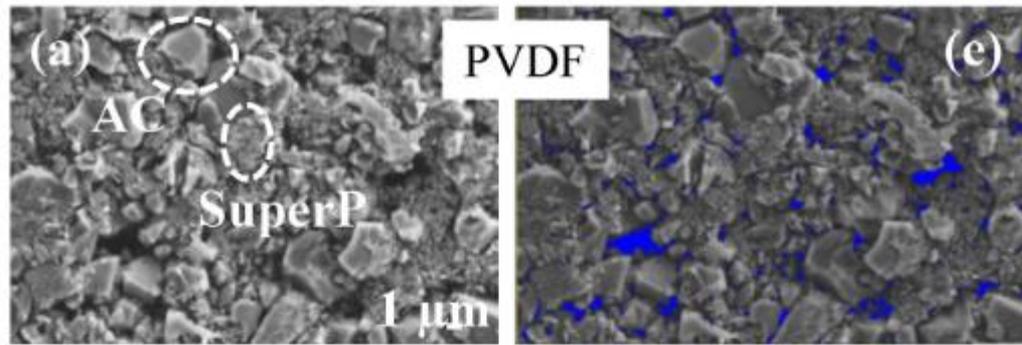
Иономер с проводимостью по OH^-



Nafion

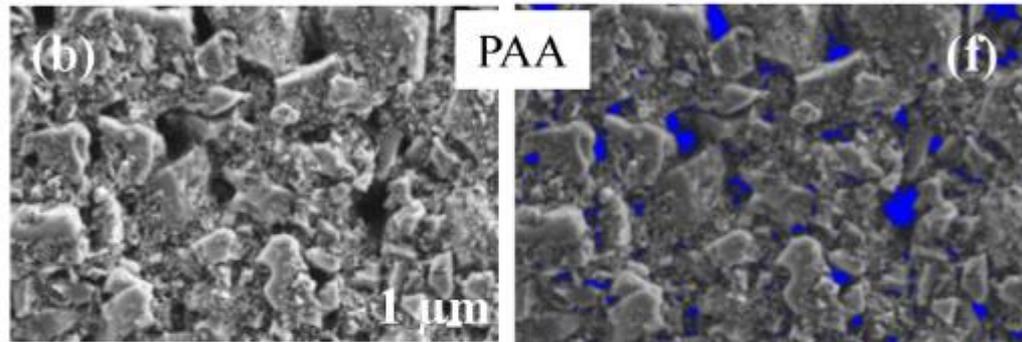


Можно замещать H^+ на катион щелочного металла

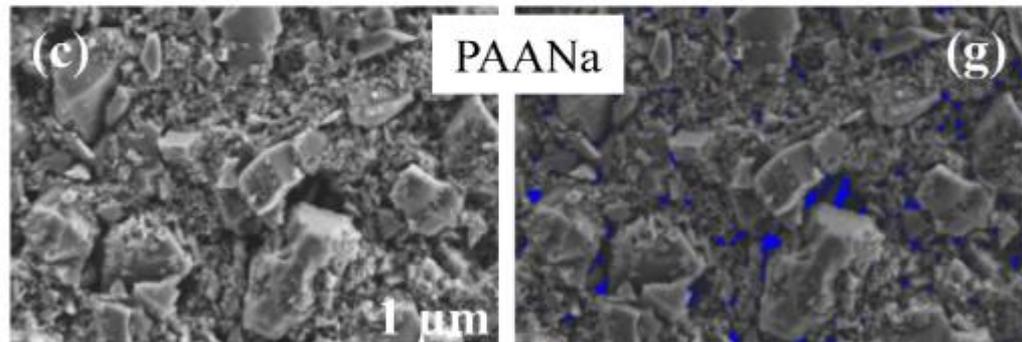


Непроводящие связующие

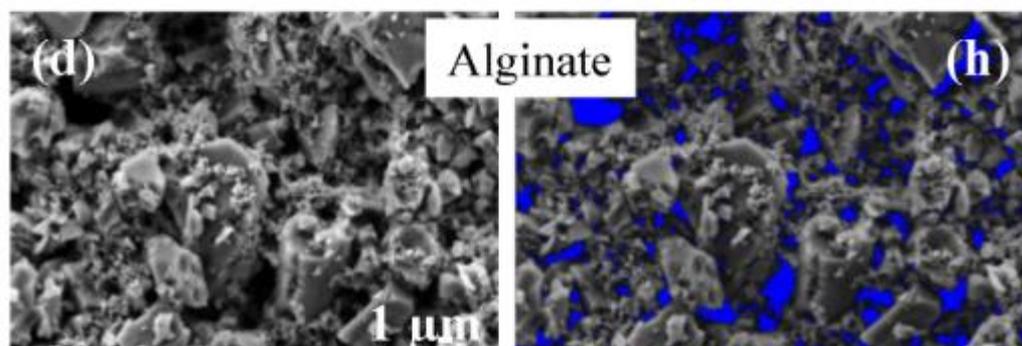
polyvinylidene difluoride



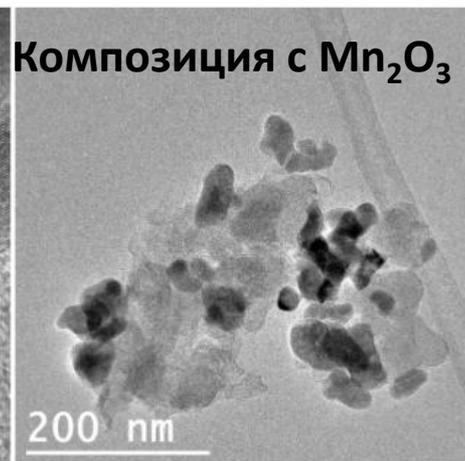
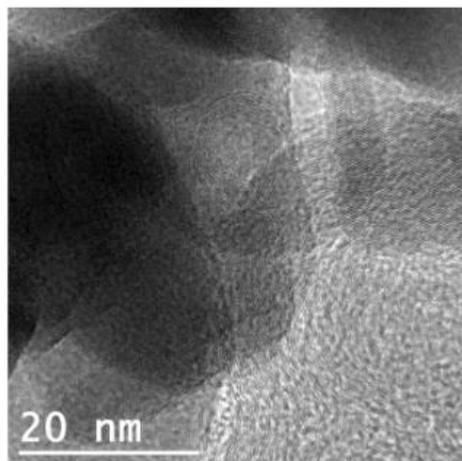
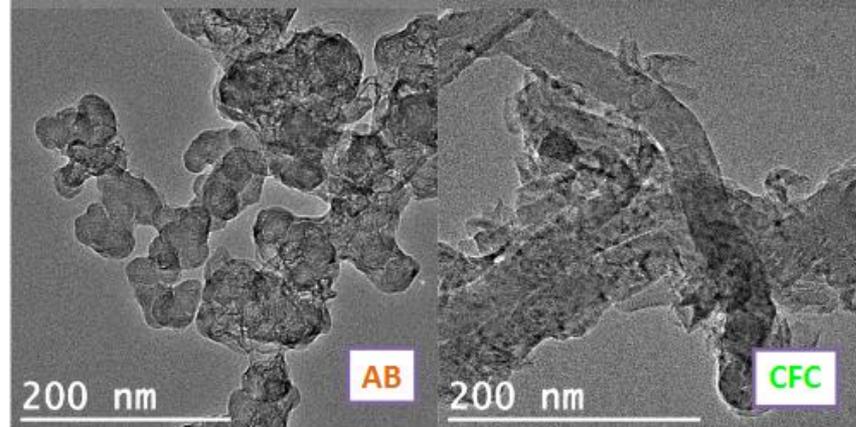
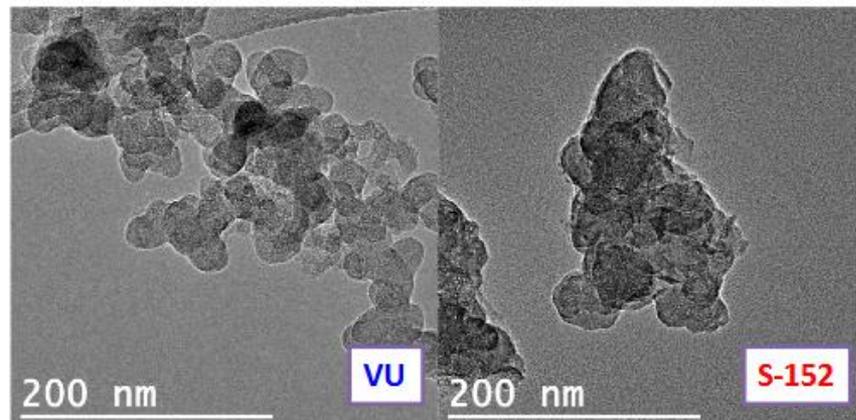
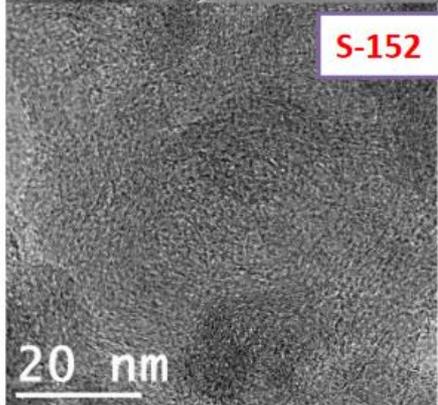
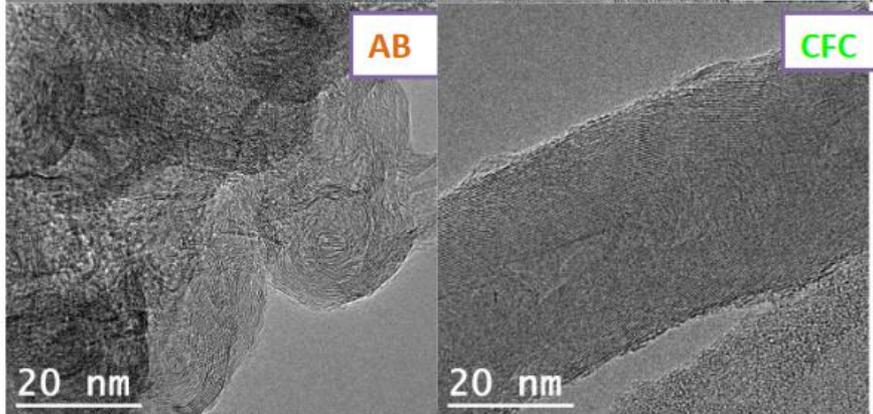
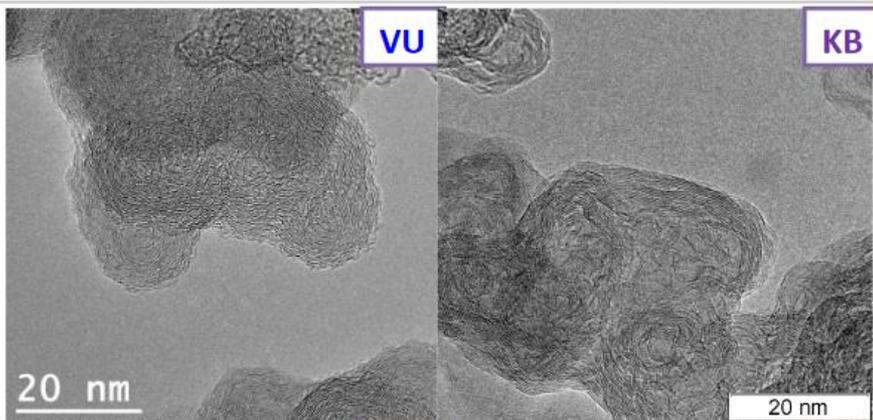
poly(acrylic acid)



sodium polyacrylate



sodium alginate

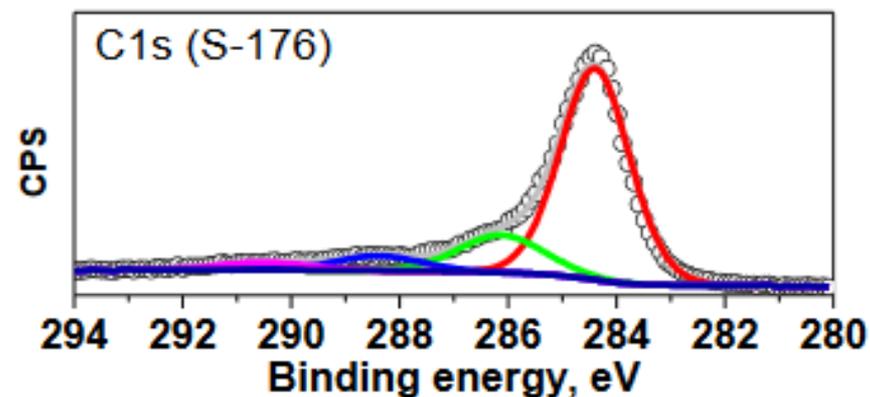
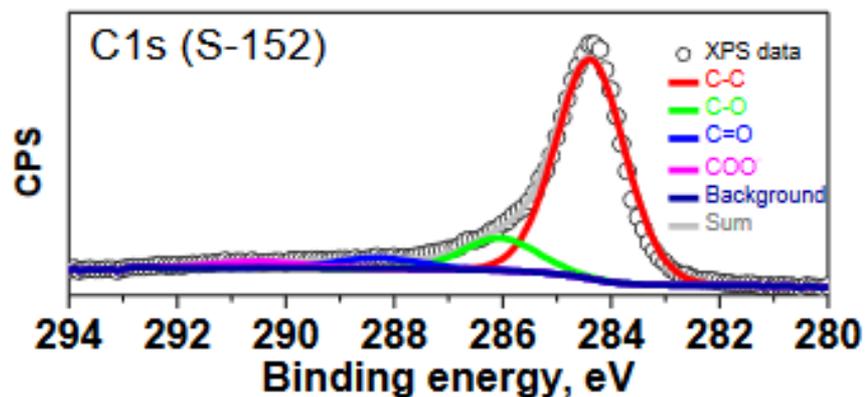


Композиция с Mn₂O₃

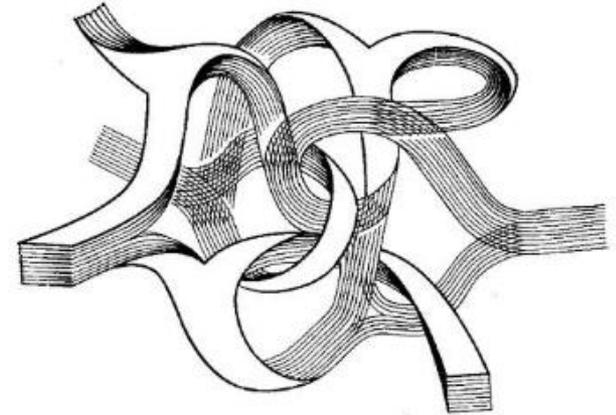
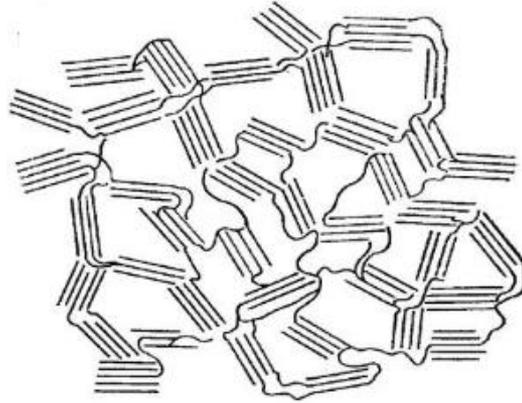
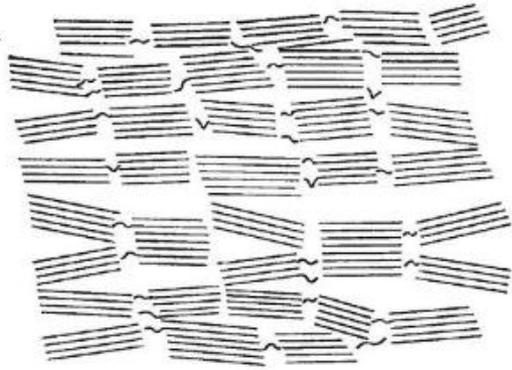


Поверхность большинства углеродов на воздухе сильно окислена:

Углерод	C-C	C-O	C=O	C-OO ⁻
	BE = 284.4 эВ	BE = 286.0 эВ	BE = 288.5 эВ	BE = 290.4 эВ
S-176	74.2	16.2	6.3	3.3
S-152	79.7	12.6	4.7	3.0
AB	74.7	16.7	5.1	3.5
CNT	77.8	14.9	2.8	4.5
VU	71.7	17.4	7.9	3.0
CFC	78.3	13.5	5.5	2.7
S-1519	71.7	19.7	5.9	2.7
KB	71.2	19.8	5.8	3.2



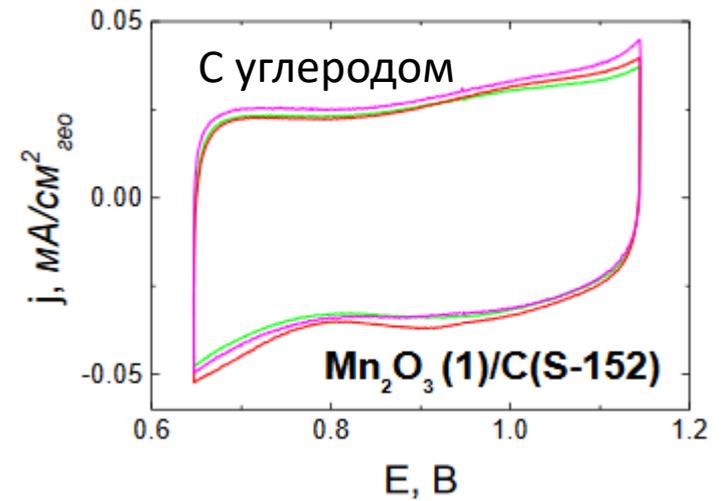
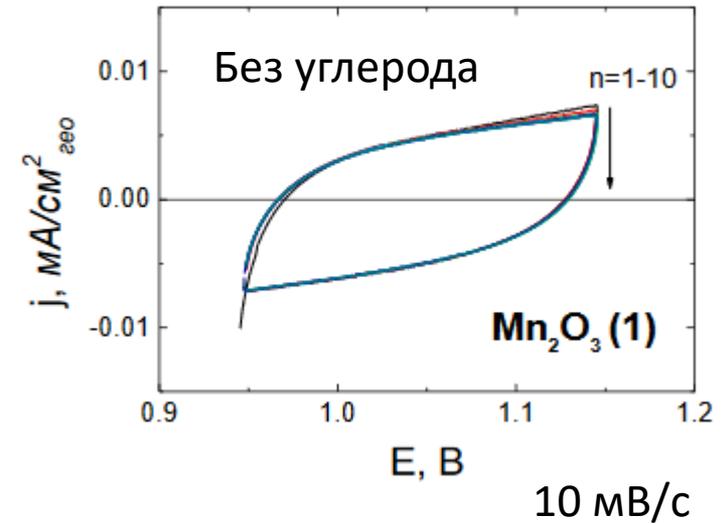
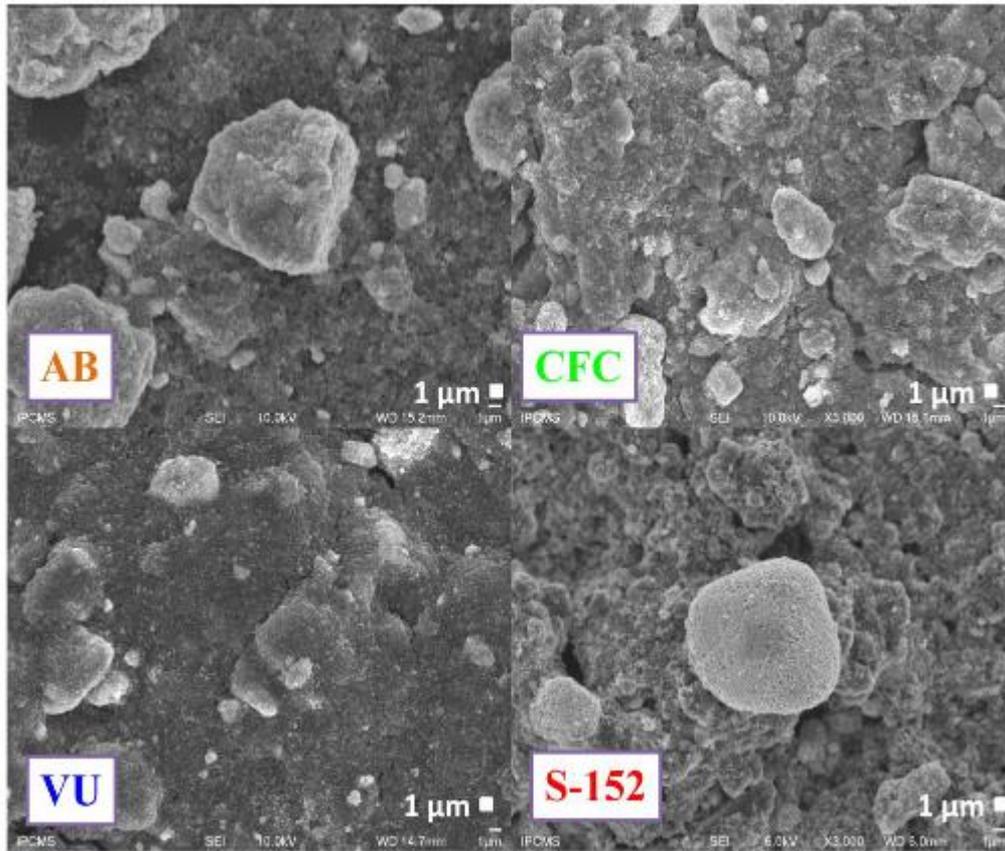
Микроструктура (схематически)



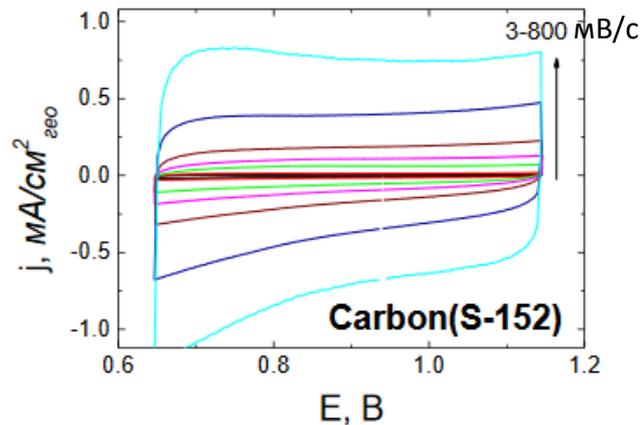
Окисленная поверхность



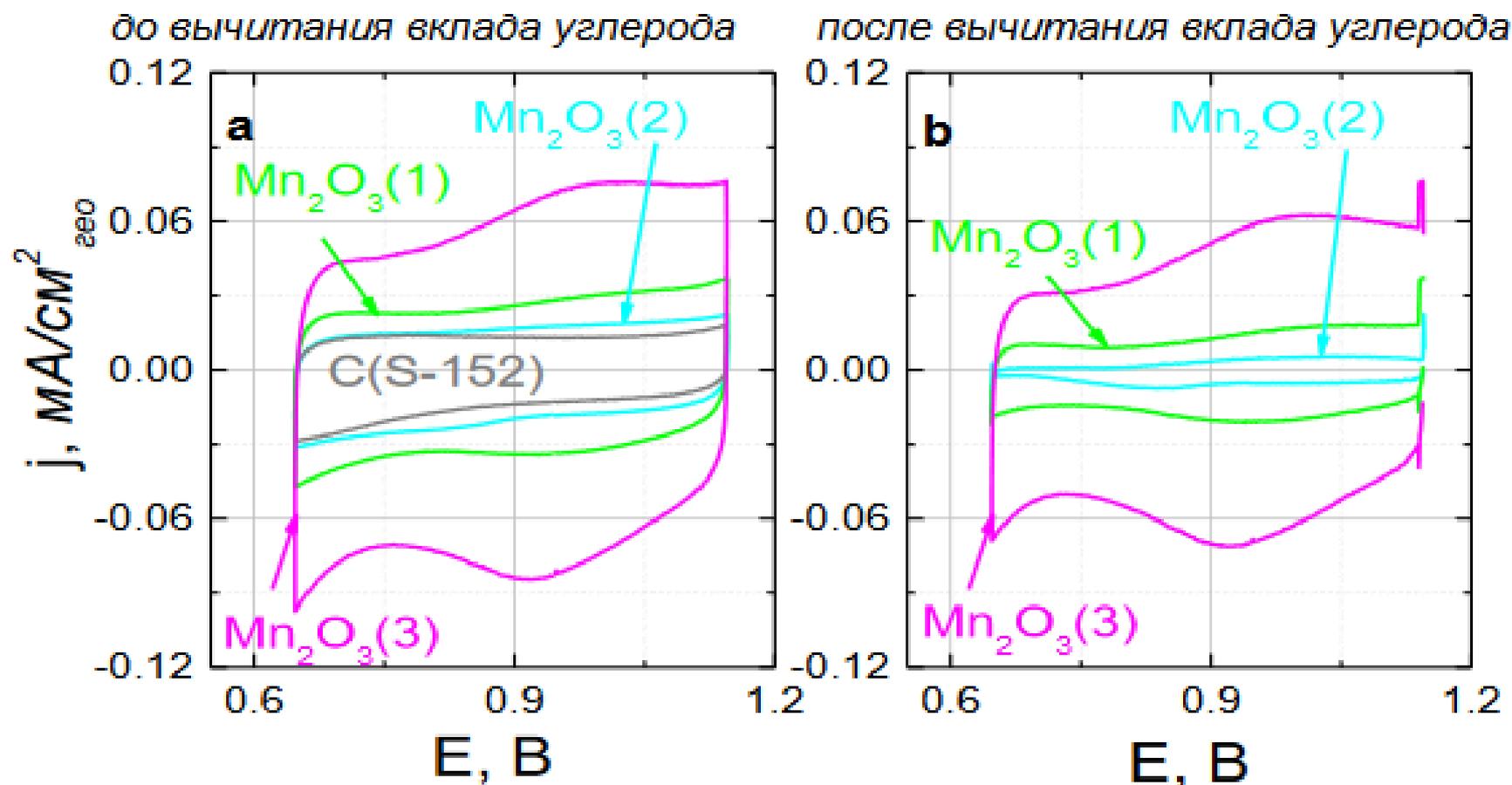
Нанесенные (около 0.1 мг/см²) композиции с Mn₂O₃

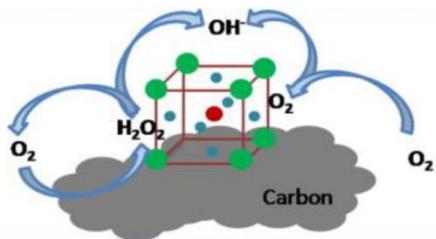


Нанесенный
с той же загрузкой
углерод

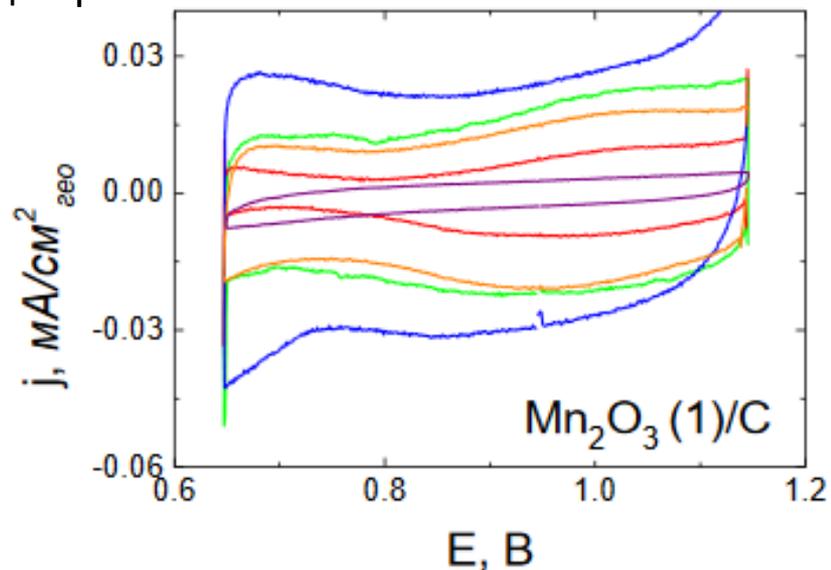
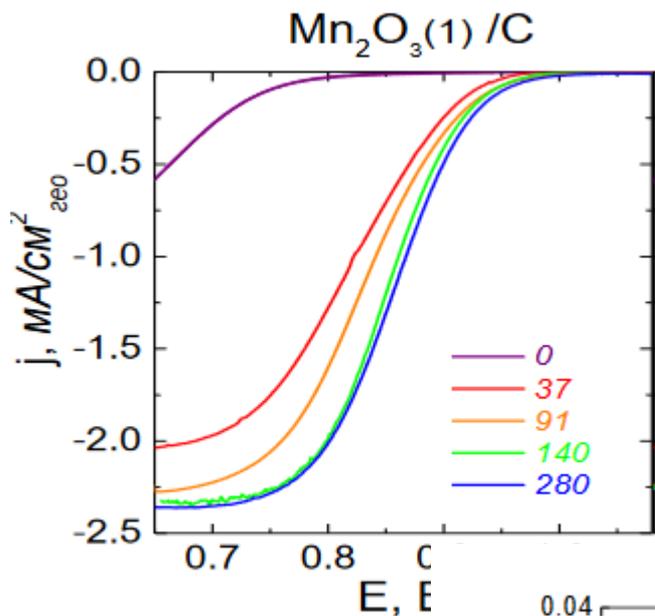


Название	Основная фаза (структурный тип)	площадь по БЭТ, м ² /г
Mn ₂ O ₃ (1)	α-Mn ₂ O ₃ (биксбиит)	8
Mn ₂ O ₃ (2)	α-Mn ₂ O ₃ (биксбиит)	3
Mn ₂ O ₃ (3)	α-Mn ₂ O ₃ (биксбиит)	27

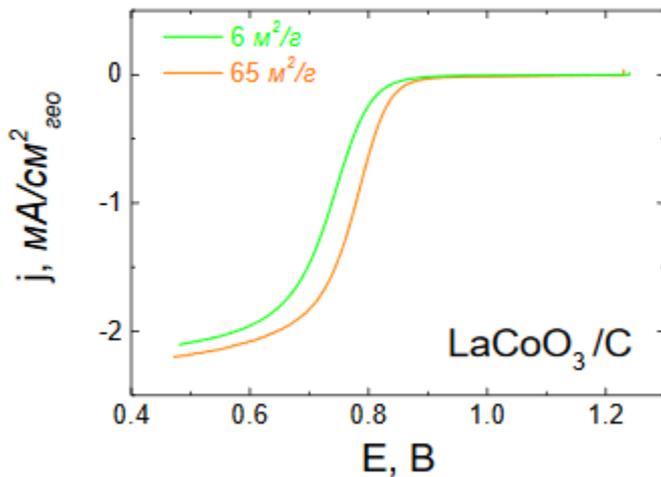
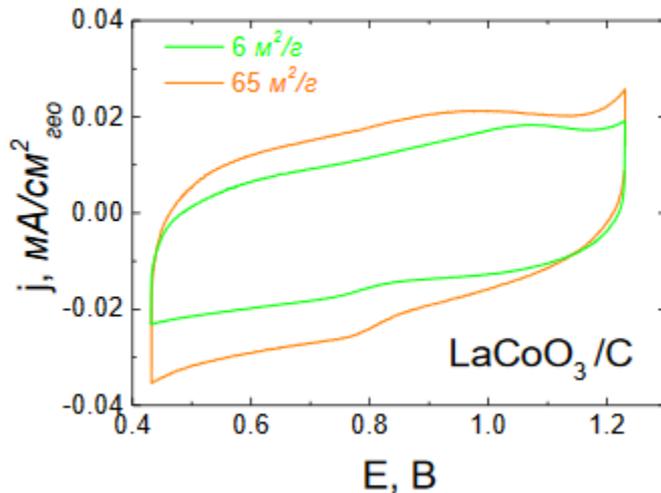




Одинаковая загрузка оксида при
разной загрузке углерода

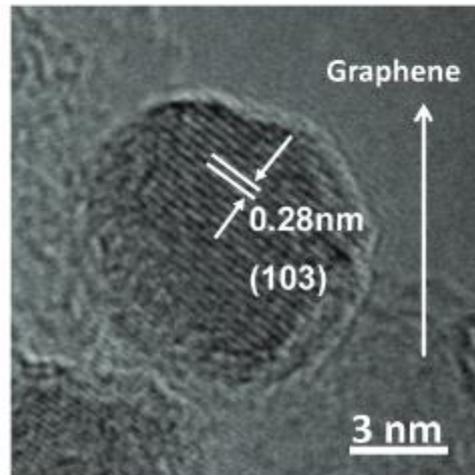
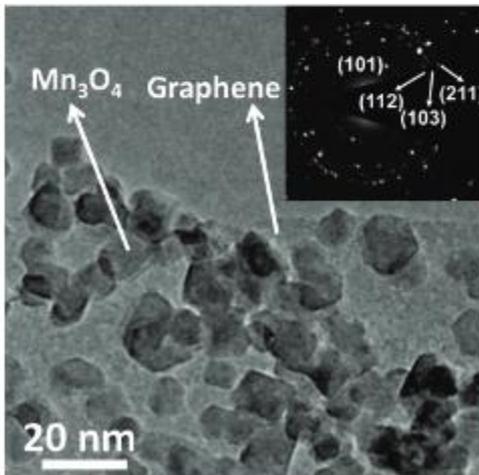
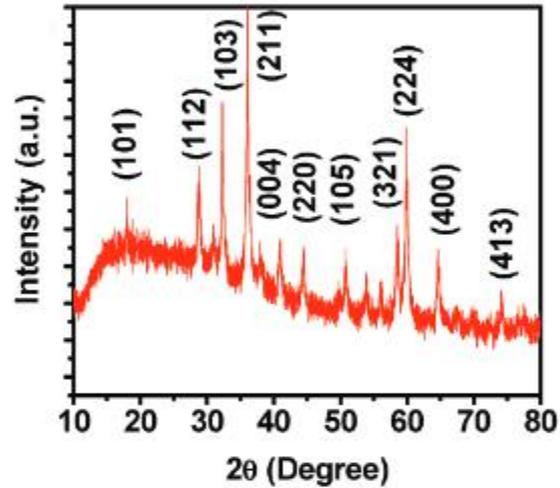
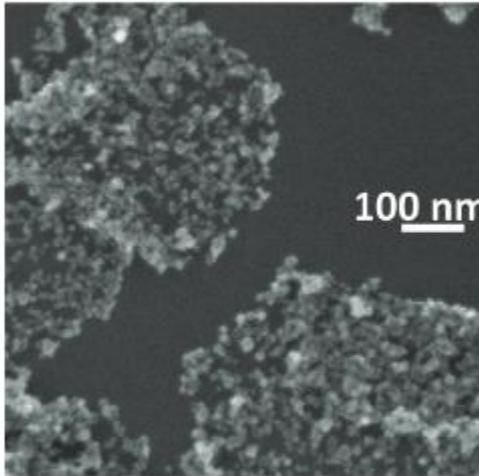
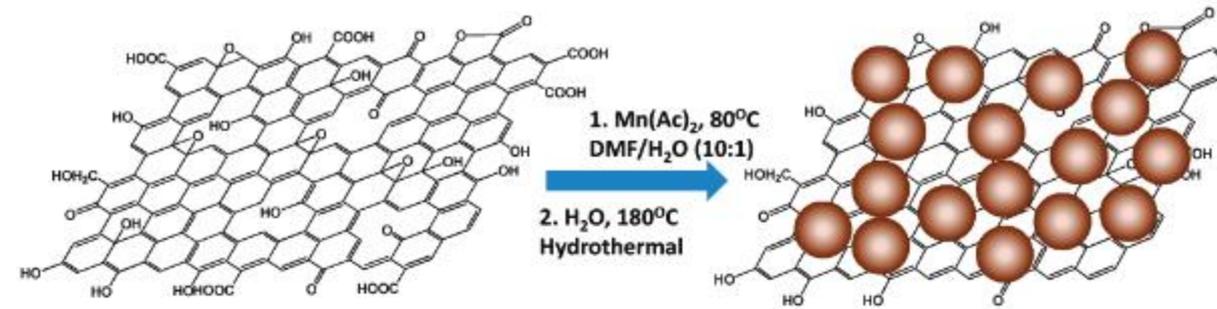


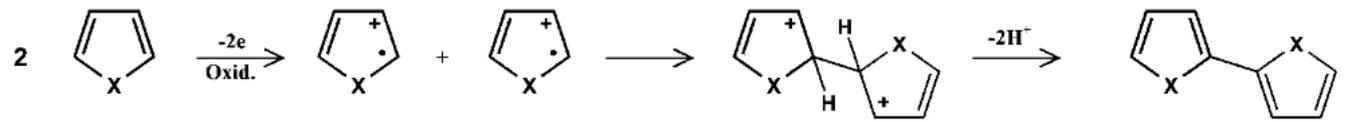
Одинаковая загрузка оксида при одинаковой
загрузке углеродов с разными удельными
поверхностями



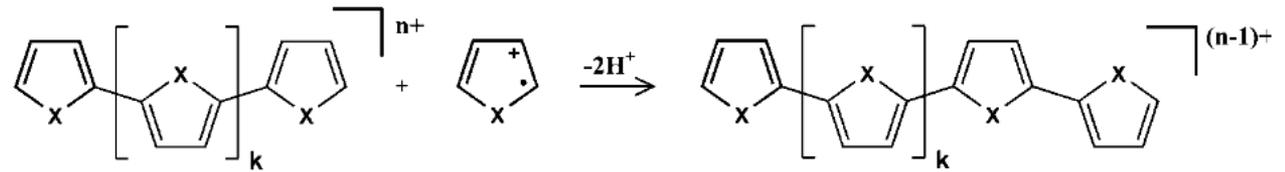
Синтез композиции вместо механического перемешивания

- синтез оксида «прямо» на углероде
- одновременно синтез и оксида, и углерода

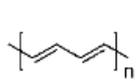




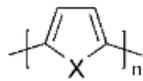
электрохимический синтез



X = NH, S

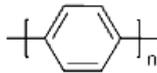


1

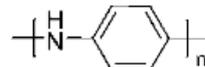


X = NH, S

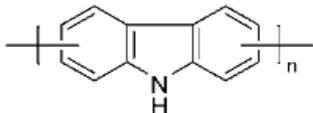
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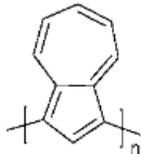
3



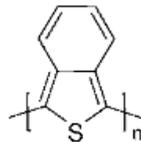
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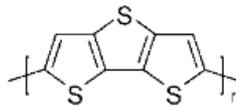
5



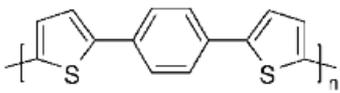
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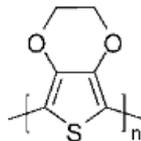
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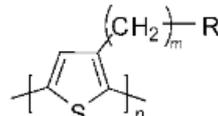
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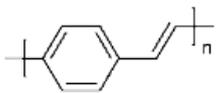
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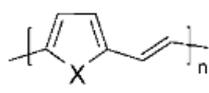
10



11

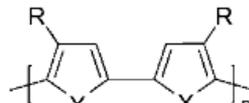


12



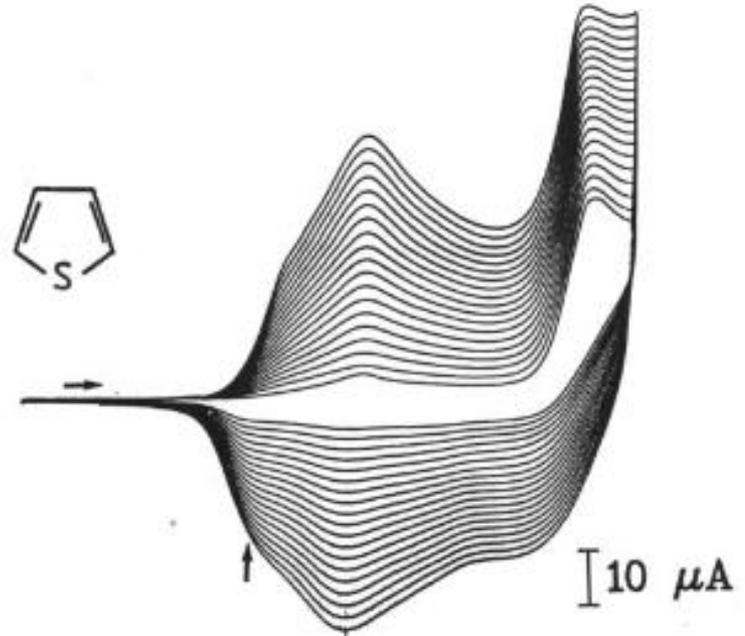
X = S

13

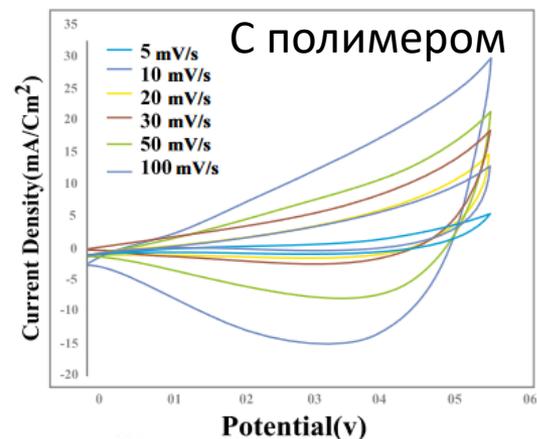
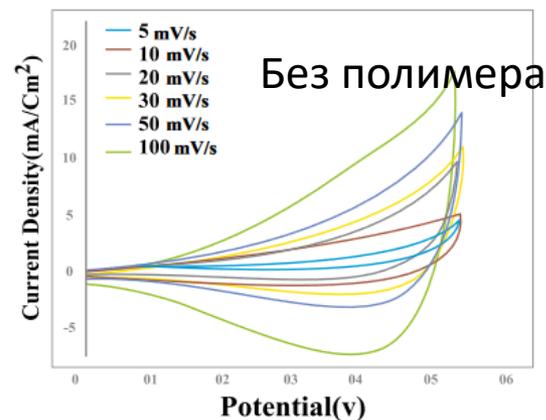
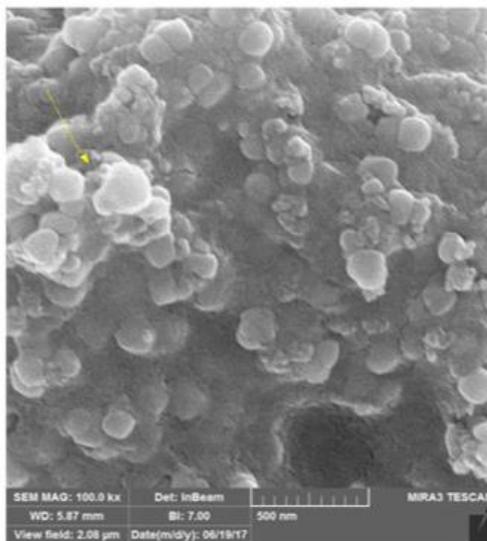
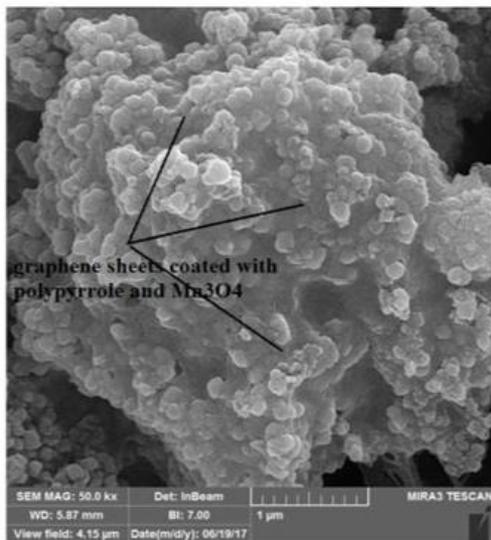


X = NH, S

14

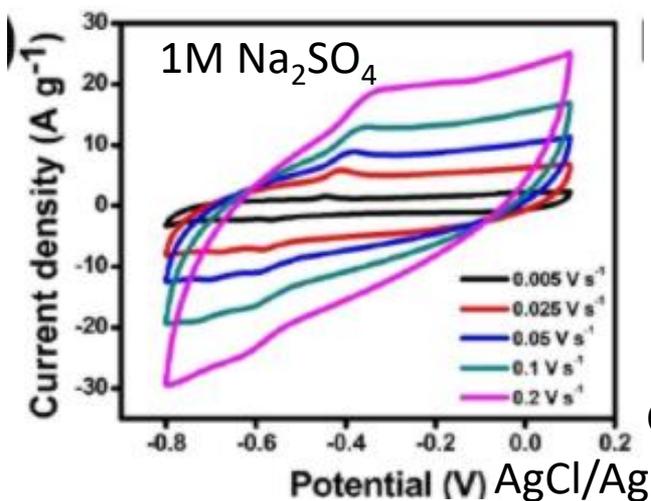
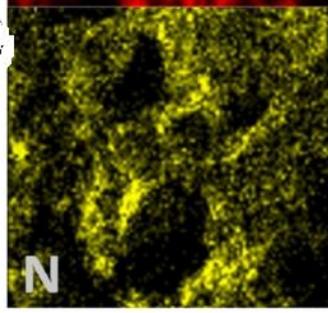
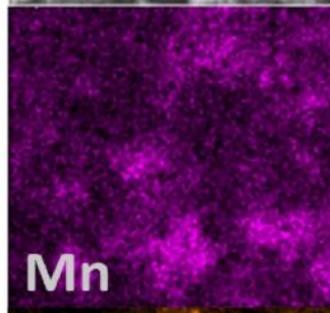
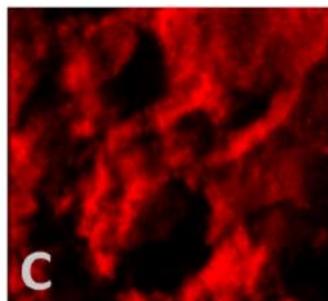
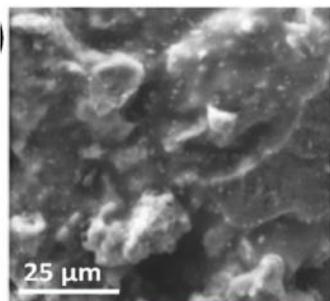


Проводящие полимеры как связующие



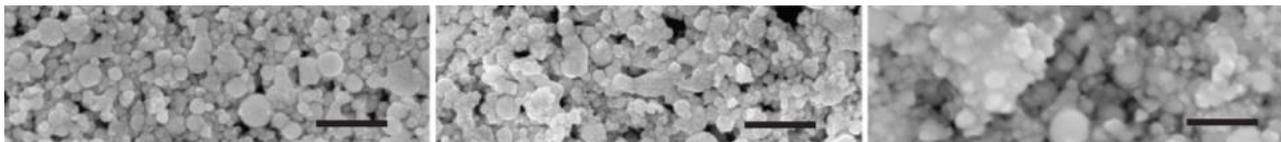
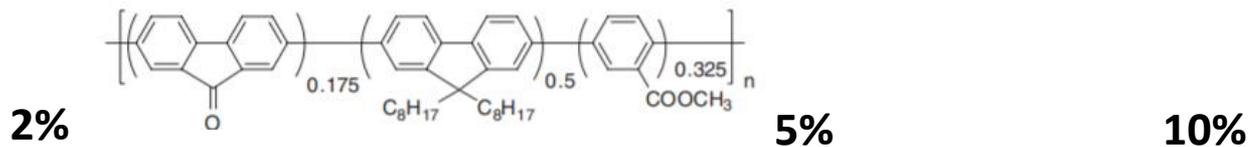
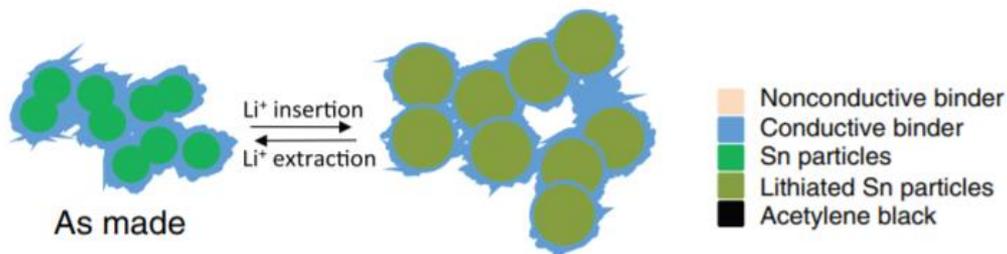
C/полипиррол/MnO_x

J. Solid State Electrochem. 22 (2018) 3317

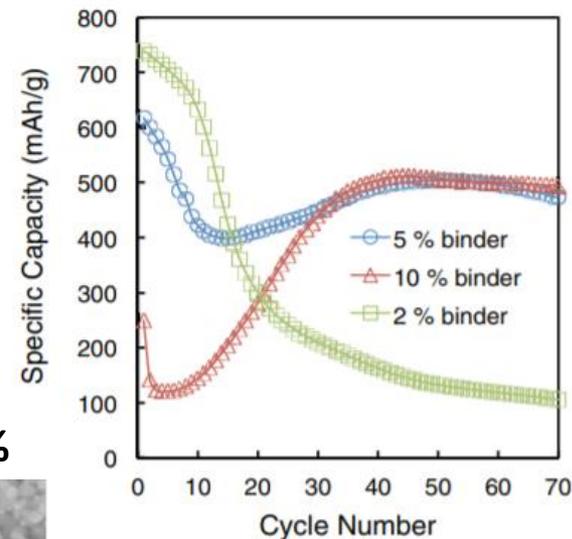


ChemistrySelect
5 (2020) 11769

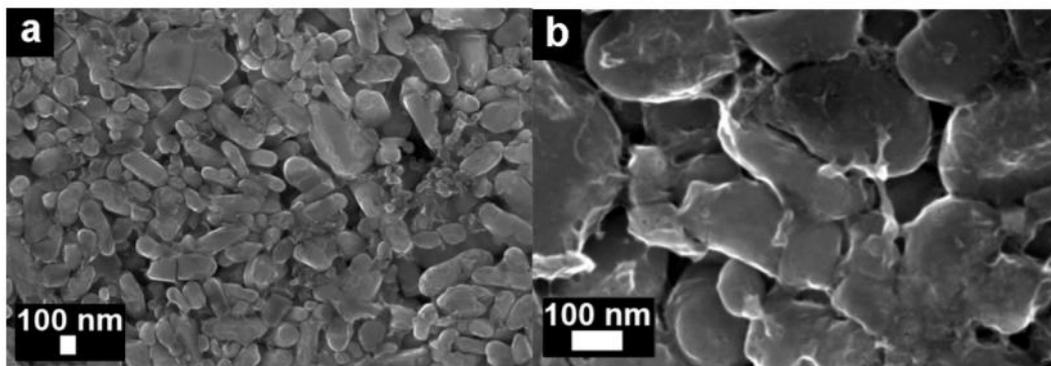
C/полипиррол/MnO₂



Если интеркаляция сопровождается изменением объема, то проводящий полимер лучше, чем обычный, «подстраивается» под эти изменения.



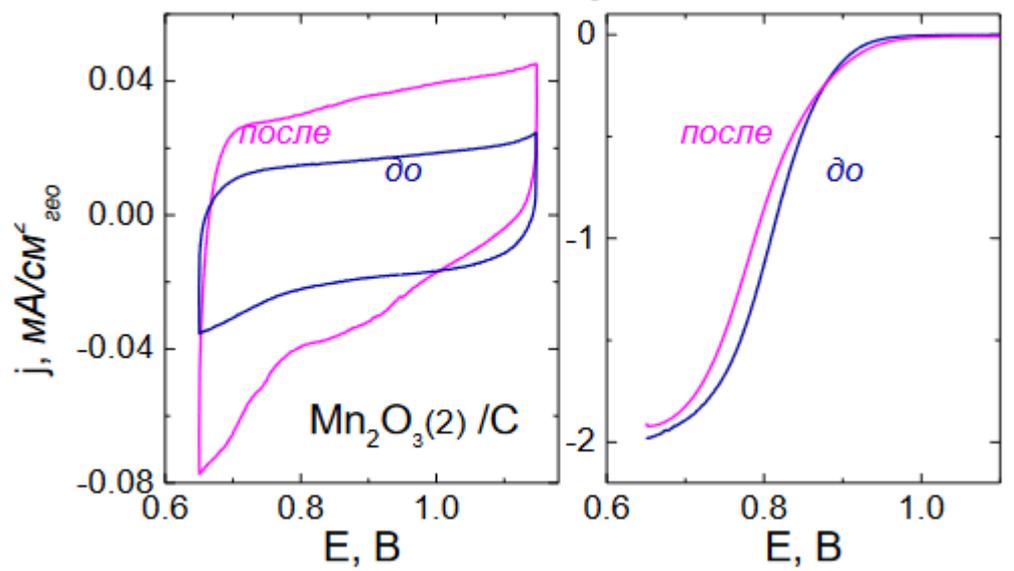
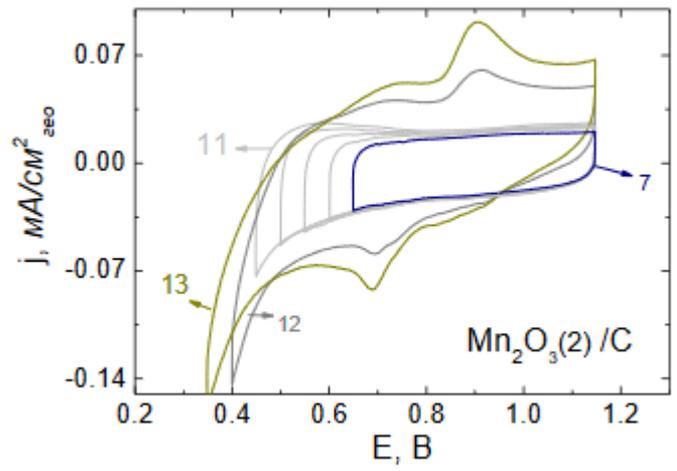
J. Electrochem. Soc.
160 (2013) A849-A855



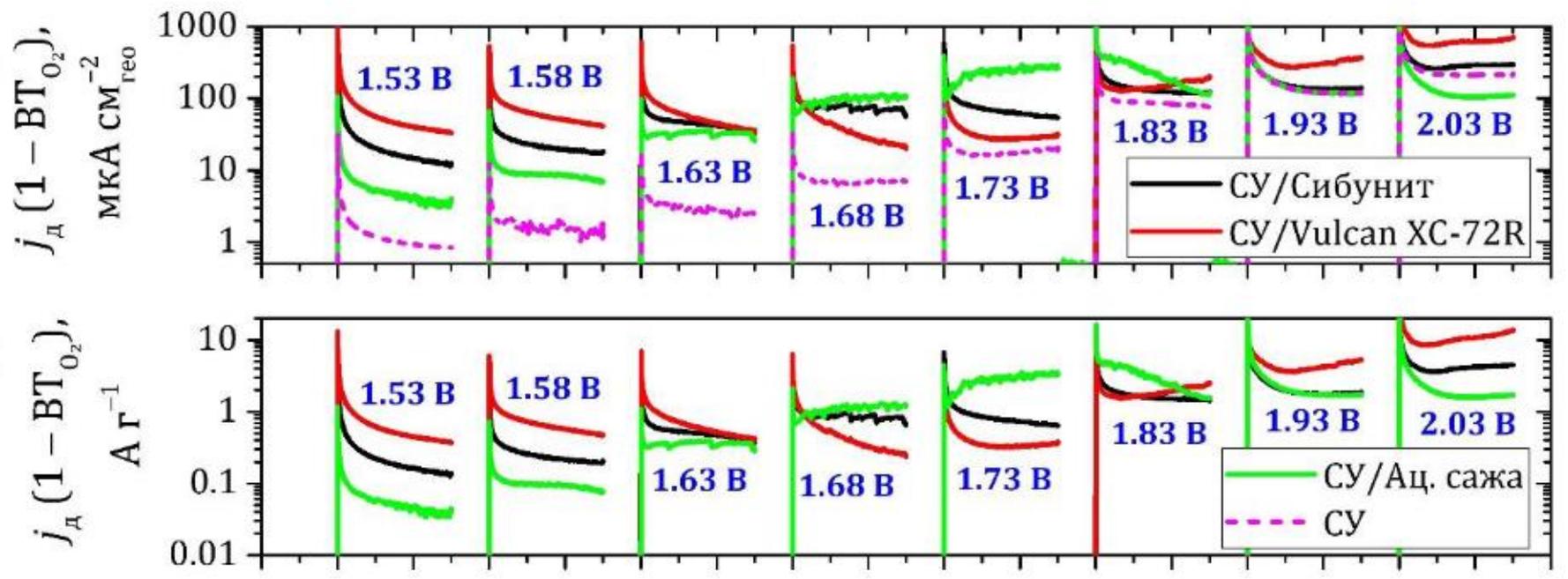
LiFePO₄ + проводящий полимер,
до и после циклирования

Energies 13 (2020) 2163.

Катодная деградация оксида

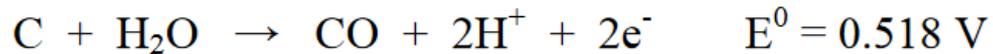
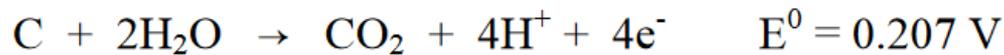


Анодное окисление углерода



Анодное окисление углерода

J. Electrochem. Soc. 157 (2010)B820



ДО

после

