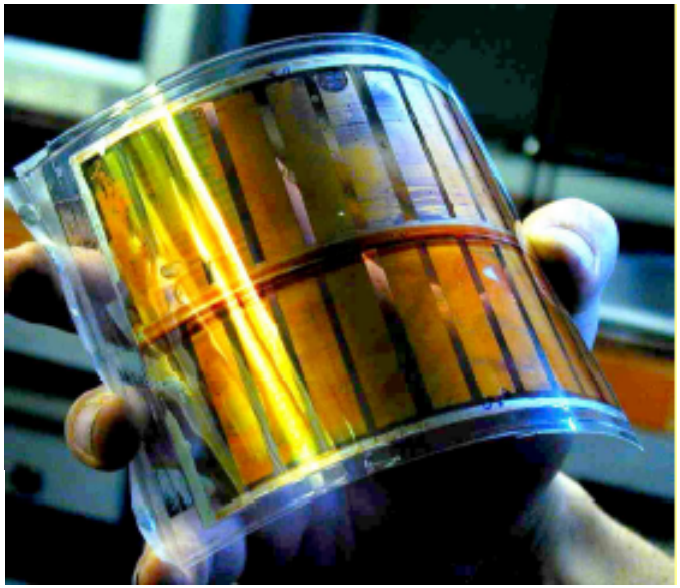
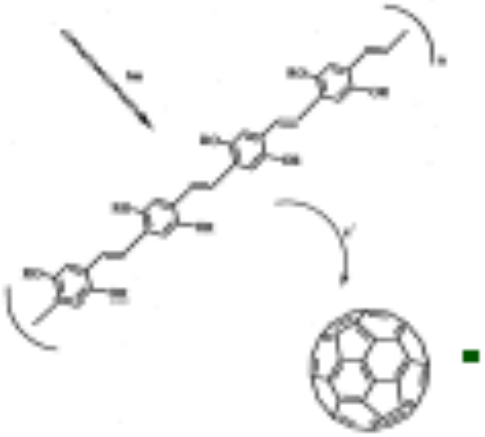
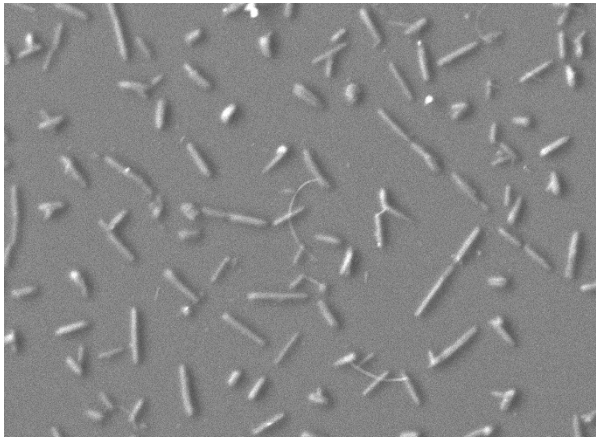
P3HT:PCBM solarne ćelije sa MoSI nanožicama

Nevena Ćelić



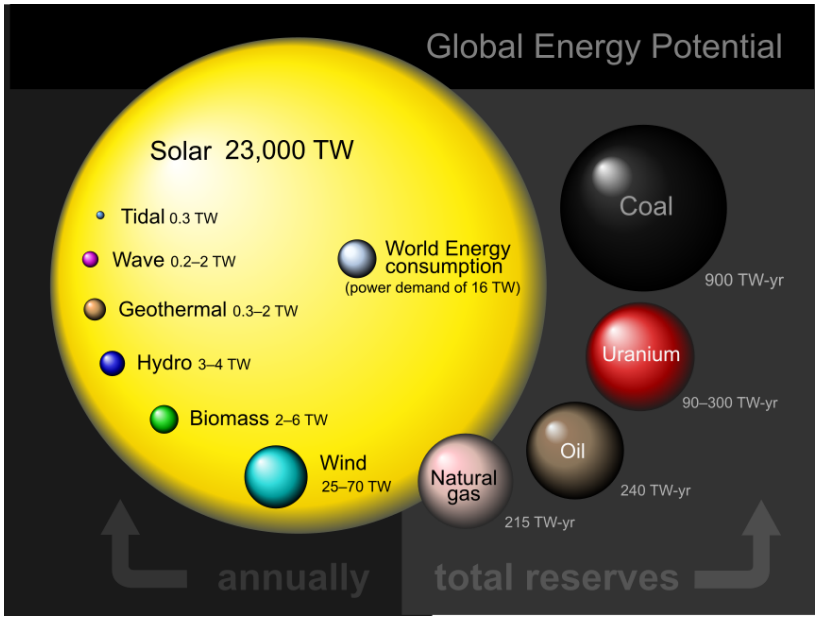


April, 2017.



Obnovljivi izvori energije

- Značajna energetska sigurnost, ekonomske koristi, smanjeno zagađenje životne sredine i poboljšano zdravlje stanovništva
- Mogućnosti solarne energije su ogromne.

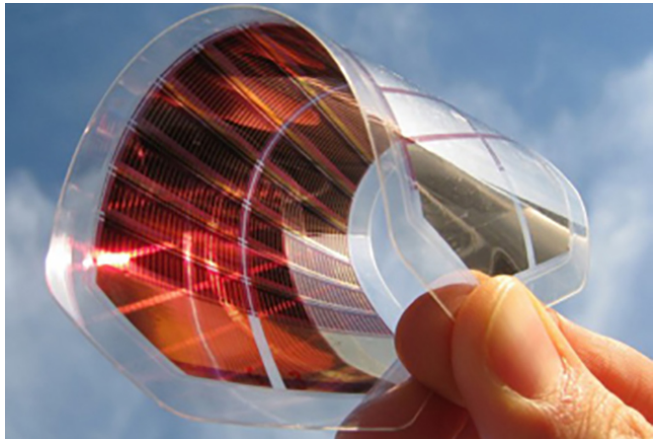


Perez et al., SHC Sol. Updat. 50 (2009)

Fotonaponski uređaji

Fotonaponski uređaji generišu električnu energiju kada se obasjavaju fotonima. Sve dok se uređaj osvetljava, generisaće električnu energiju.

- Proizvodnja uobičajenih silicijumskih solarnih ćelija je skupa.
- Naučnici konstantno traže jeftinije alternative.
- Otkriće provodnih polimera
- P3HT:PCBM solarne ćelije – najpoznatije polimerne *bulk heterojunction* solarne ćelije.



The Nobel Prize in Chemistry 2000

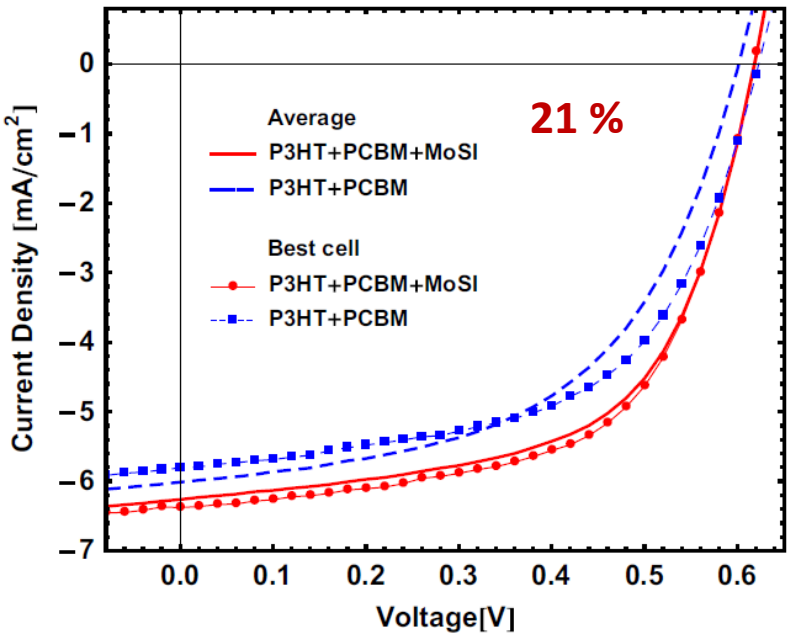
Alan J. Heeger
Prize share: 1/3

Alan G. MacDiarmid
Prize share: 1/3

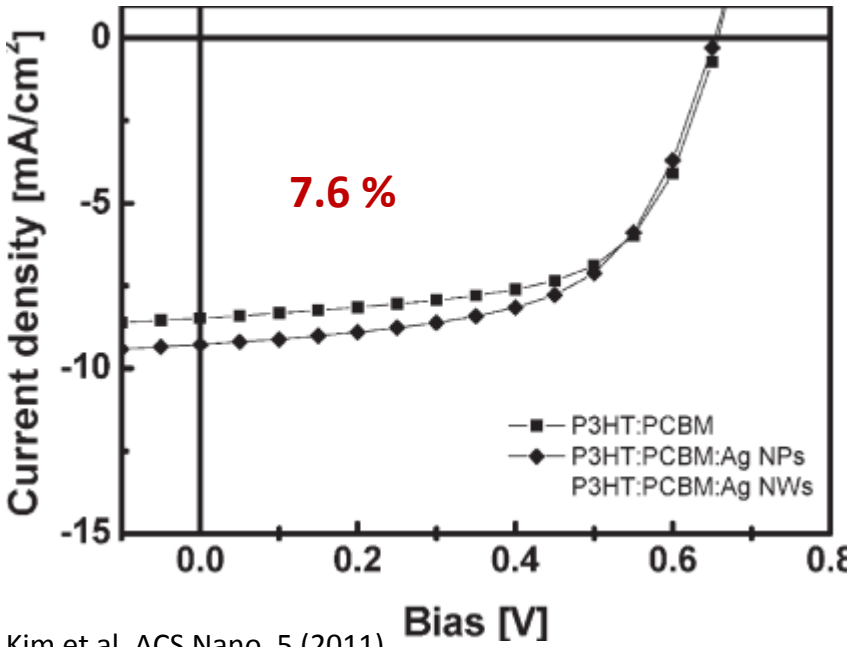
Hideki Shirakawa
Prize share: 1/3

Kako povećati efikasnost?

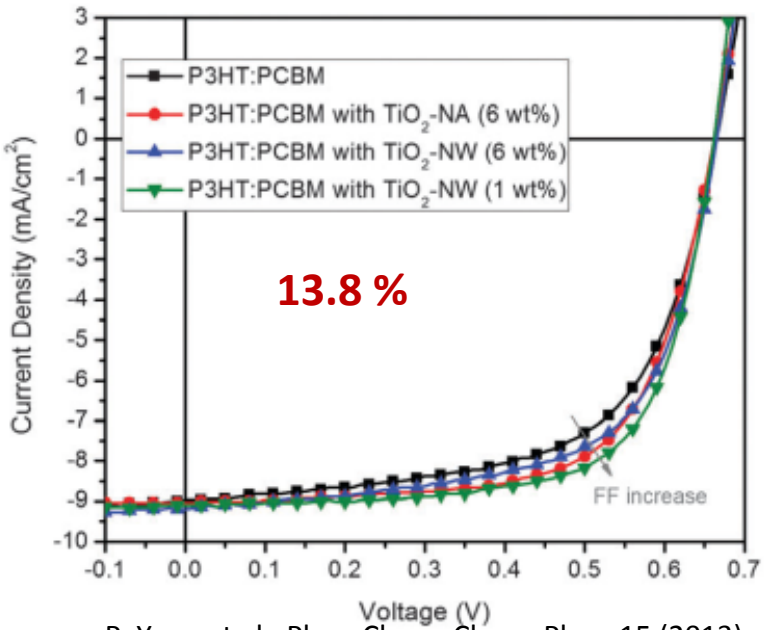
- Efikasnost solarnih ćelija je ograničena zbog nekoliko faktora.
- Različite vrste nanočestica se dodaju u solarne ćelije da bi se povećala njihova efikasnost



Majkić et al., Sol. Energy Mater. Sol. Cells. 127 (2014)

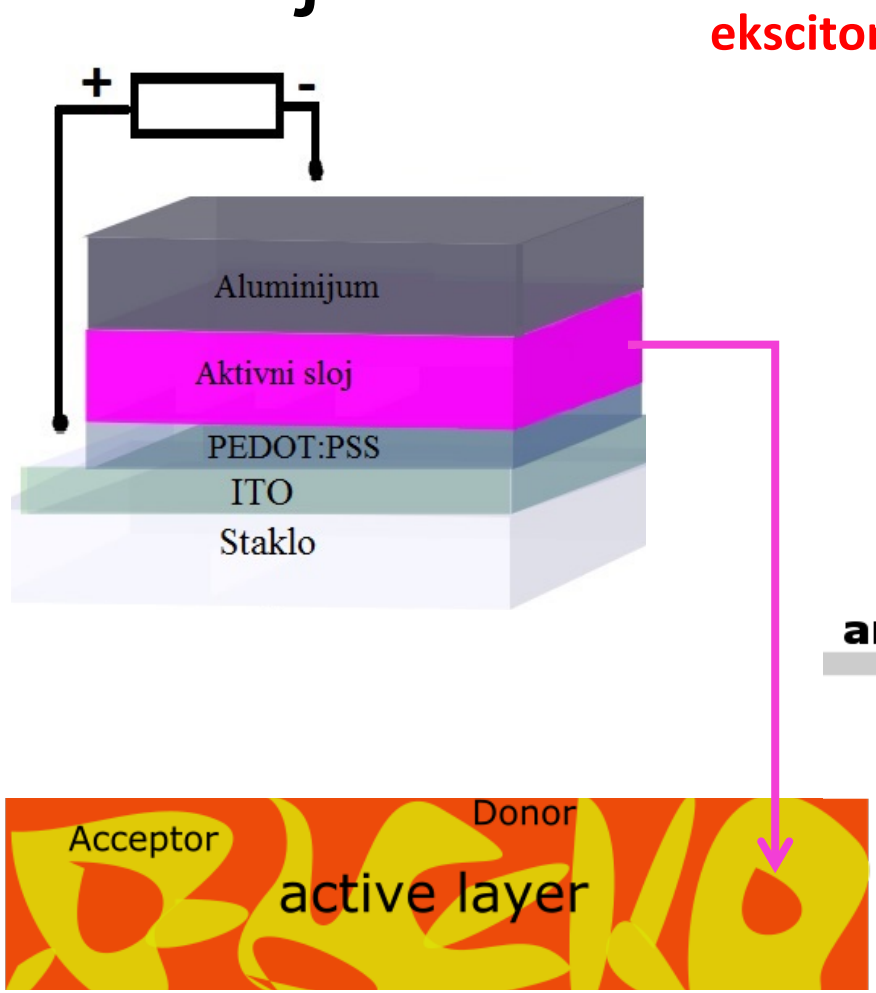


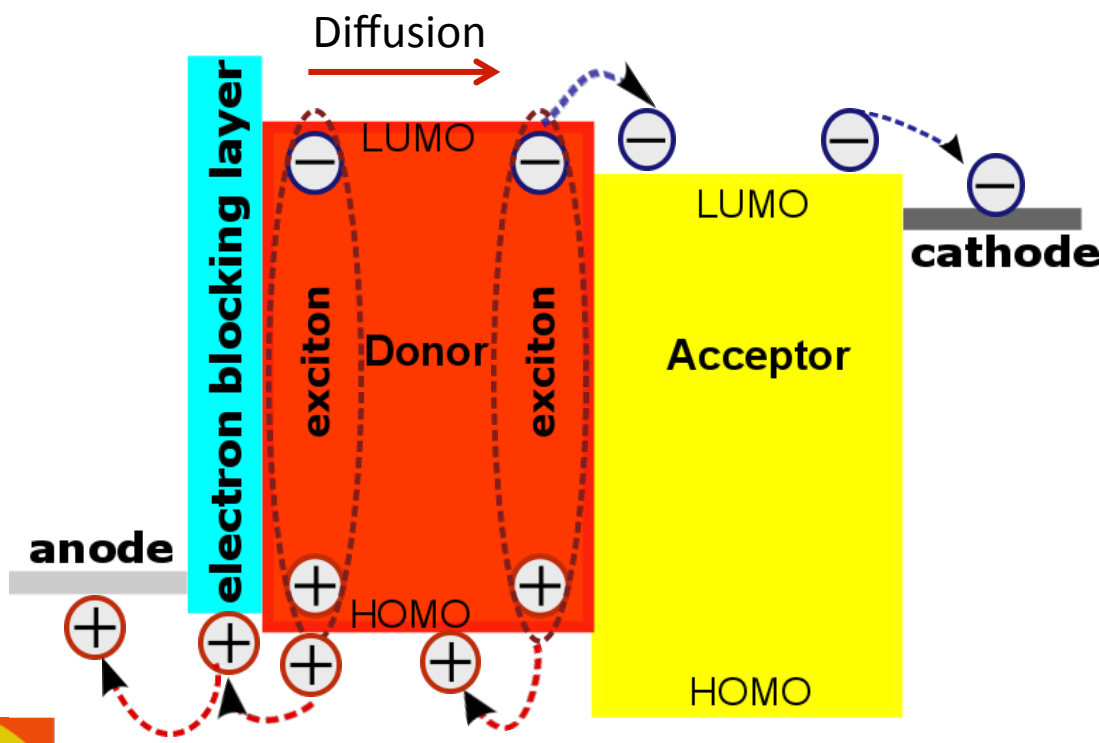
Kim et al, ACS Nano. 5 (2011)



P. Yang et al., Phys. Chem. Chem. Phys. 15 (2013)

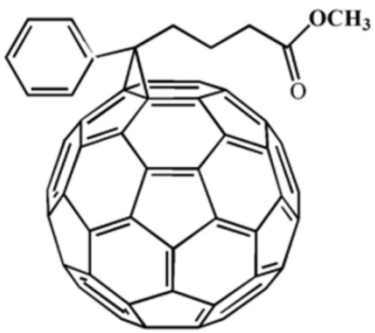
Bulk heterojunction solarne ćelije



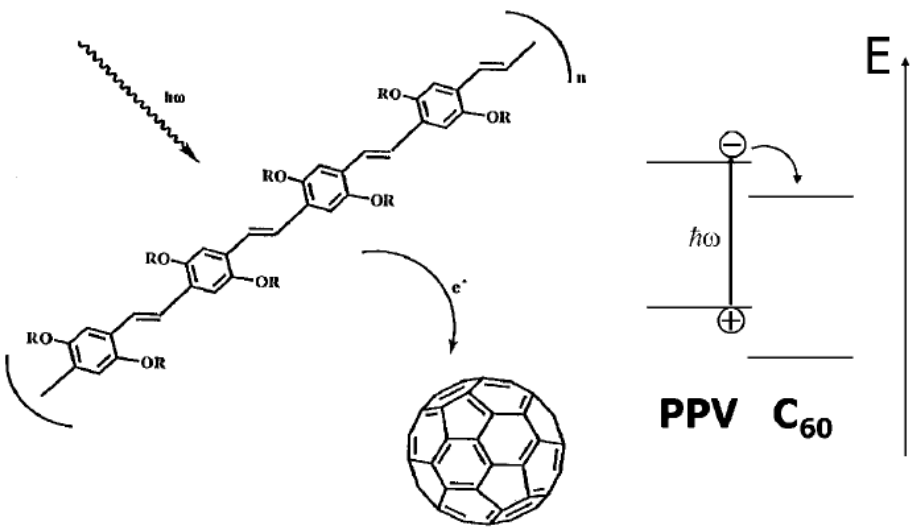


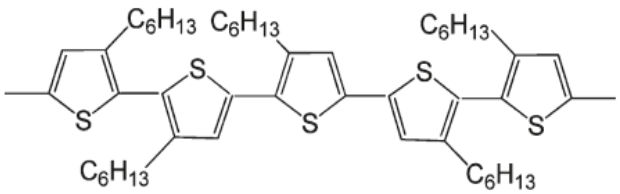
P3HT:PCBM solarne ćelije

- Ultrabrz fotoindukovan transfer naelektrisanja sa konjugovanog polimera na C_{60}
- Konjugovani polimeri su poluprovodnici p-tipa.

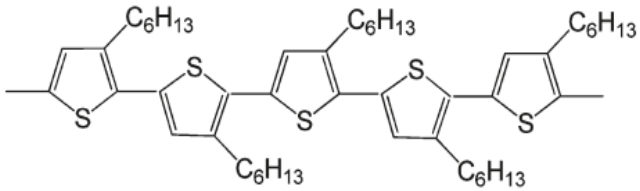


PCBM





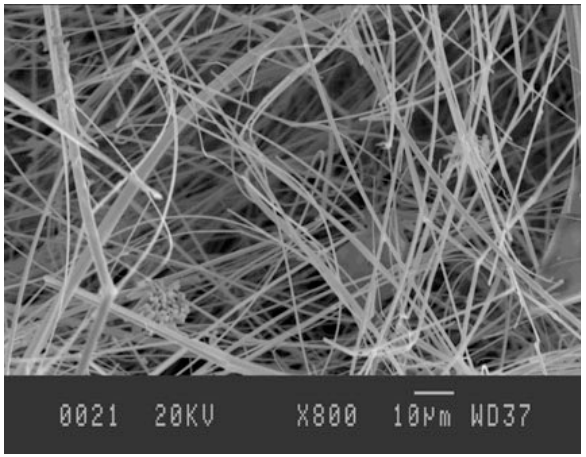
RRa-P3HT



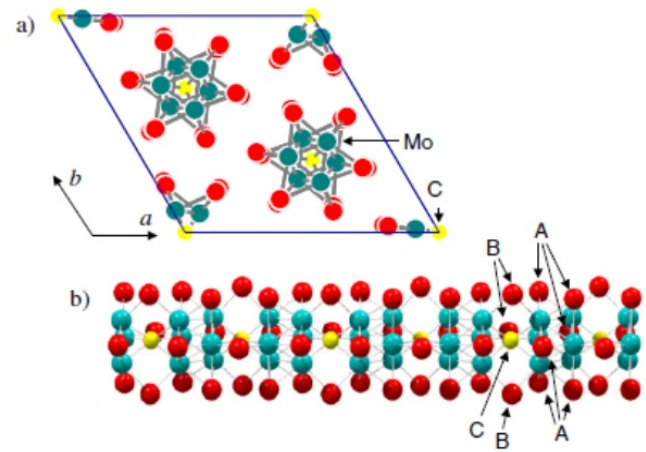
RR-P3HT

Günes et al., Chem. Rev. (2007) N.S. Sariciftci et al., Science 258(1992) Tsoi et al., Macromolecules. 44 (2011)

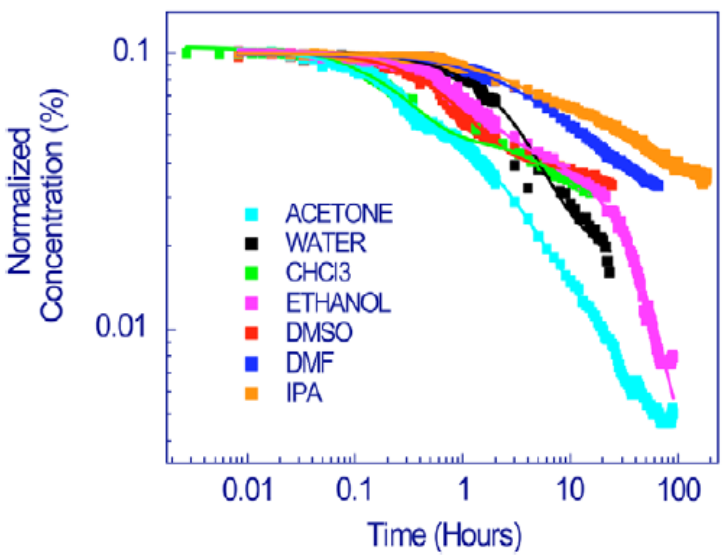
MoSI nanožice

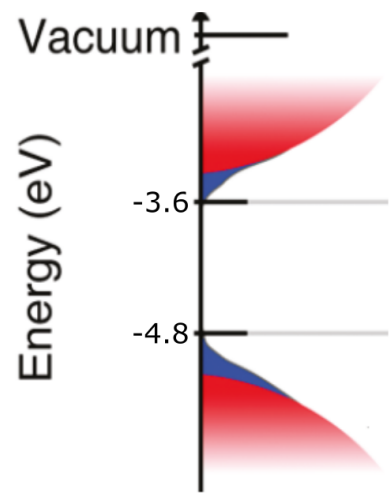


D. Vrbanič et al., Nanotechnology. 15 (2004)



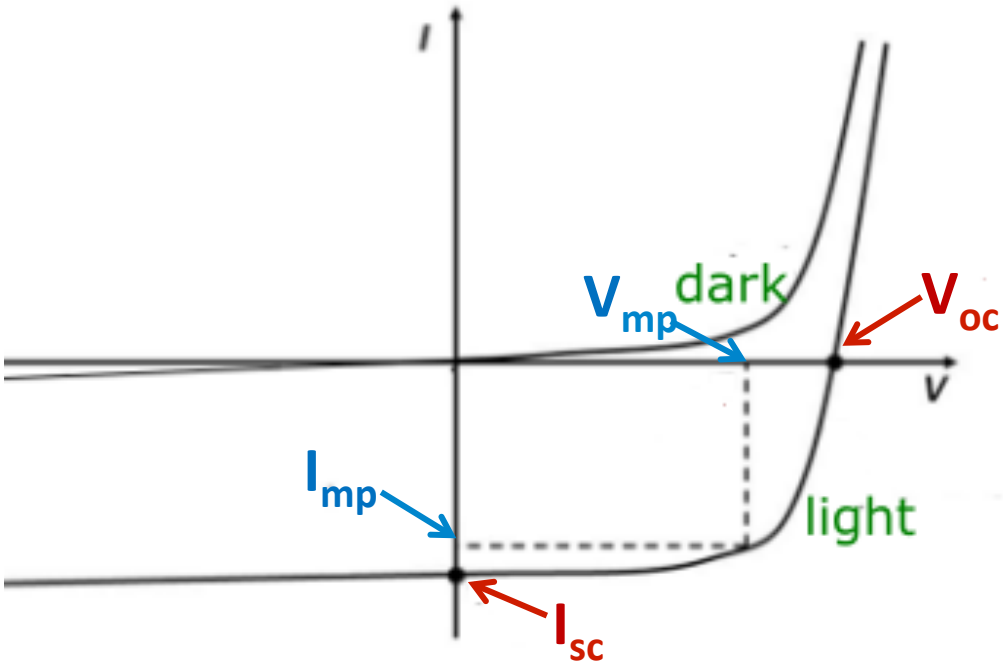
D. Mihailovic et al., Prog. Mater. Sci. 54 (2009)





M. Strojnik et al., Langmuir. 27 (2011)

Parametri solarne ćelije



Faktor popunjenosti

$$FF = I_{mp} * V_{mp} / I_{sc} * V_{oc}$$

Efikasnost

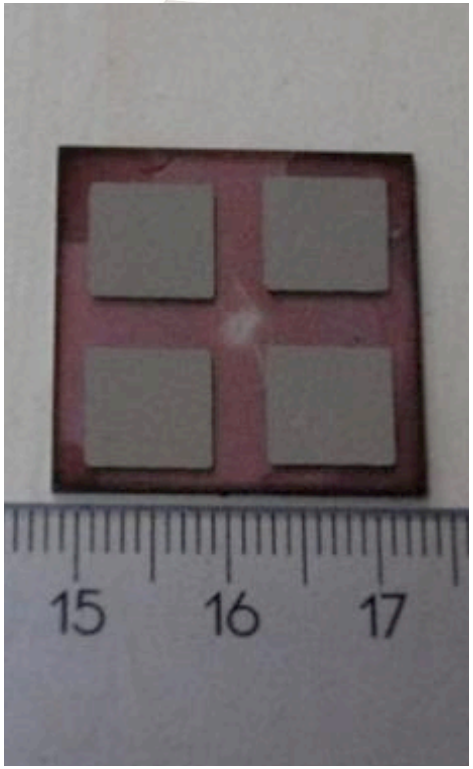
$$PCE = P_{mp} / P_{in} = I_{mp} * V_{mp} / P_{in}$$

Spoljašnja kvantna efikasnost (EQE) – broj naelektrisanja podeljen brojem fotona koji padaju na solarnu ćeliju na određenoj talasnoj dužini

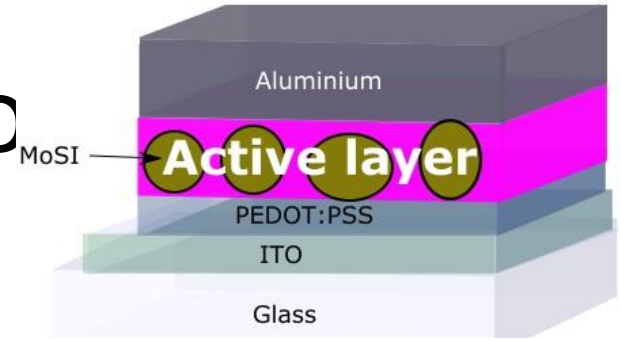
Izvršeni eksperimenti

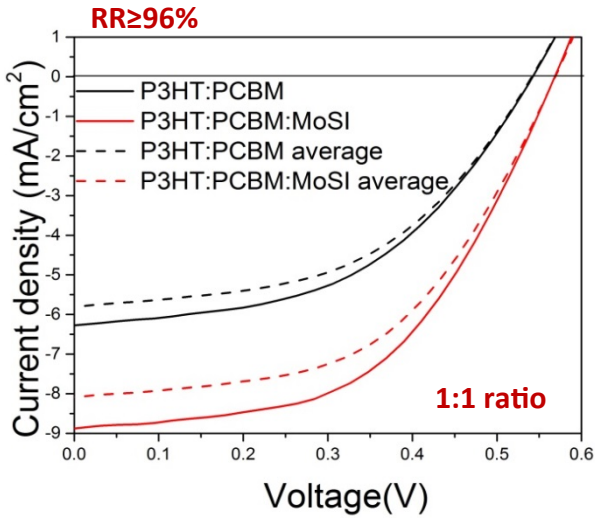
- Dodavanje različitih koncentracija MoSI nanožica
  - U aktivni sloj
  - Na vrh aktivnog sloja
  - U PEDOT:PSS
- Ispitivanje različitih faktora koji utiču na povećanje PCE

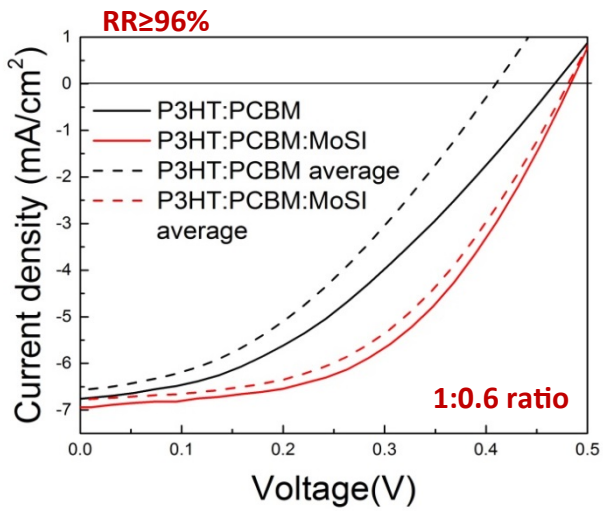
Priprema i karakterizacija solarnih ćelija

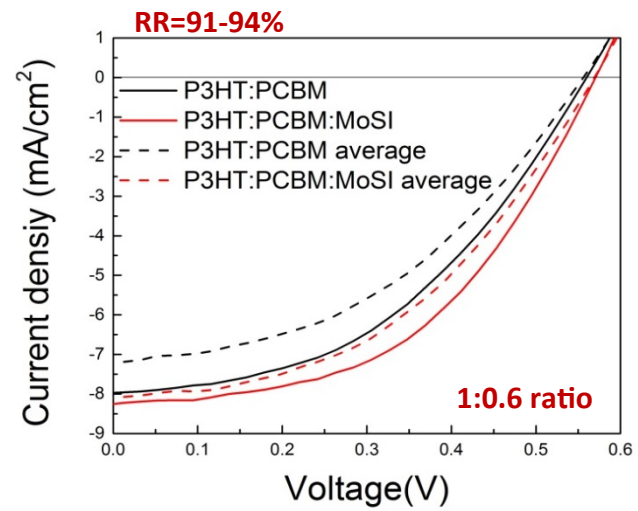


MoSI nanožice u aktivnoj sloju





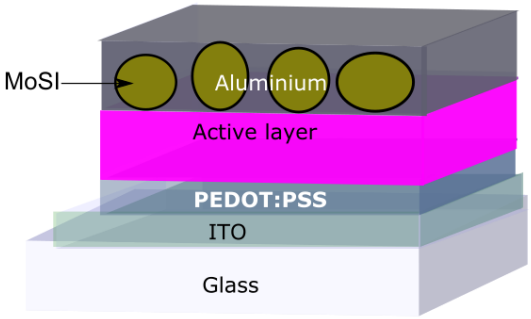


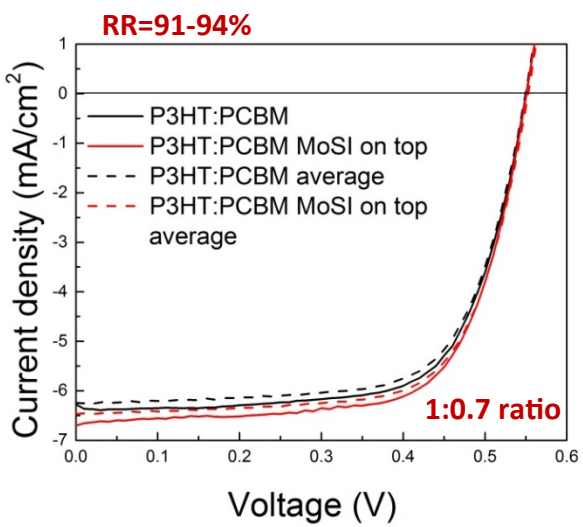


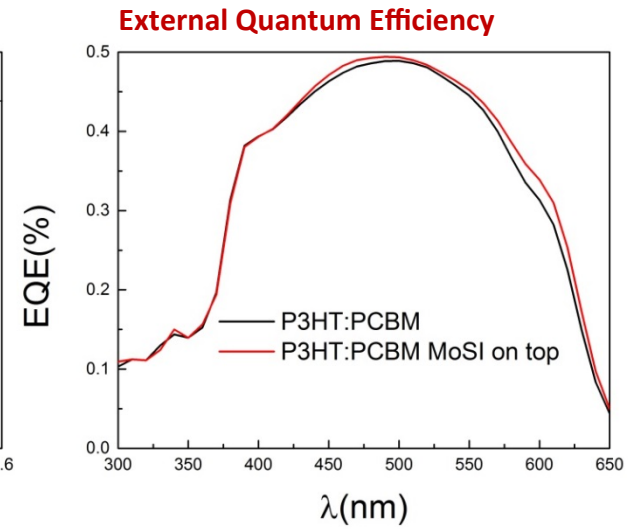
P3HT:PCBM (weight ratio)	P3HT regioregularity	Technique	MoSI content (wt %)	Maximum V_{oc}(V)	FF (%)	J_{sc} (mA/cm²)	PCE (%)	Average PCE (%)	
1:1	96% or greater	Spin coat	0	0.54	48.9	6.29	1.65	1.57±0.1	
1:1	96% or greater	Spin coat	1	0.57	52.3	8.89	2.63	2.40±0.2	52%
1:0.6	96% or greater	Spin coat	0	0.47	39.2	6.78	1.24	1.07±0.1	
1:0.6	96% or greater	Spin coat	1.25	0.48	50.9	6.99	1.71	1.62±0.1	51%
1:0.6	91-94%	Spin coat	0	0.56	45.1	8	1.99	1.85±0.2	
1:0.6	91-94%	Spin coat	1.25	0.57	49.5	8.3	2.32	2.07±0.2	12%

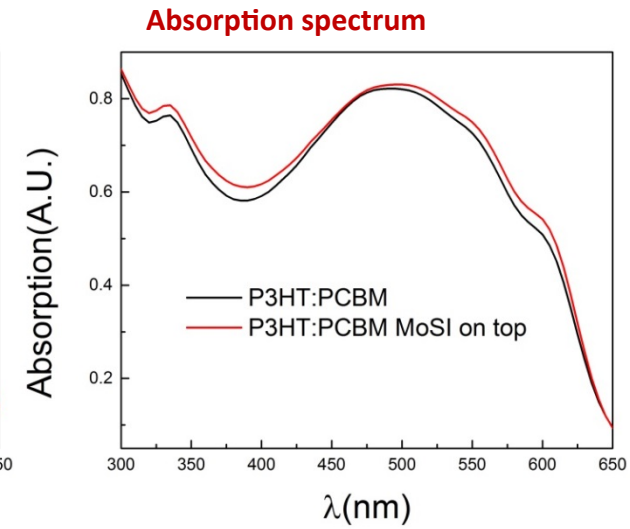
Ćelić et al, Synth. Met. 212 (2016)

MoSI nanožice na aktivnom sloju







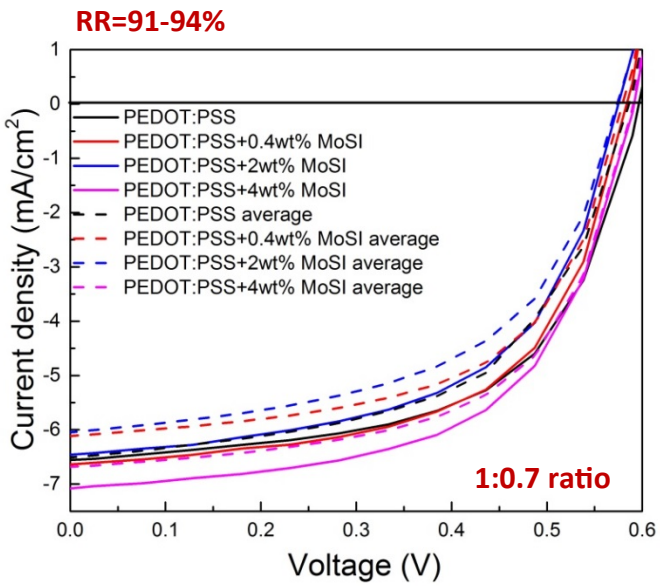


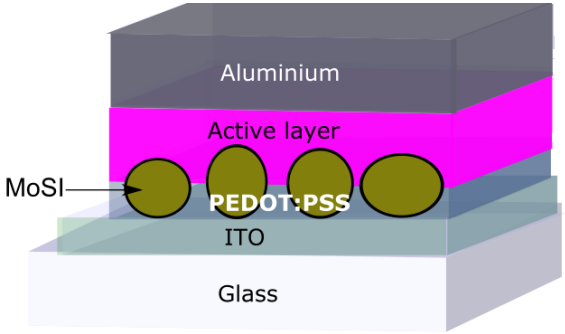
P3HT:PCBM (weight ratio)	P3HT regioregularity	Technique	MoSI on top	Maximum				Average
				V_{oc}(V)	FF (%)	J_{sc} (mA/cm^2)	PCE (%)	PCE (%)
1:0.7	91-94%	Doctor blade	No	0.55	71.1	6.33	2.49	2.38±0.04
1:0.7	91-94%	Doctor blade	Yes	0.55	69	6.67	2.53	2.48±0.04

→ **4.2%**

Ćelić et al, Synth. Met. 212 (2016)

MoSI nanožice u PEDOT:PSS



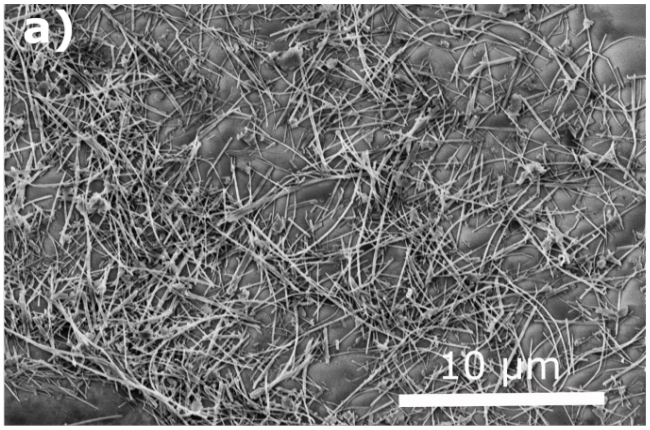


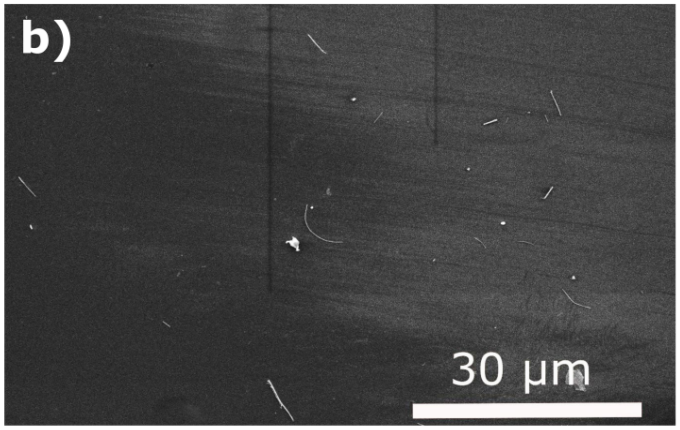
Potrebno je optimizovati

P3HT:PCBM (weight ratio)	P3HT regioregularity	Technique	MoSI content (wt%)	Maximum				Average
				V_{oc}(V)	FF (%)	J_{sc} (mA/cm^2)	PCE (%)	PCE (%)
1:0.7	91-94%	Spin coated	0	0.6	58.2	6.56	2.30	2.17±0.1
1:0.7	91-94%	Spin coated	0.4	0.59	59.0	6.64	2.29	2.08±0.1
1:0.7	91-94%	Spin coated	2	0.58	56.6	6.46	2.11	1.90±0.1
1:0.7	91-94%	Spin coated	4	0.59	58.6	7.08	2.46	2.34±0.1

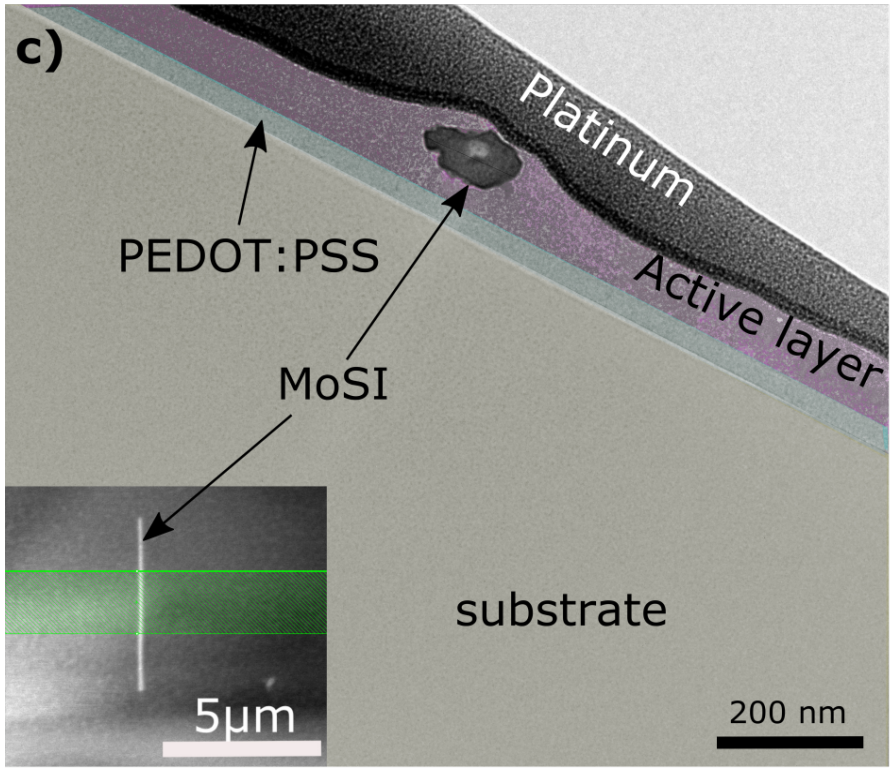
Raspodela MoSI nanožica

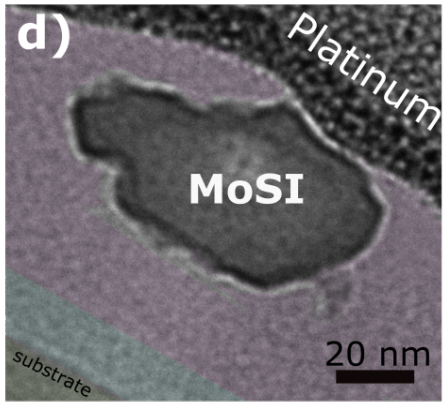
Drop casted **disperzija**

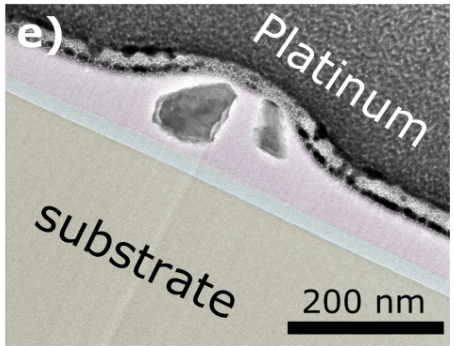




Pogled odgore





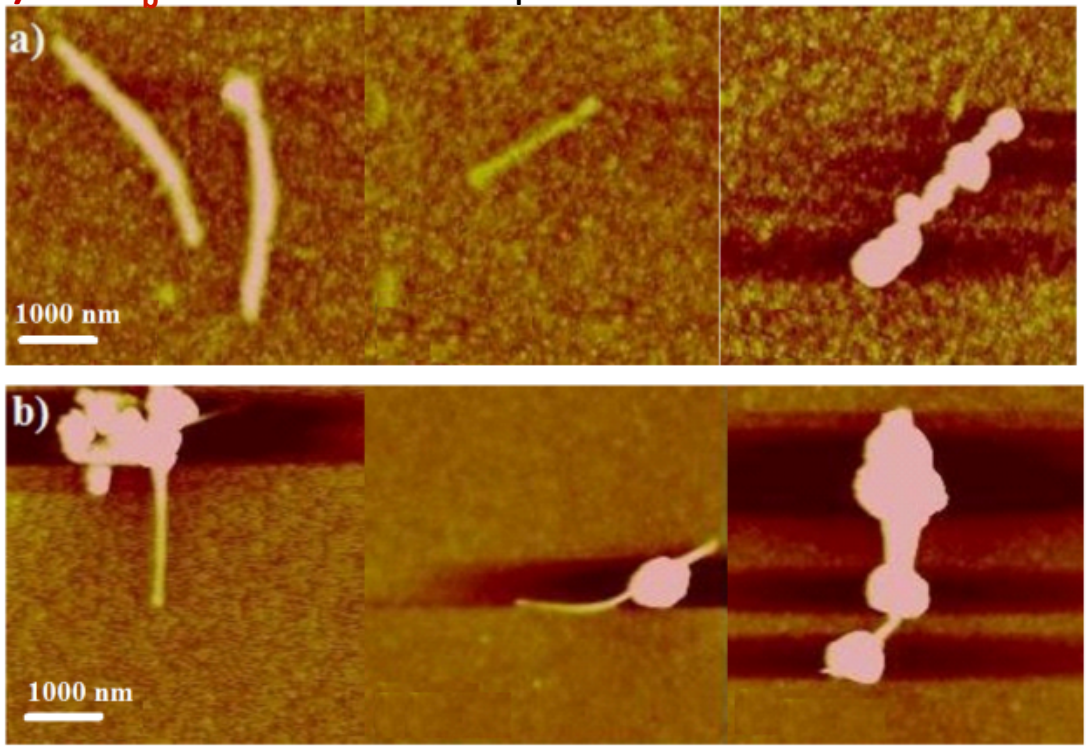


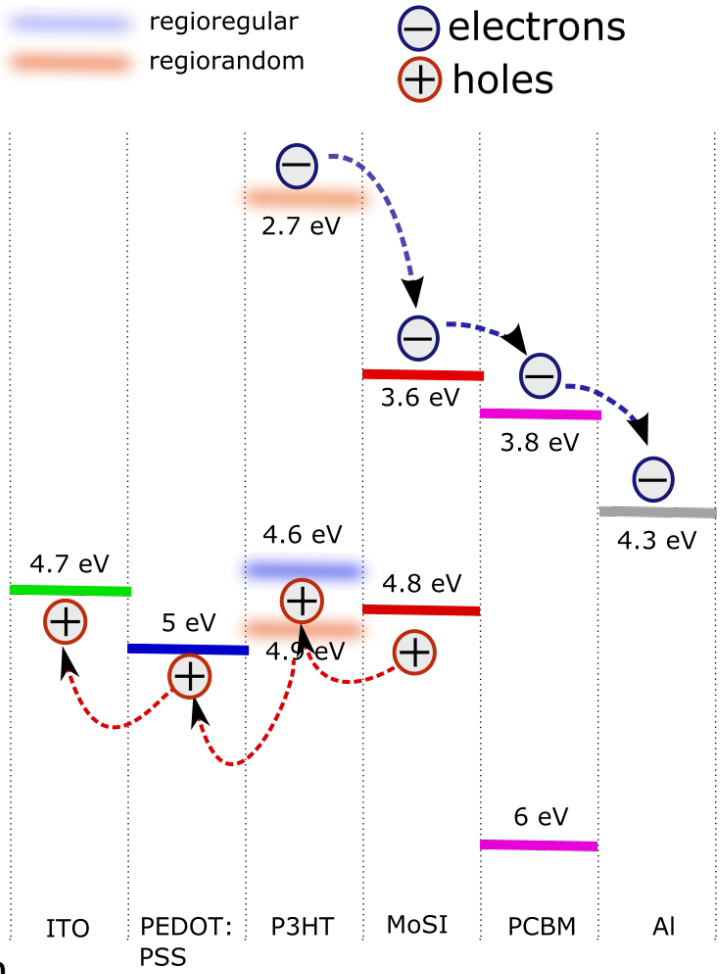
Poprečni presek

Uticaj regioregularnosti P3HT

$P3HT_a$ – P3HT sa RR 91-94%
$P3HT_b$ – P3HT sa RR većom od 96%

a) $P3HT_b$:PCBM:MoSI hrapavost: 5.3±0.4 nm

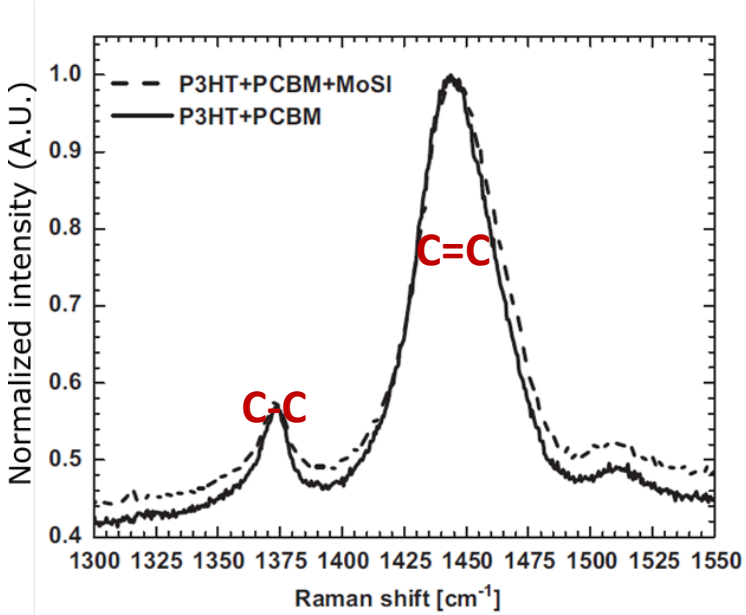




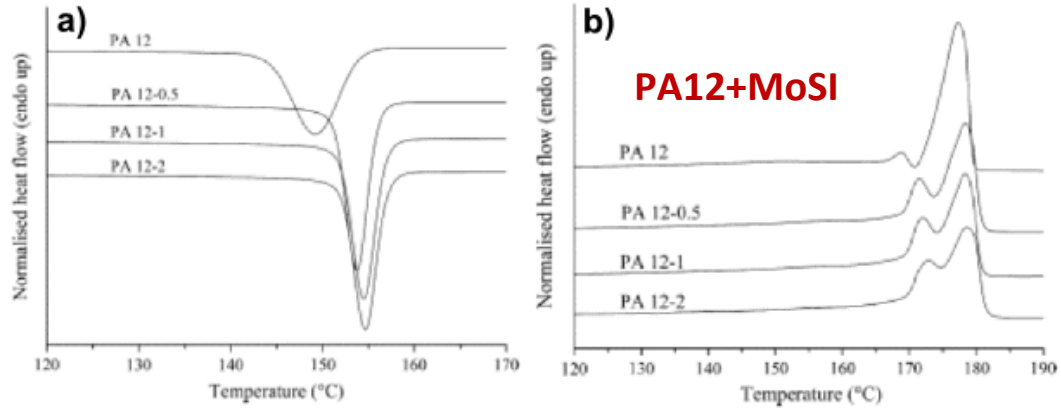
b) $P3HT_a$:PCBM:MoSI Hrapavost: 0.89±0.13→1.3±0.5 nm

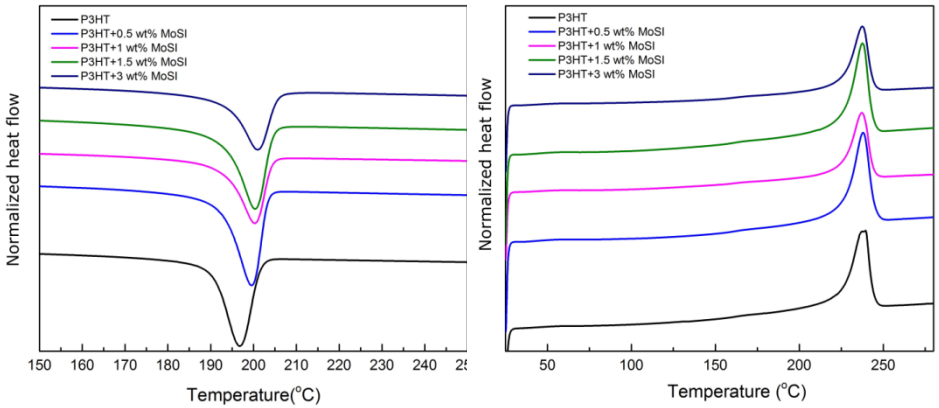
Ćelić et al, Synth. Met. 212 (2016)

Uticaj MoSI nanožica na kristaliničnost



Mosi nanožice nemaju pozitivan uticaj na kristaliničnost P3HT.





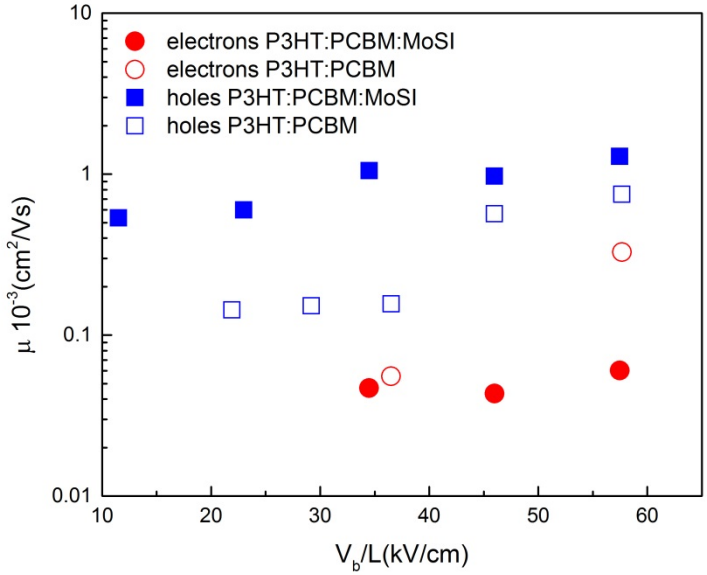
MoSI	T_c (°C)	ΔH_c (J/g)	T_m (°C)	ΔH_m (J/g)	% χ_c
P3HT	196.7	21.1	239.4	26.0	13.2
P3HT + 0.5% MoSI	199.7	20.9	237.8	25.3	11.9
P3HT + 1% MoSI	200.4	20.9	237.5	24.6	10.0
P3HT +1.5% MoSI	200.5	21.1	237.5	25.1	10.8
P3HT + 3% MoSI	201.1	20.8	237.6	24.7	10.5

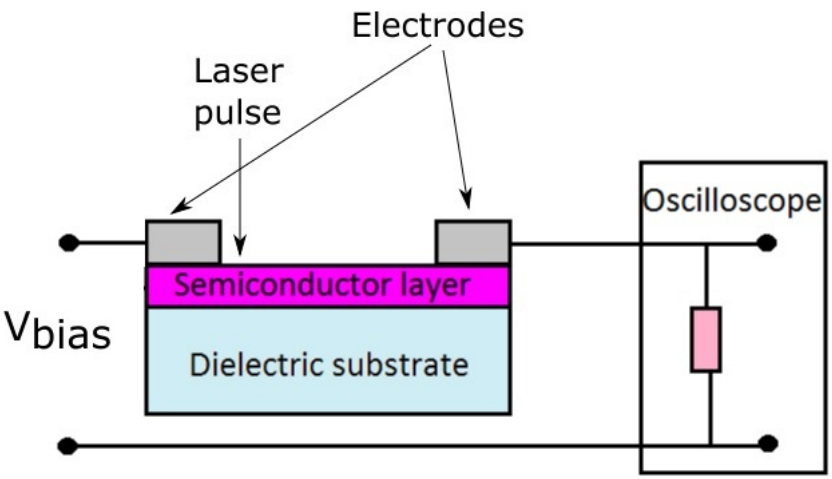
Majkić et al., Sol. Energy Mater. Sol. Cells. 127 (2014)

Huskić et al., Compos. Part B Eng. 56 (2014)

Merenje pokretljivosti naelektrisanja

$$\mu = d^2 / \tau * V_{bias}$$



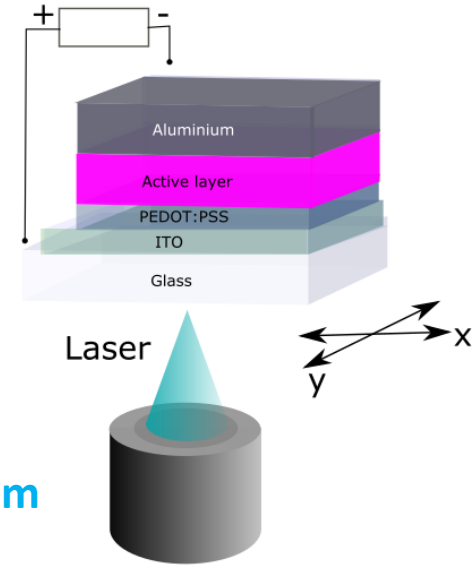


Charge mobility (cm^2/Vs)	holes	electrons
P3HT:PCBM	$2.9 \pm 0.1 \times 10^{-4}$	$0.56 \pm 0.01 \times 10^{-4}$
P3HT:PCBM:MoSI	$7.2 \pm 0.3 \times 10^{-4}$	$0.48 \pm 0.03 \times 10^{-4}$

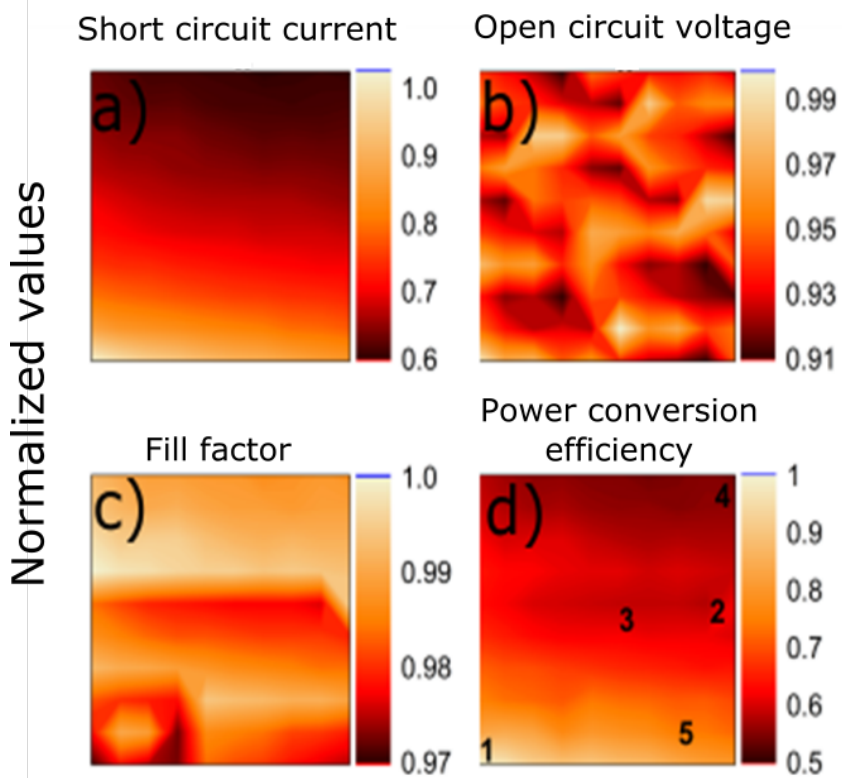
2.5 puta veća pokretljivost šupljina

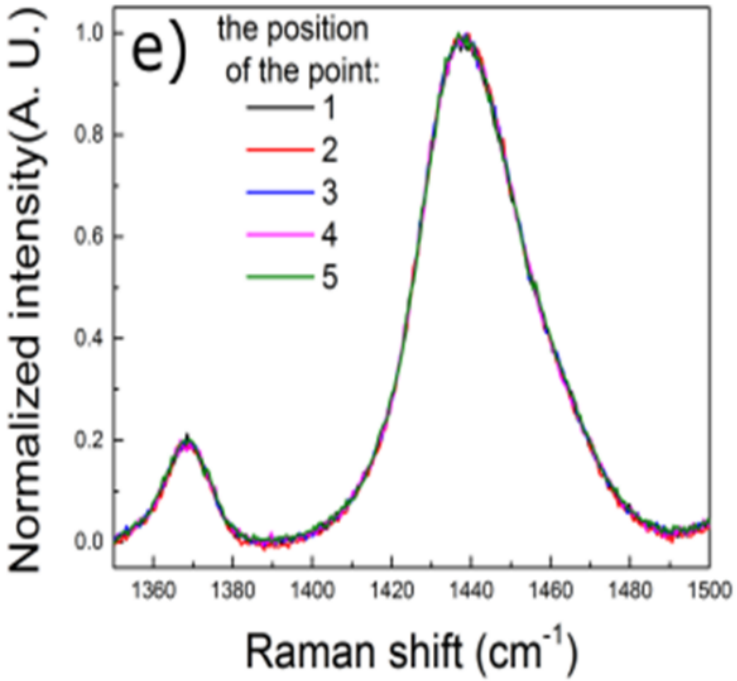
Ćelić et al, Synth. Met. 212 (2016)

Rezonantna Ramanova spektroskopija i skeniranje fotostruje (RRPI)



488 nm





Ćelić et al, Synth. Met. 212 (2016)

Zaključak

- Dodavanje MoSI nanožica u P3HT:PCBM aktivni sloj relativno povećava PCE do 52 %.
- Regioregularnost P3HT-a utiče na povećanje PCE.
- Pokretljivost šupljina u uzorcima sa MoSI nanožicama je 2.5 puta veća.
- RRPI ukazuje na važnu ulogu MoSI nanožica u transportu naelektrisanja.
- Potrebna dalja optimizacija.

Hvala na pažnji!