

Structural, optical and photoelectric properties of femtosecond laser-modified a-Si:H films

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UNIVERSITY OF
Southampton



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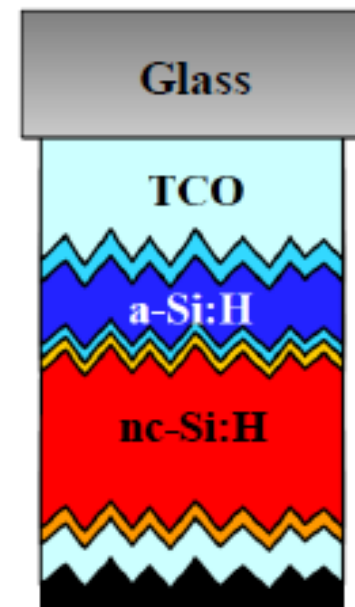
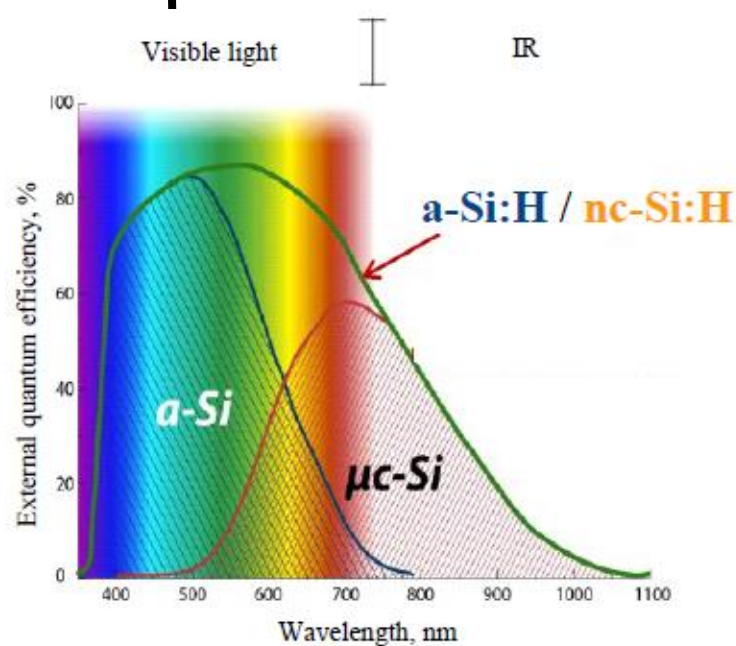
Hydrogenated silicon films

Amorphous (a-Si:H)

- ✓ High absorption of visible light
- ✓ Low production cost
- ✓ High-area devices
- ✗ Photoinduced degradation
- ✗ Low mobility

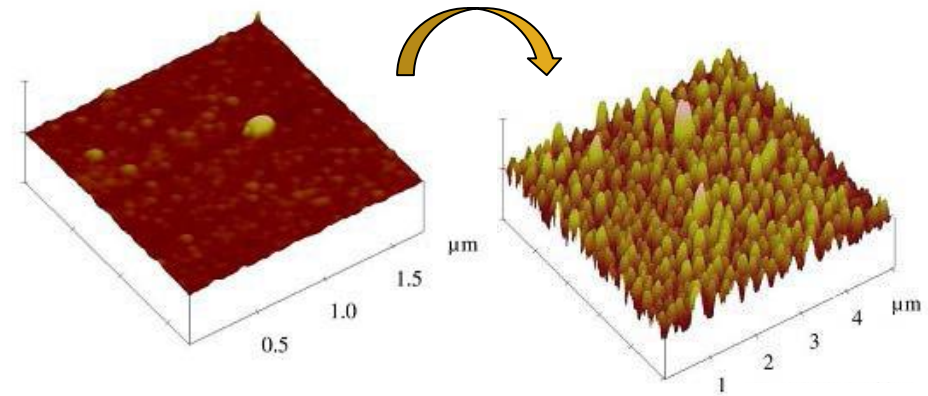
Nanocrystalline (nc-Si:H)

- ✓ High mobility
- ✓ No photoinduced degradation
- ✗ Low absorption
(as compared to a-Si:H)



Laser crystallization a-Si:H

- ✓ Localized structure modification
- ✓ No effect on a substrate
- ✓ Simultaneous surface texturing



X. C. Wang et al.,
Optics express, 2010

Why femtosecond pulses?

“Cold melting”

Fundamental difference
in modification stages

Two-phonon
absorption

Allows to crystallize
thick films uniformly

Very little
known so far

Mostly structural
studies

Samples

Pristine films:

a-Si:H films were deposited by PECVD method
from silane/argon gas mixture

Ioffe Physical-technical Institute (Saint-Petersburg)



Laser treatment

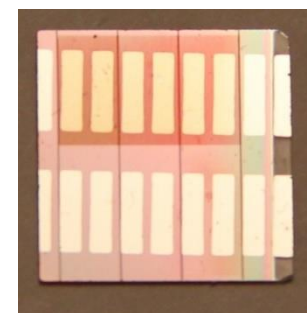
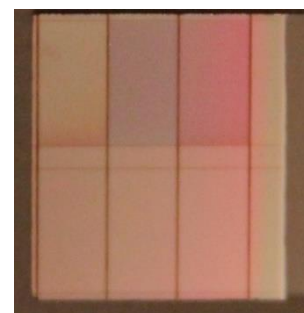
$\lambda = 515 / 640 / 1030 \text{ nm};$

$\tau = 300 \text{ fs}$

rep. rate 100-200 kHz

fluence 0-450 mJ/cm²

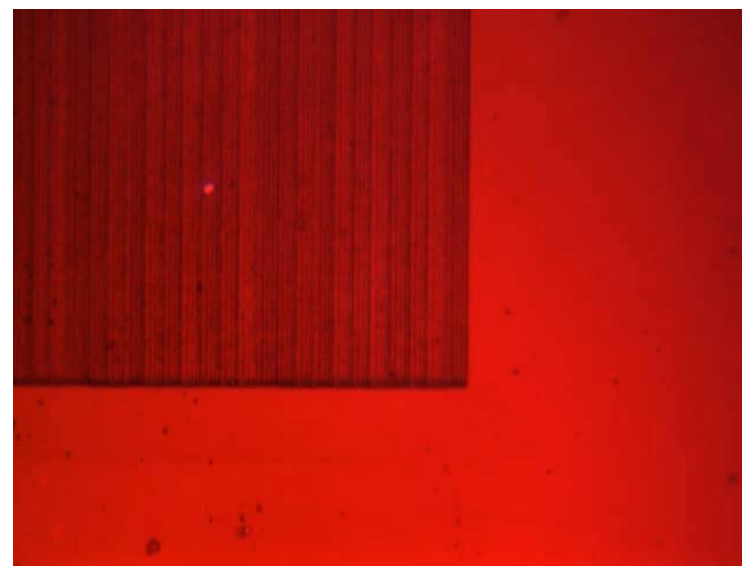
Southampton University






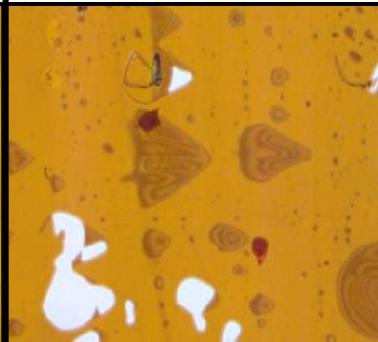
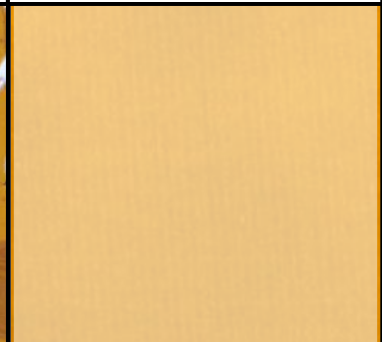
Laser scanning

$v = 1-5 \text{ mm/s}$

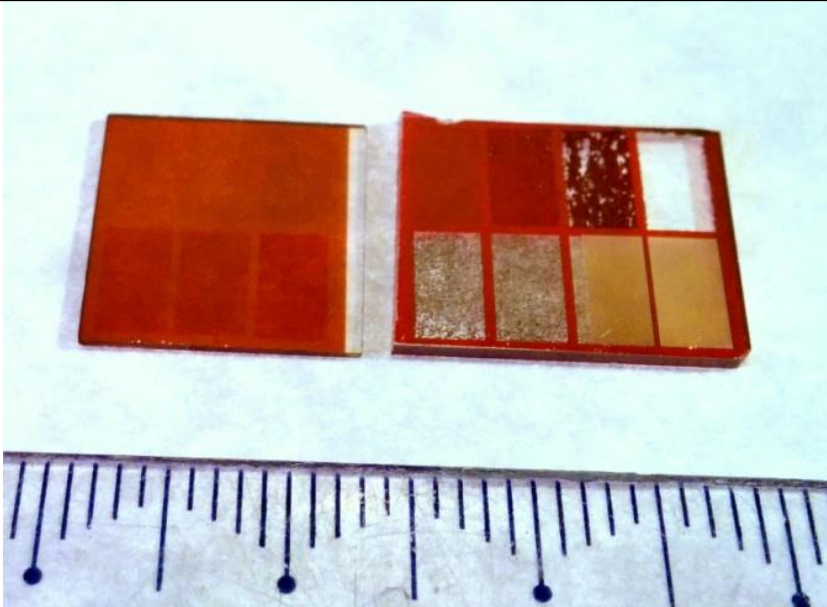
beam diameter 15-100 μm



Structural modification

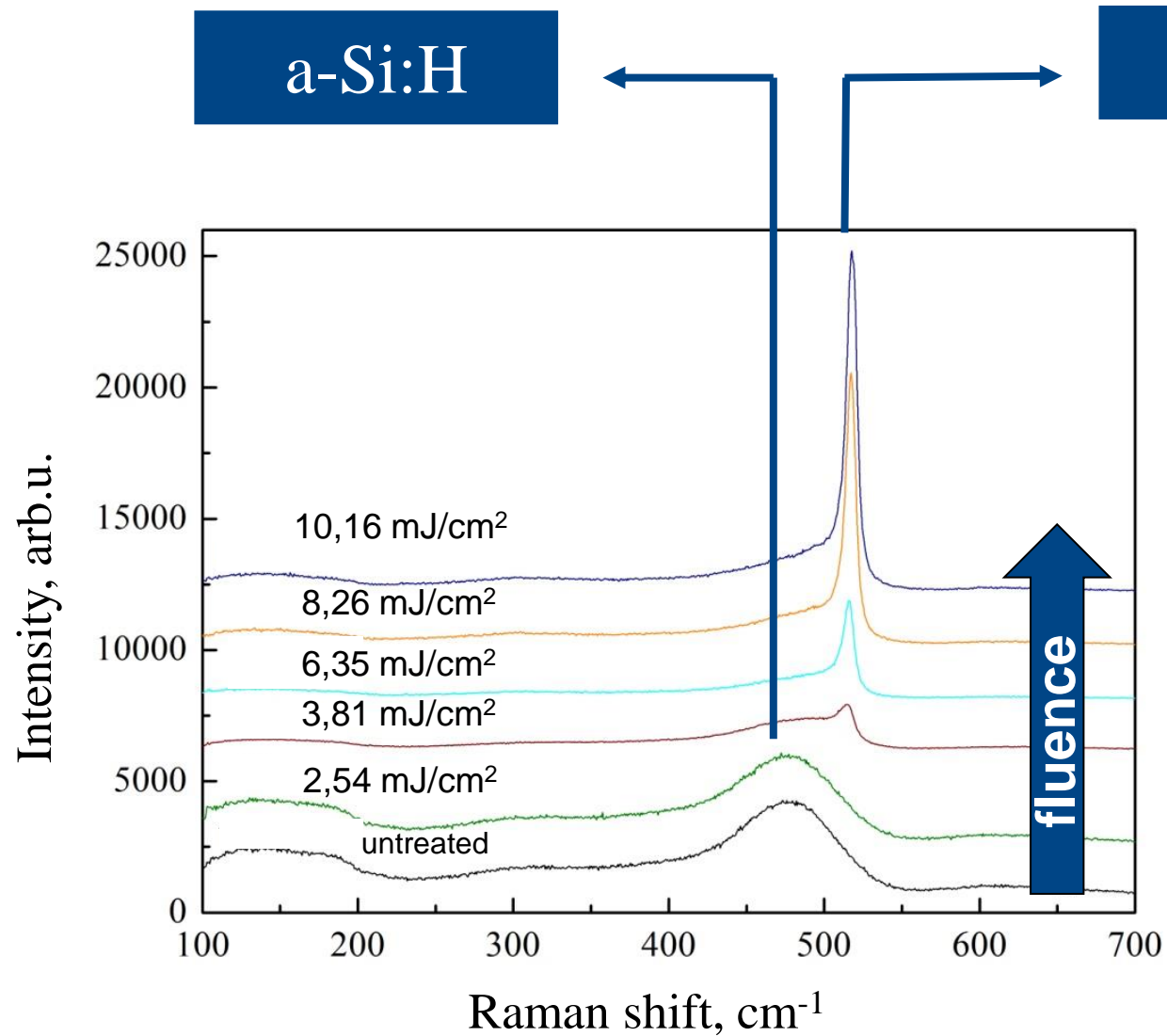
a-Si:H	Hydrogen out-diffusion	Crystallization	Spallation	Oxidation
				

Laser fluence 



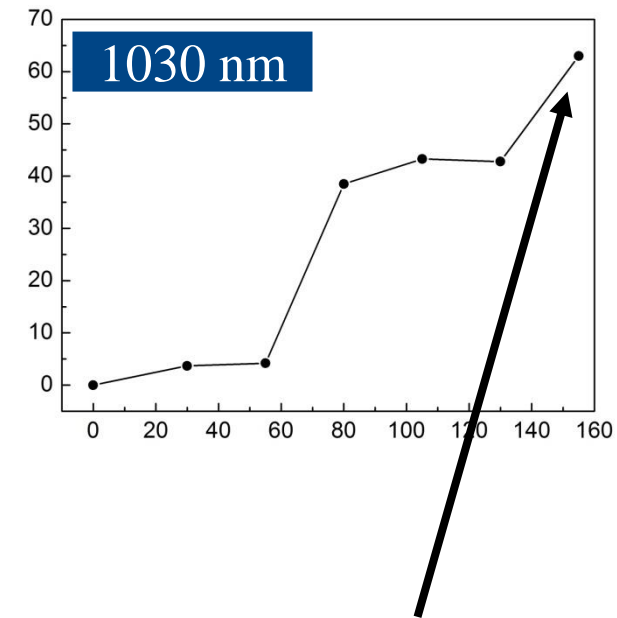
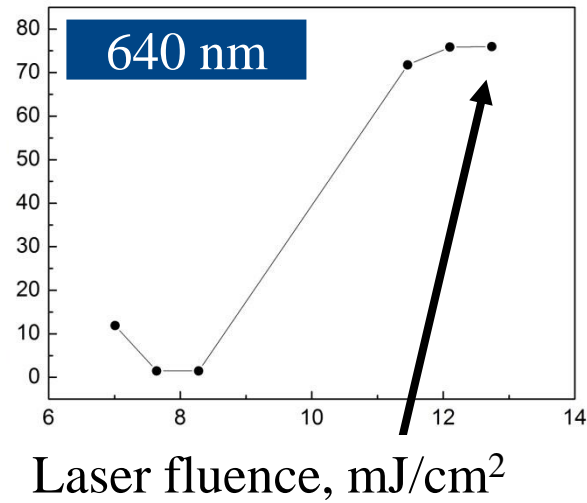
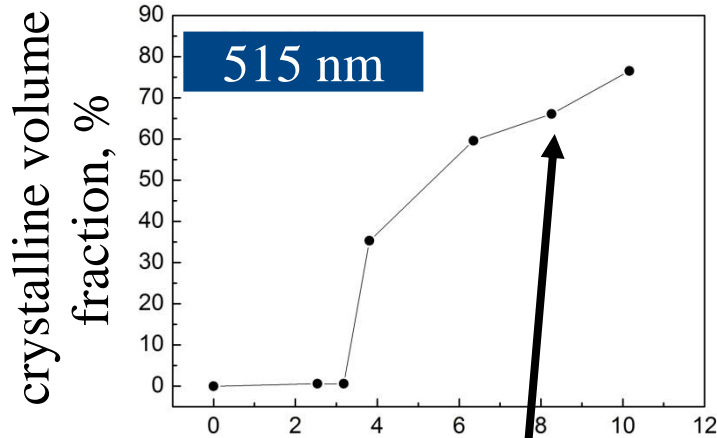
Crystallization

Raman spectroscopy

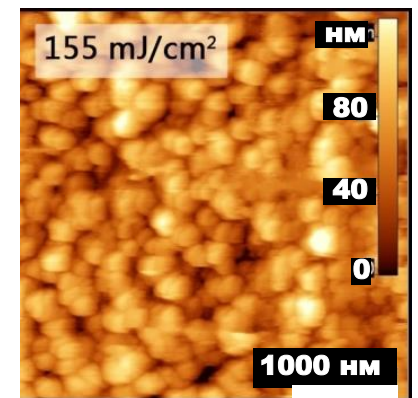
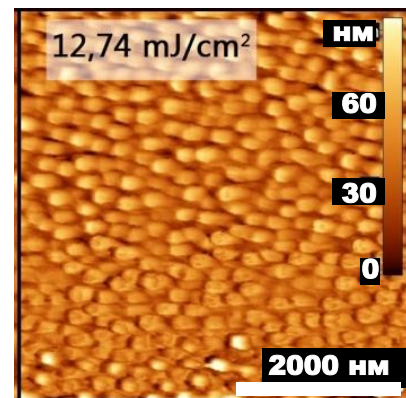
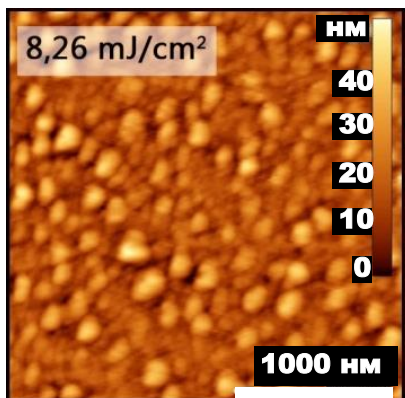


Crystallization

Raman spectroscopy

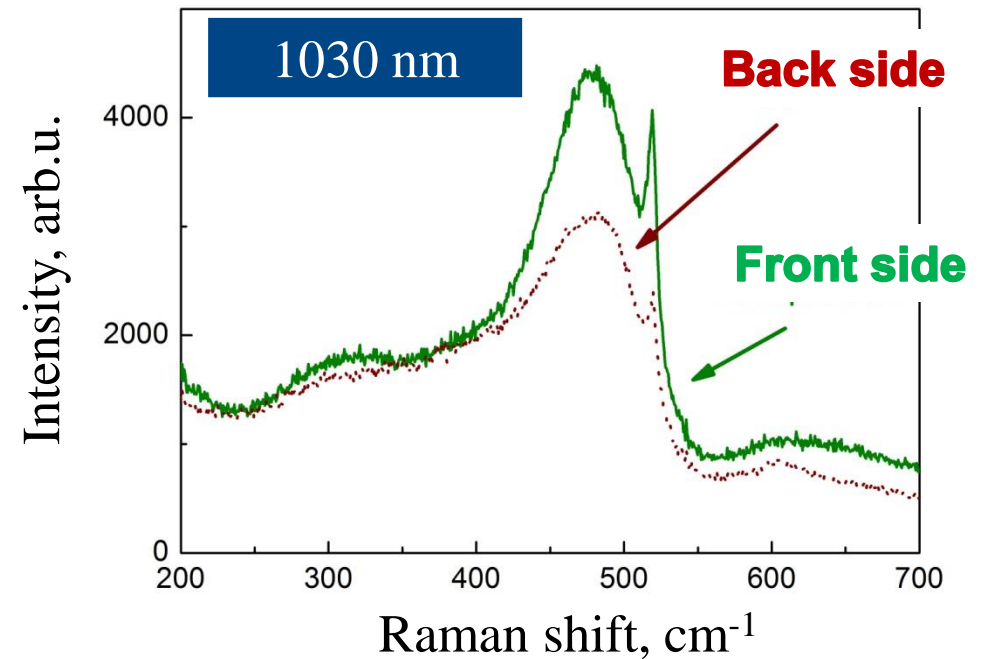
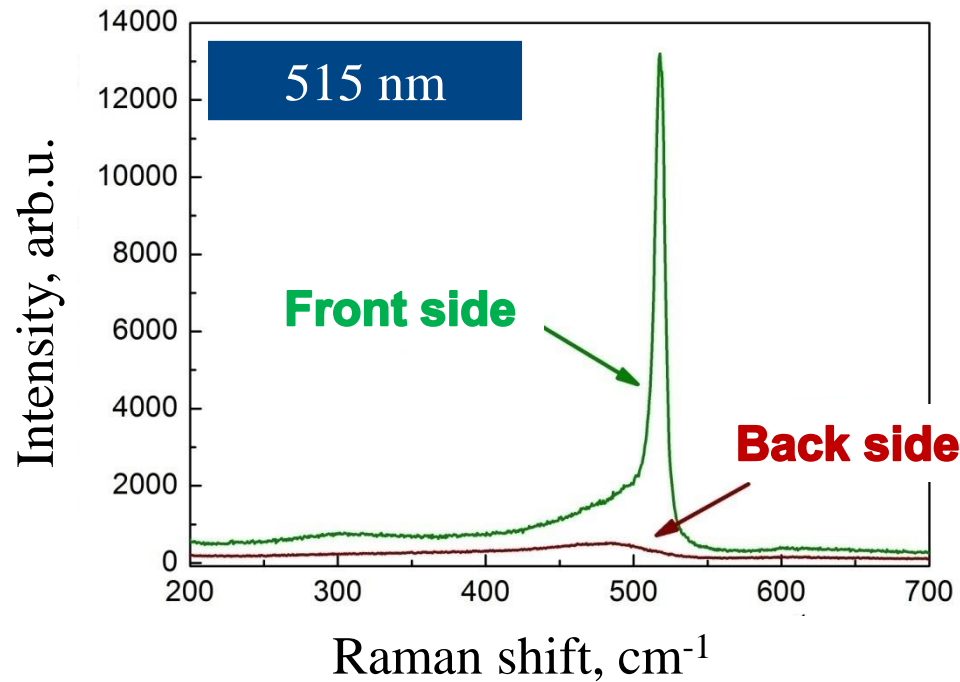


AFM

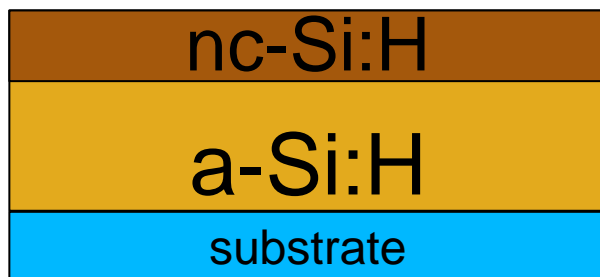


The effect of wavelength

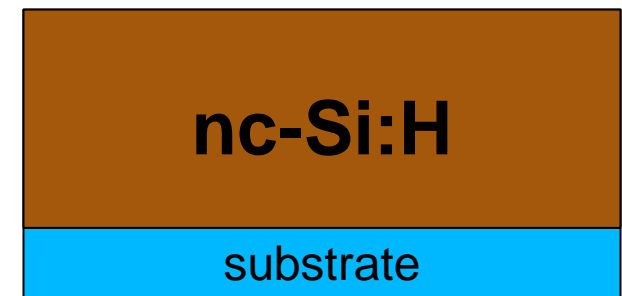
Raman spectroscopy



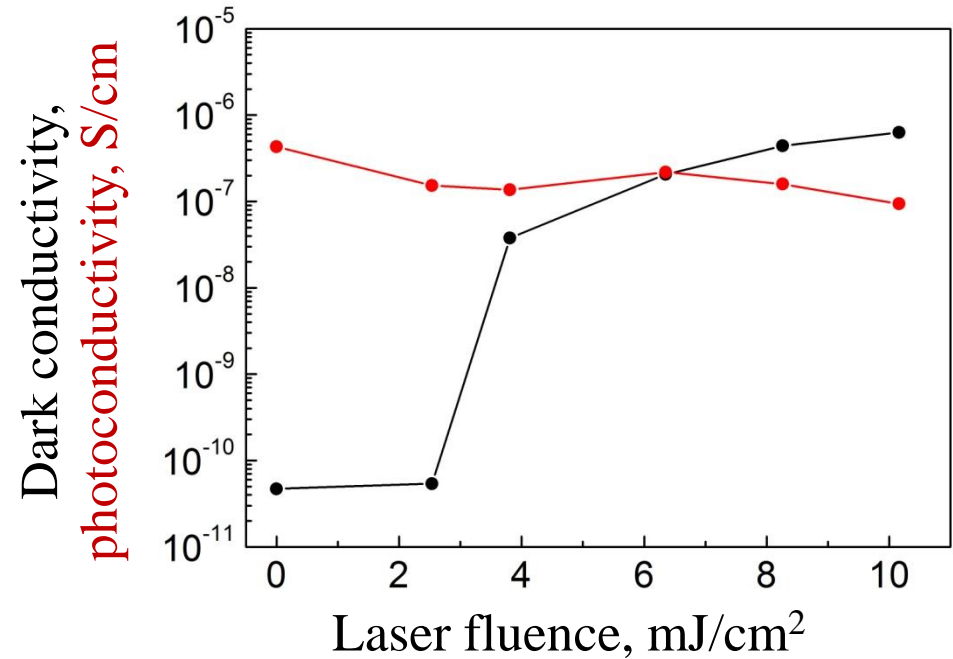
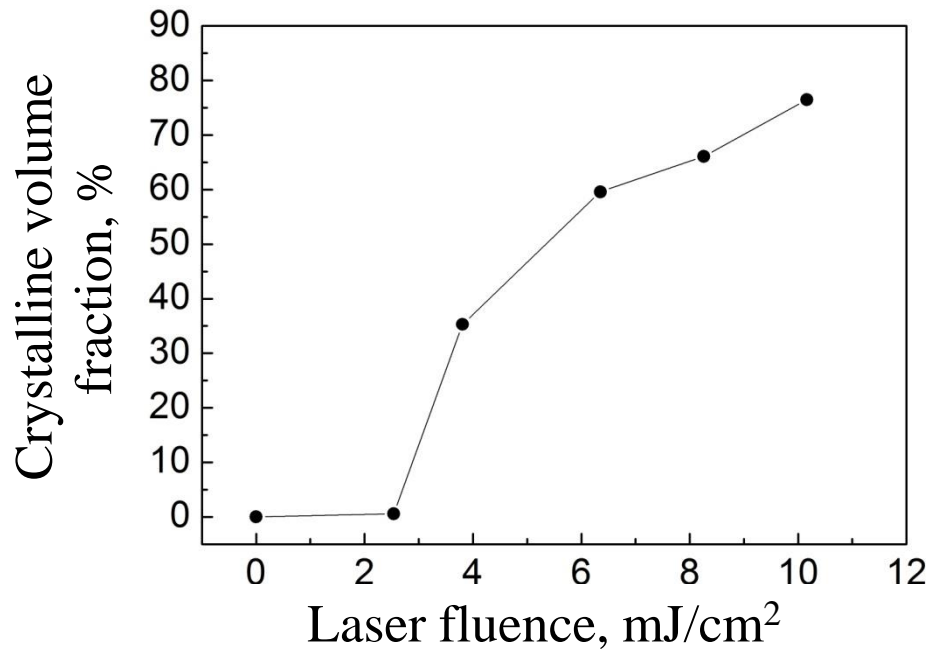
Two-layer structures:



Uniform:



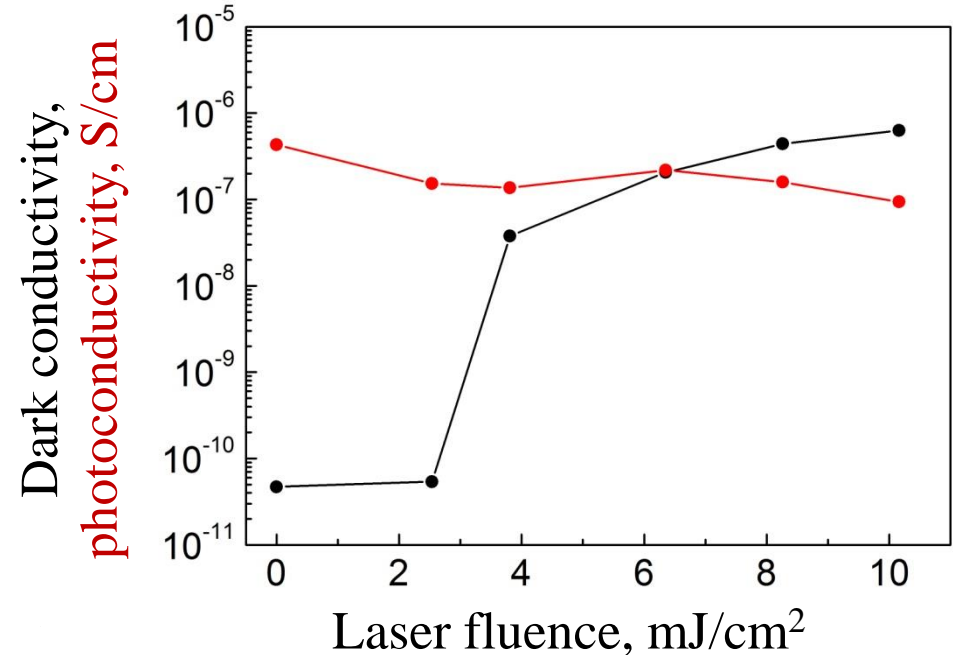
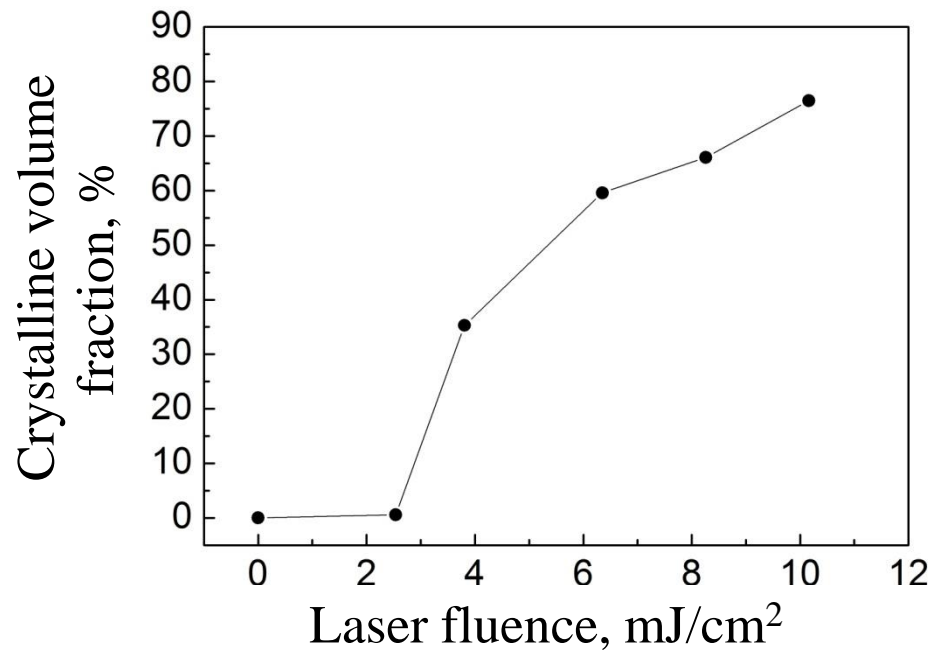
Conductivity & Photoconductivity



Sharp increase of
dark conductivity

Decrease of
photoconductivity

Conductivity & Photoconductivity



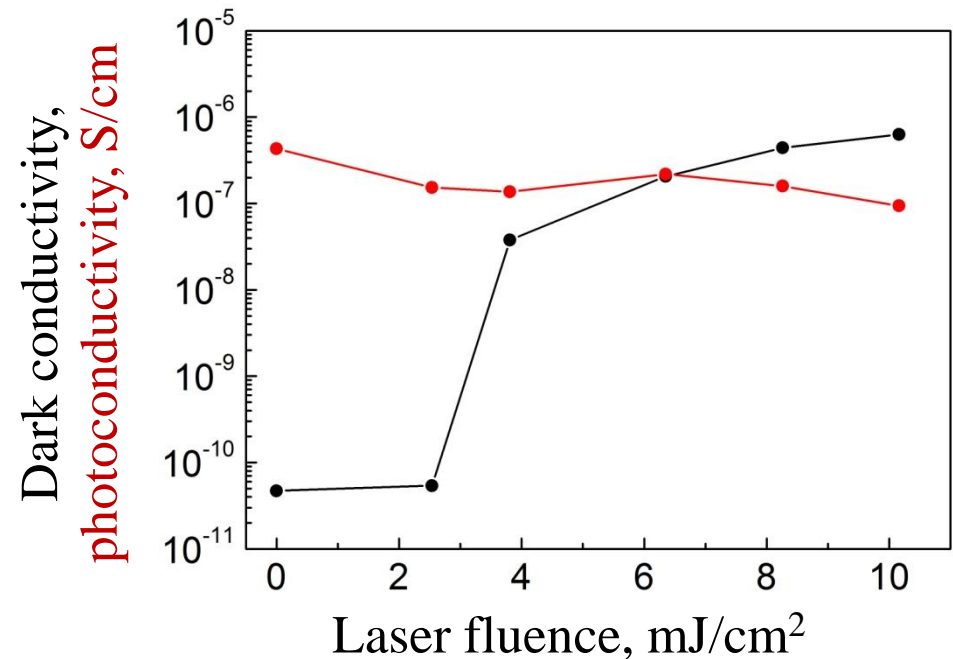
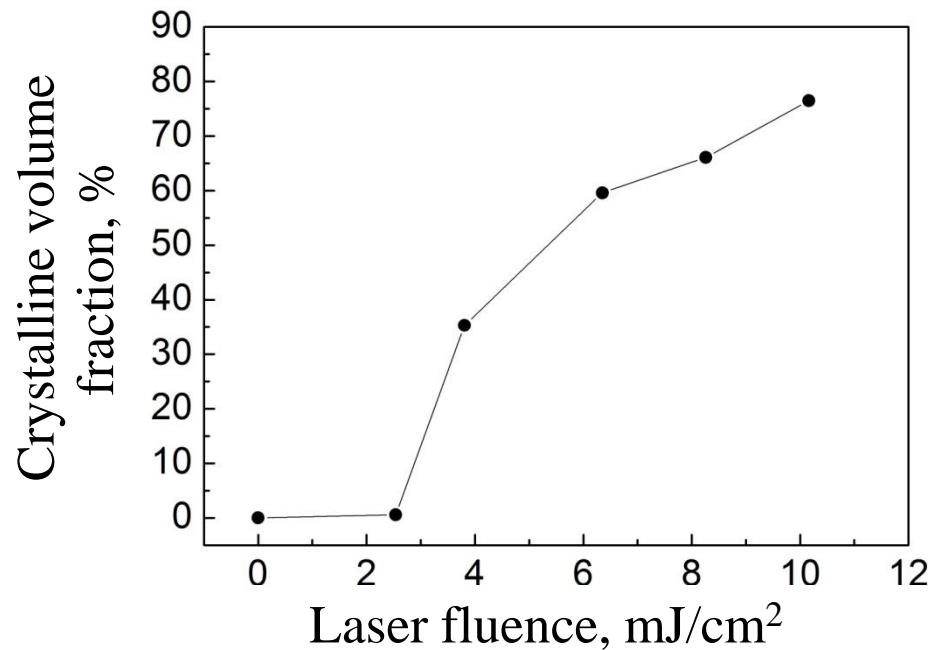
Percolation threshold



Sharp increase of dark conductivity

Decrease of photoconductivity

Conductivity & Photoconductivity



Percolation threshold



Sharp increase of dark conductivity

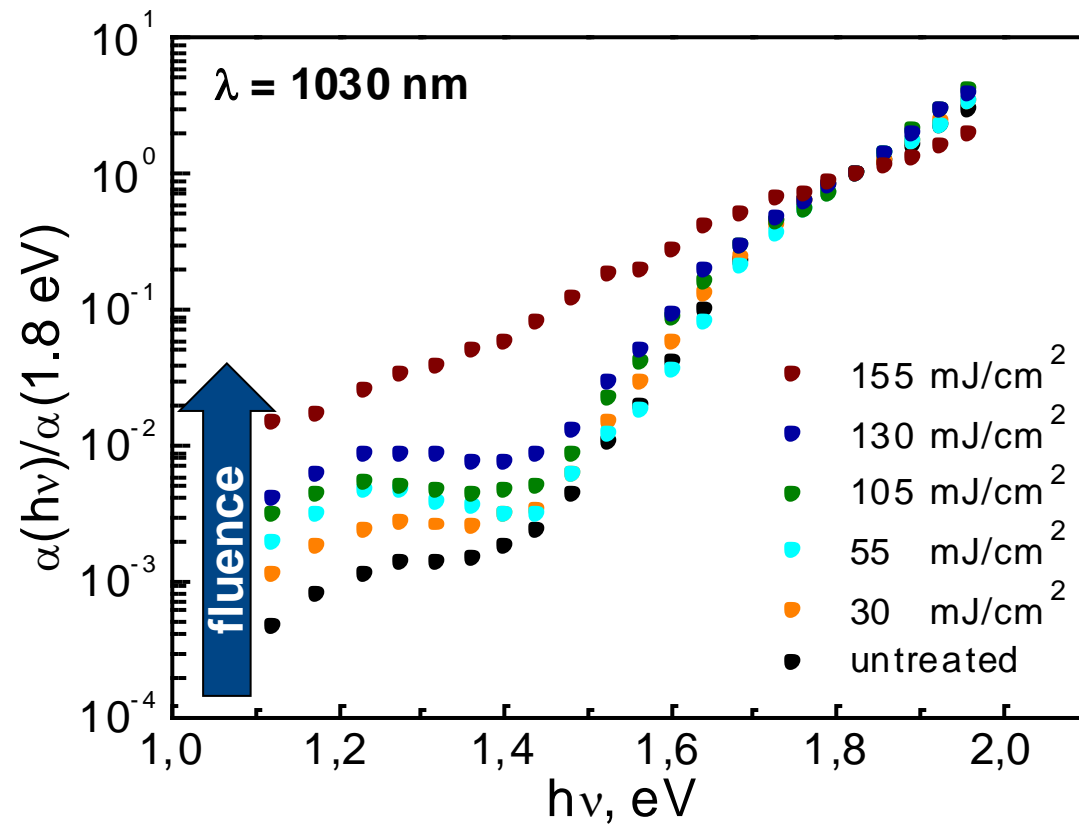
Defects



Decrease of photoconductivity

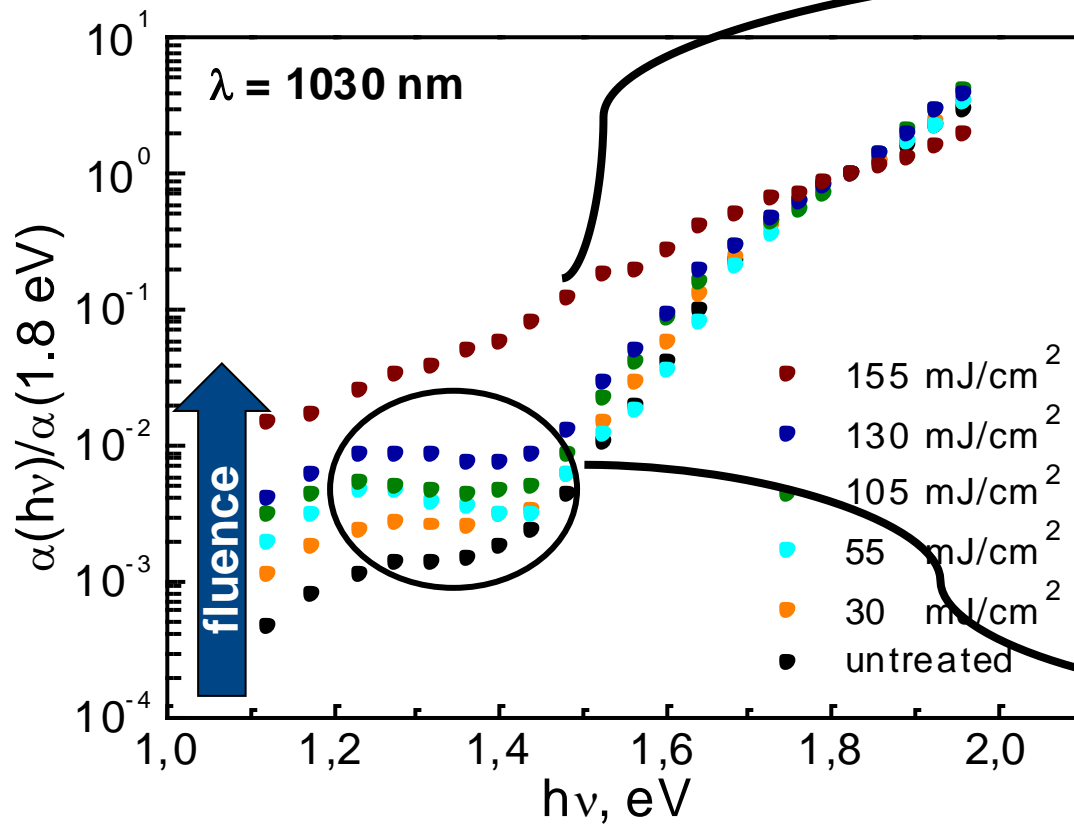
Absorption spectra

Constant photocurrent method (CPM)



Absorption spectra

Constant photocurrent method (CPM)

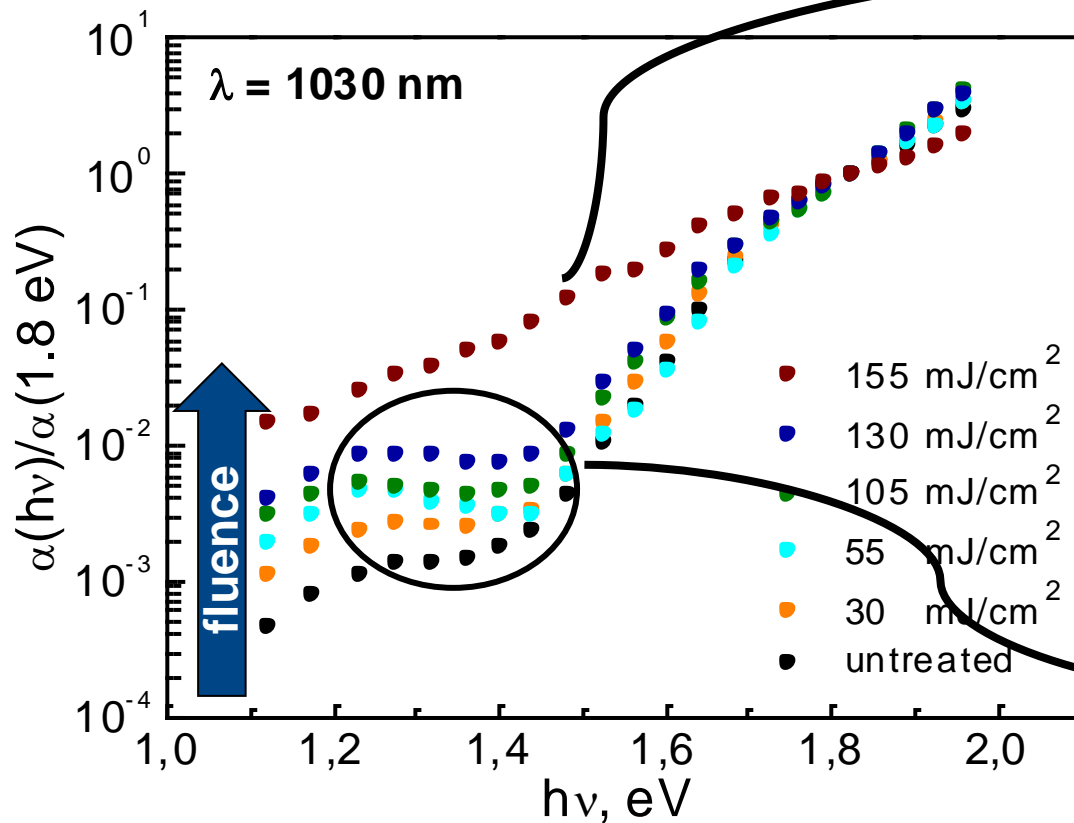


“nc-Si:H type”

“a-Si:H type”

Absorption spectra

Constant photocurrent method (CPM)

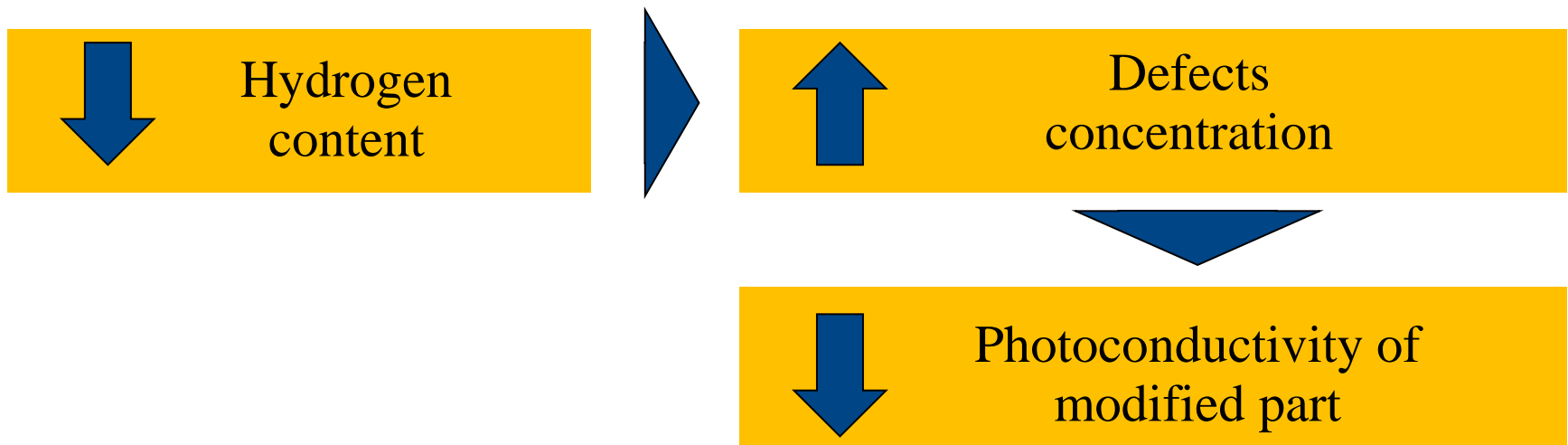
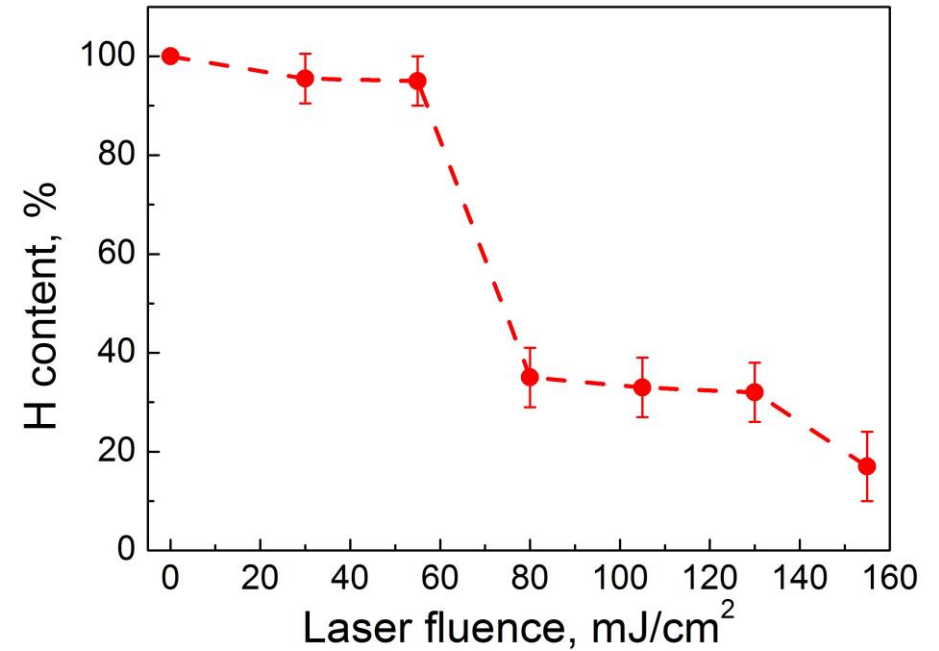
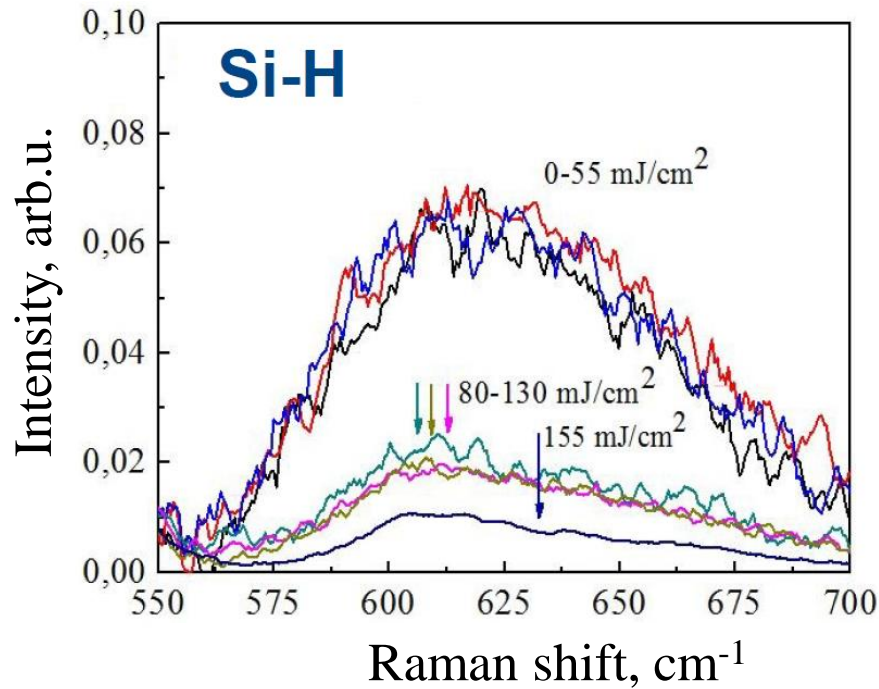


“nc-Si:H type”

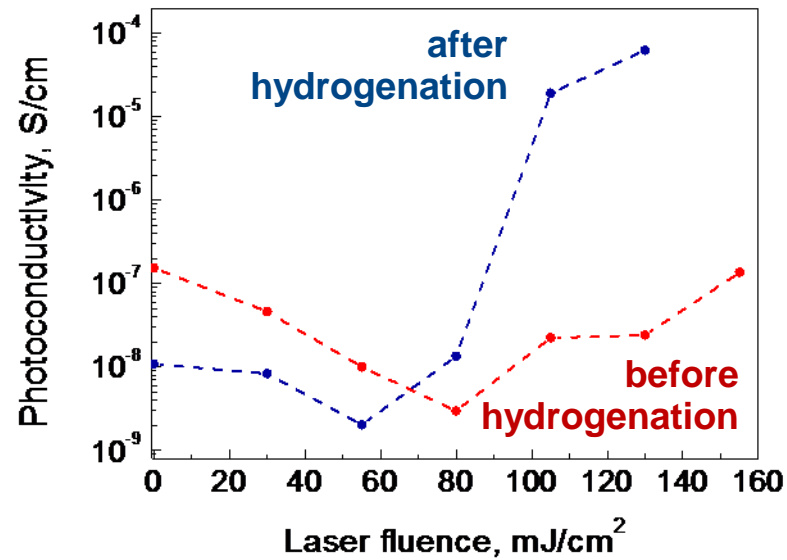
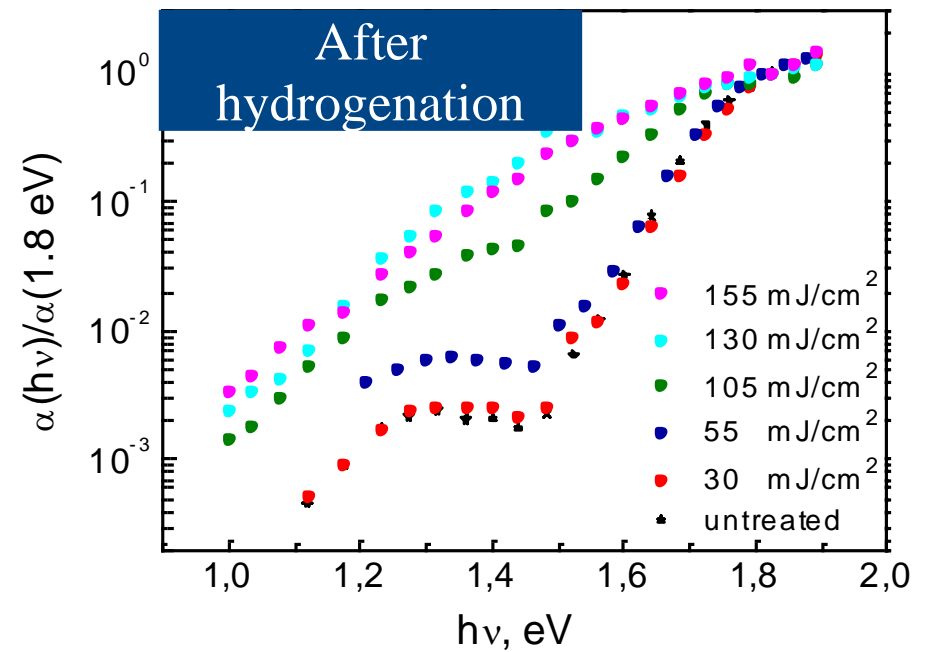
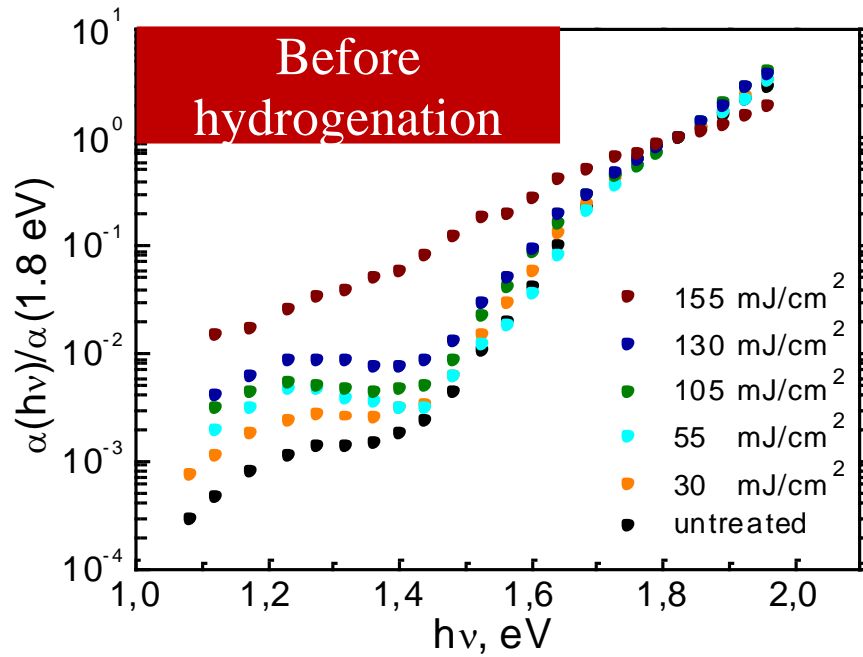
“a-Si:H type”

No impact from Si nanocrystals on photoconductivity!

Hydrogen content change

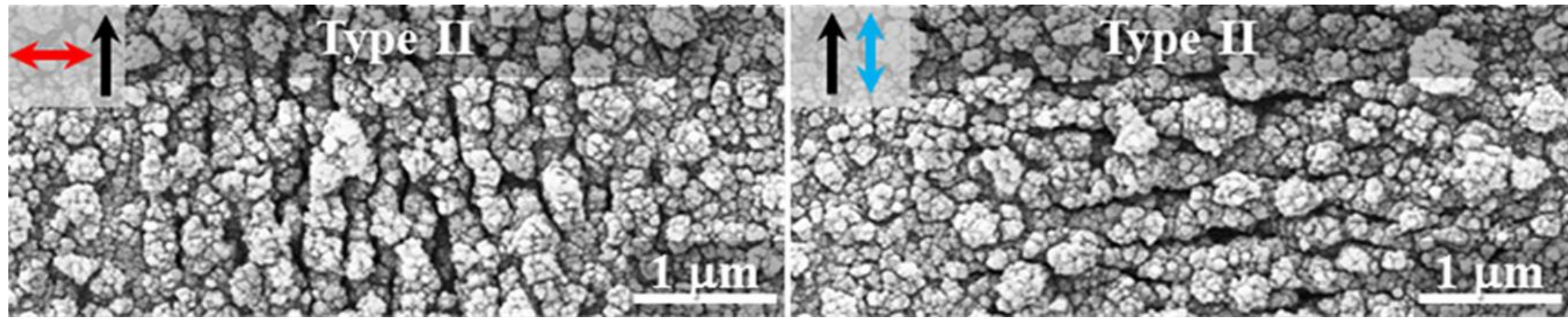


Post-hydrogenation



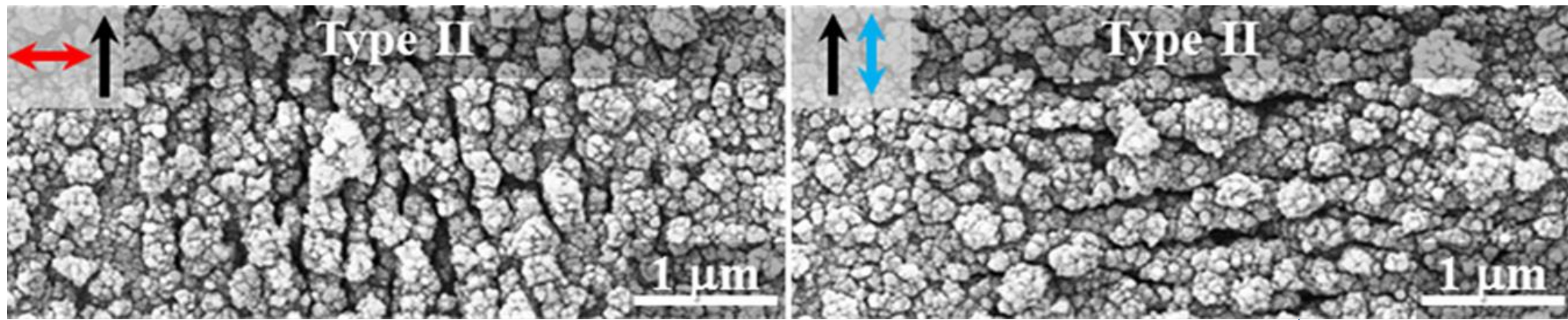
Periodic surface structures

SEM

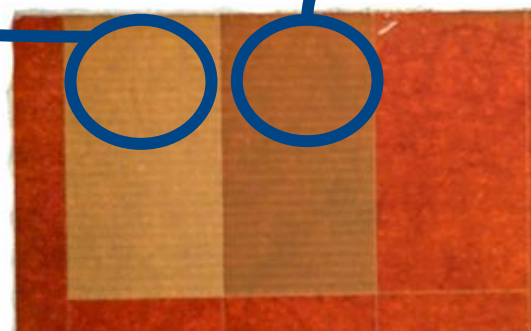


Periodic surface structures

SEM

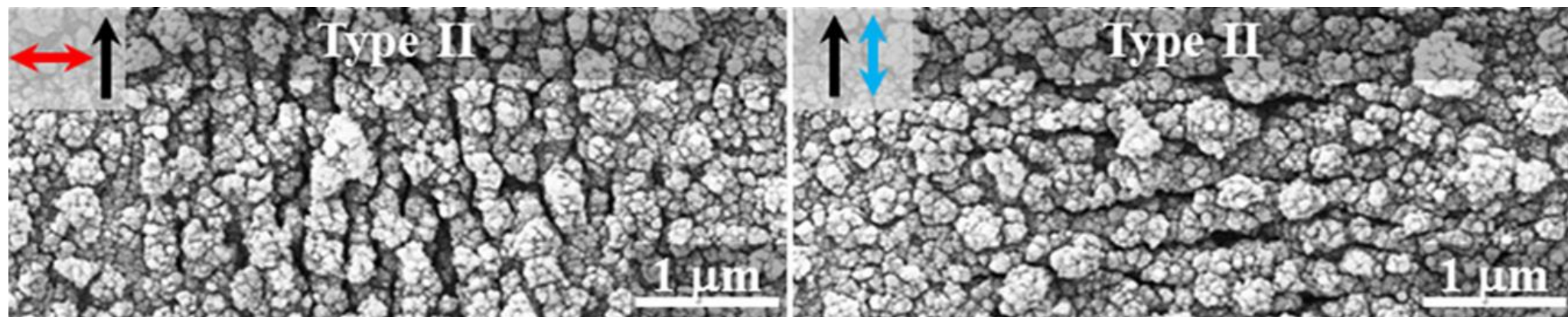


Transmission in polarized light:

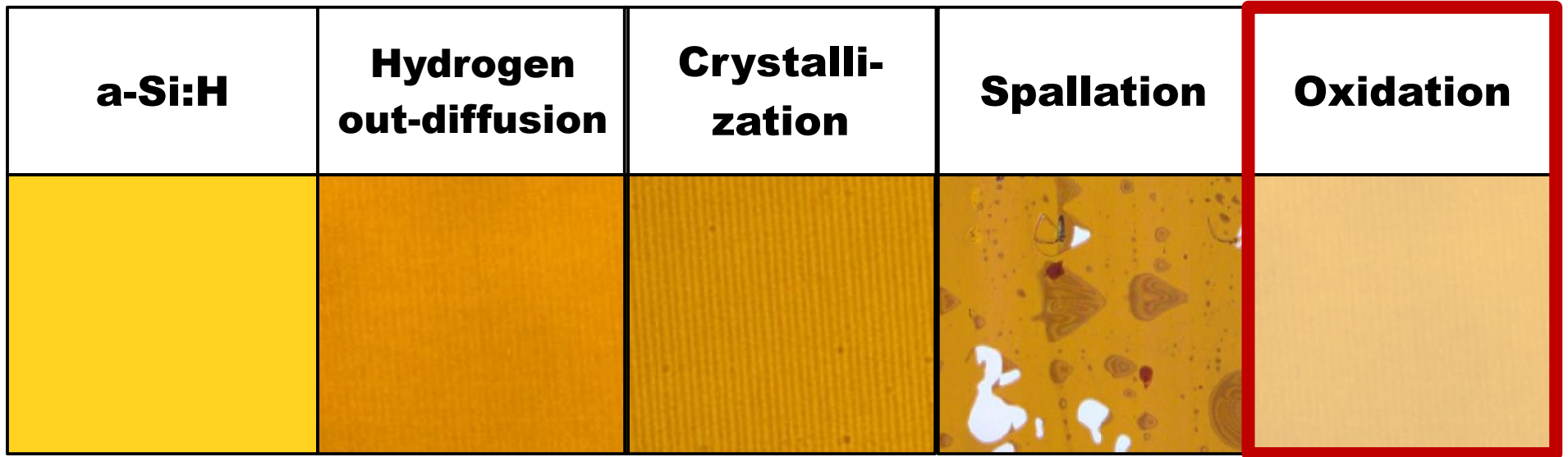


Polarization sensitive imaging

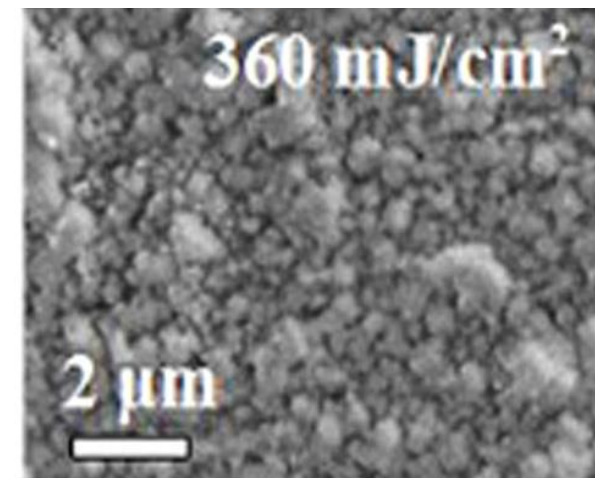
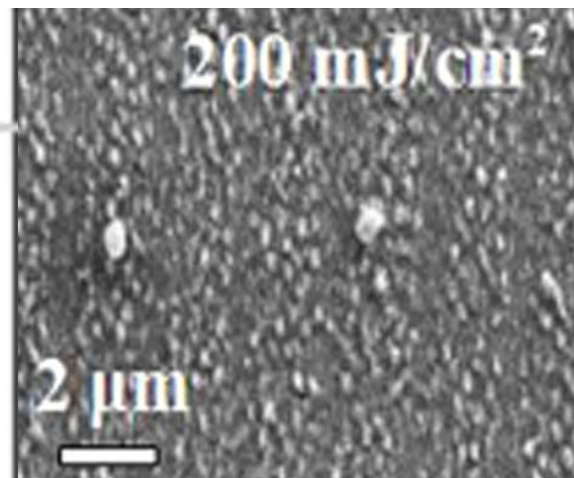
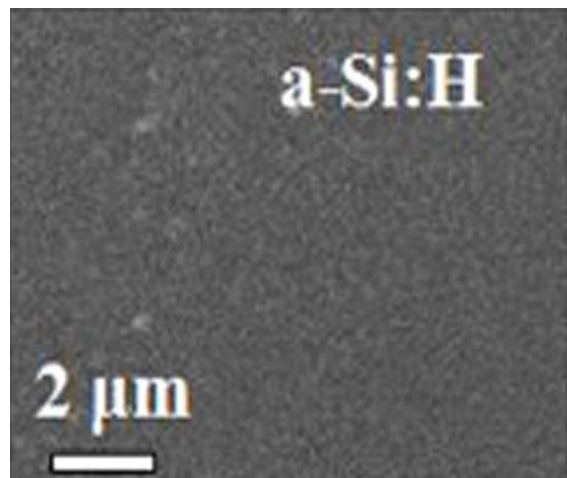
SEM



Structural modification

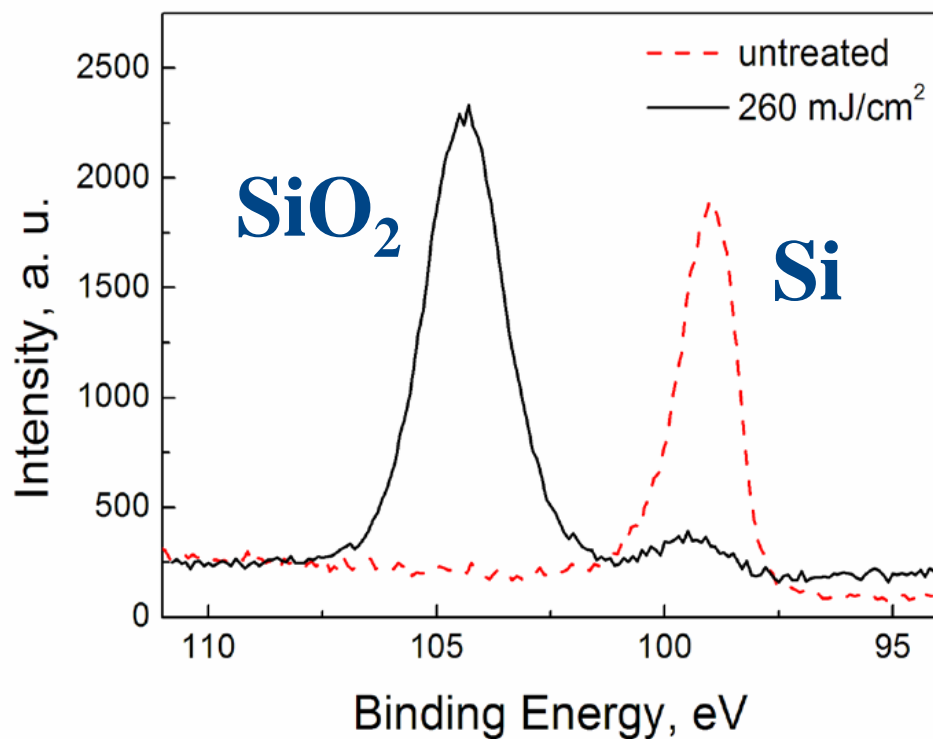


SEM

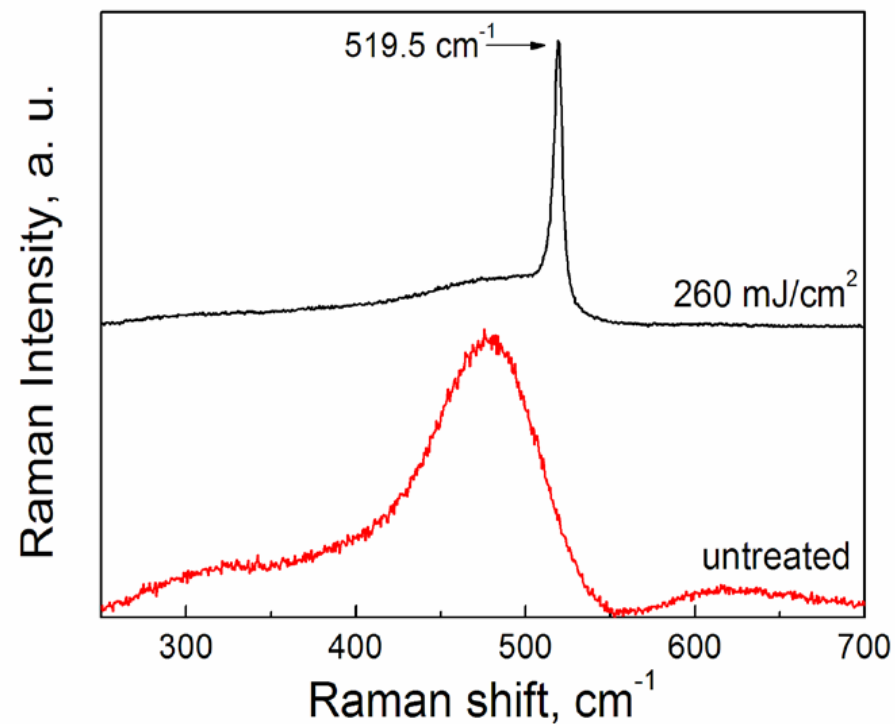


Structure of oxidized films

XPS

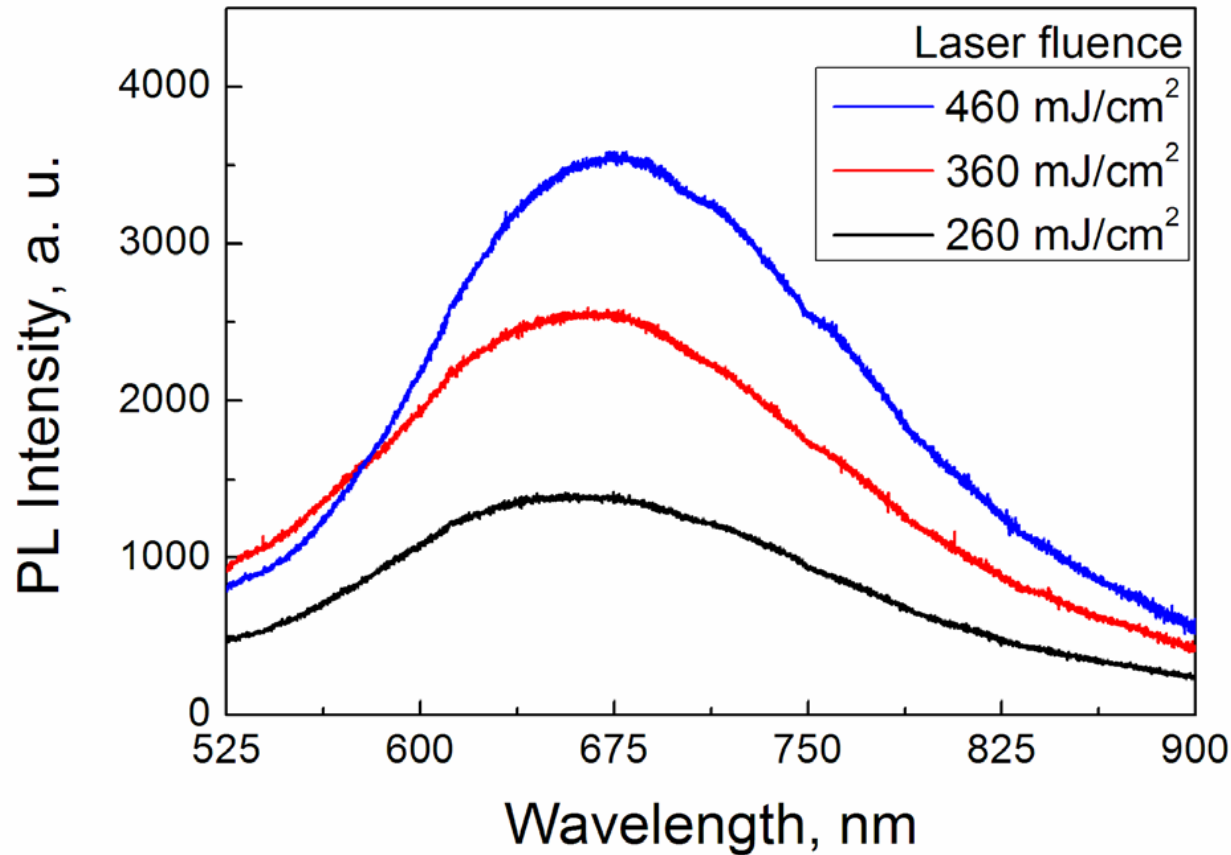


Raman spectroscopy



10% of Si in SiO₂ matrix

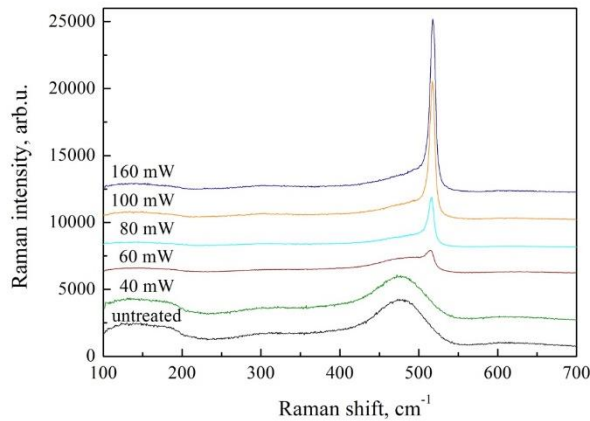
Photoluminescence (PL) of oxidized films



$$\lambda_{\text{exc}} = 488 \text{ nm}$$

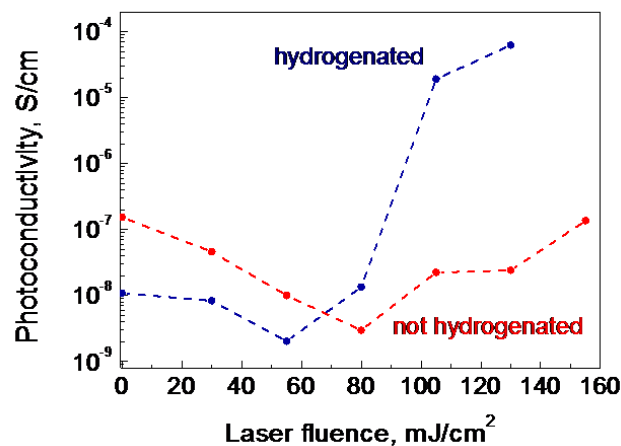
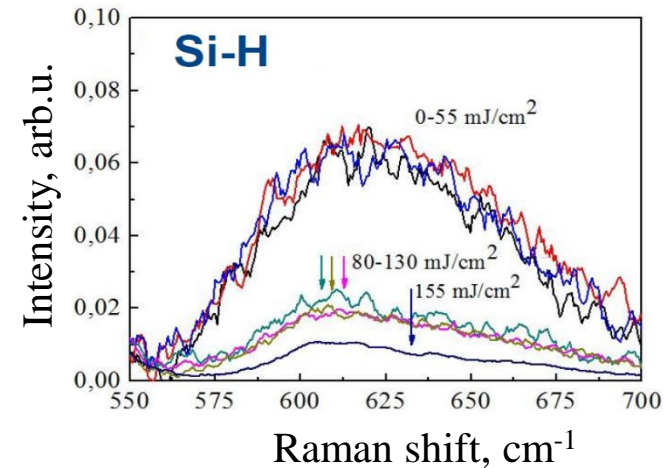
Downshifting for solar cells?

Conclusions



a-Si:H films can be crystallized by femtosecond laser treatment with control of crystalline volume fraction and it's distribution over the films' thickness

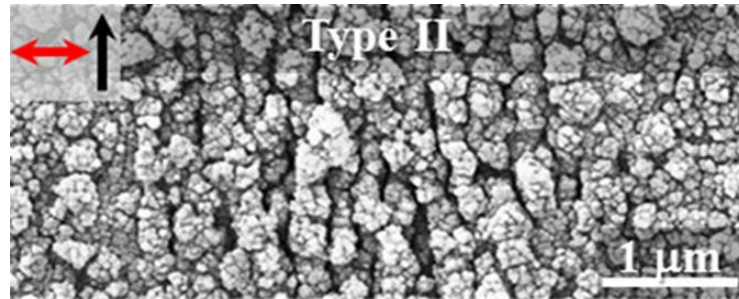
Modified part shows little contribution into films photoconductivity due to hydrogen out-diffusion



Post-hydrogenation allows to restore partially hydrogen content in the films and increase their photoconductivity

Conclusions

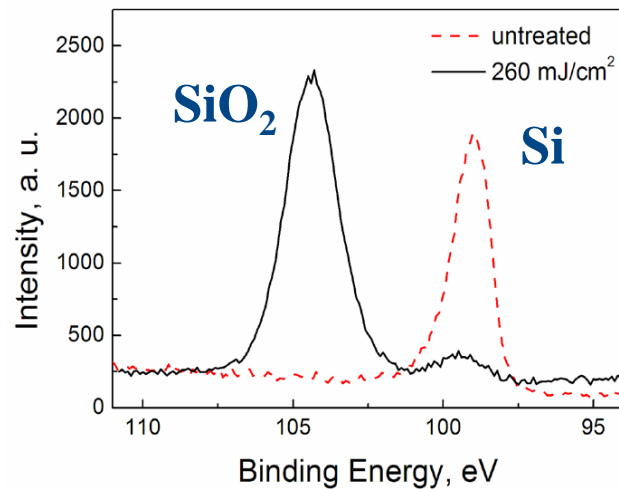
Periodic surface structures



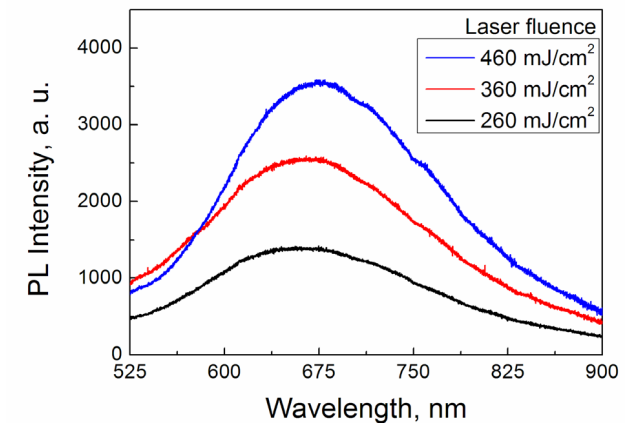
Polarization sensitive imaging



Partial oxidation



Visible photoluminescence



Thank you for your attention