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Post-deposition Catalytic-doping of Microcrystalline Silicon Thin-layer for the Application in Silicon Heterojunction Solar Cell

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Research Center Jülich

Finance

- Budget: 525 Mio. €
- Third Party: ~ 191 Mio. €

Personnel

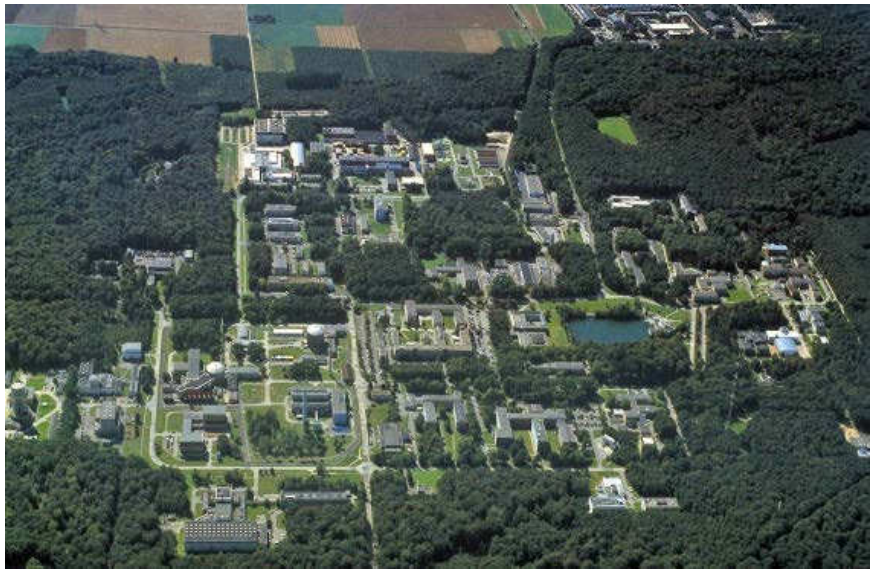
- Staff: 5.800
- scientists: 2.074 (incl.PhDs) + 907 guest scientists from more than 45 countries

Scientific Output

- 8.500 patents
- 192 licenses
- 1.800 articles/year

Research Area

- **Energy and Climate**
- Health
- Information Technology



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IEK5-Photovoltaics

Staff: 120
Scientists: ~25
Students : ~25

- **Thin-film technology for silicon wafer solar cells**
- Si thin-film solar cell application platform
- Novel thin-film materials and concepts
- Thin-film analytics and modeling

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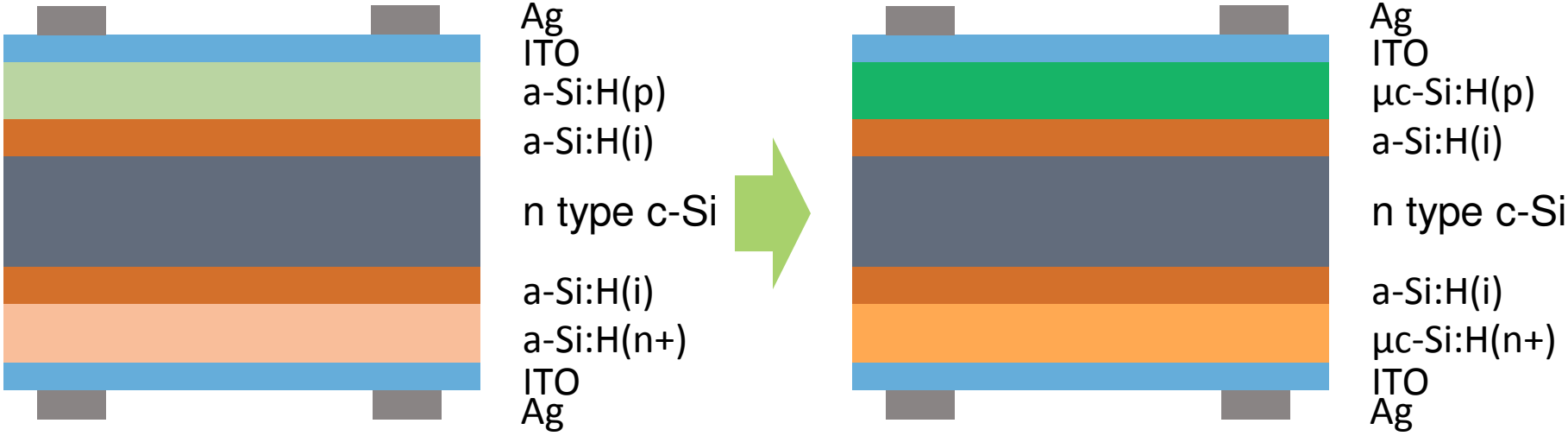
Silicon Heterojunction (SHJ) Solar Cell



- High V_{OC} due to excellent surface passivation
- Simple, low temperature and up-scalable processes for industrial production
- Compatible with thin wafer process

- µc-Si:H→FF↑
- rear emitter→ J_{SC}↑
- a-Si:H passivation→V_{OC}↑
- Efficiency ↑

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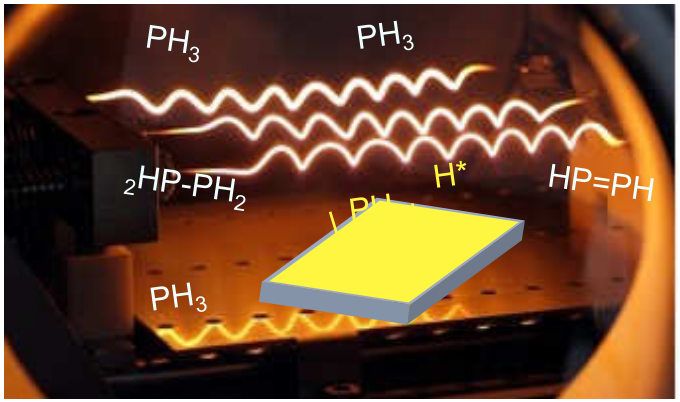
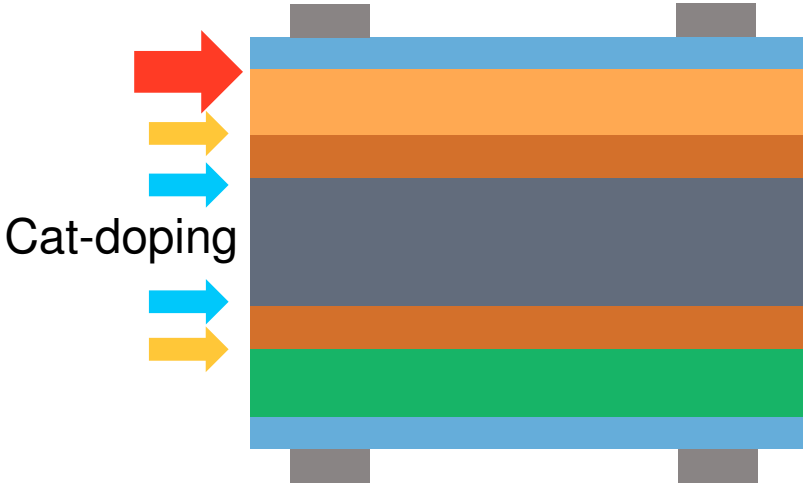
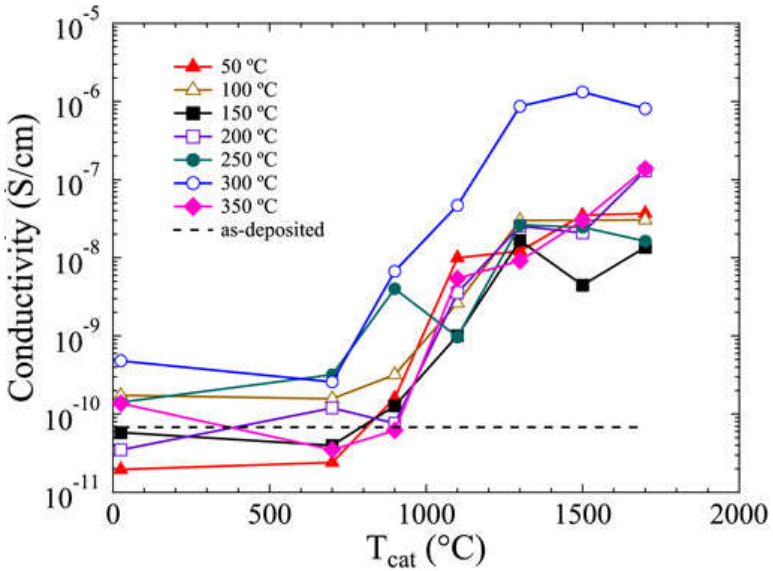
Cat-doping in µc-Si:H SHJ Solar Cell





- Low temperature
- Shallow doping depth
- Type conversion

- Improve lifetime by field effect/ H atoms
- Increase condutivity by post-doping
- Compatible with IBC solar cell process



S. Tsuzaki et al., *Jpn. J. Appl. Phys*. 54, 072301 (2015)
J. Seto et al., *Jpn. J. Appl. Phys.* 55, 04ES05 (2016)

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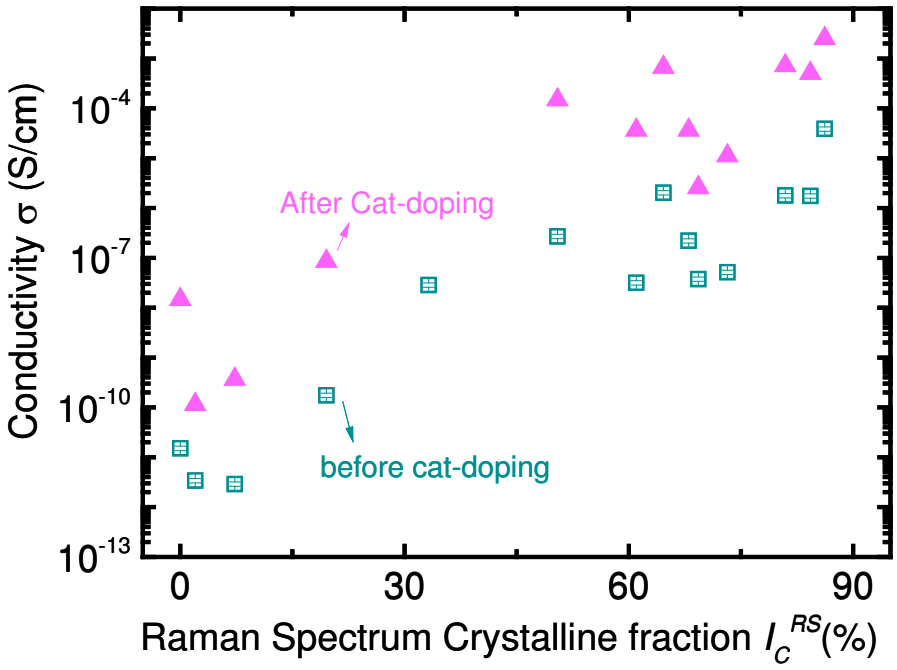
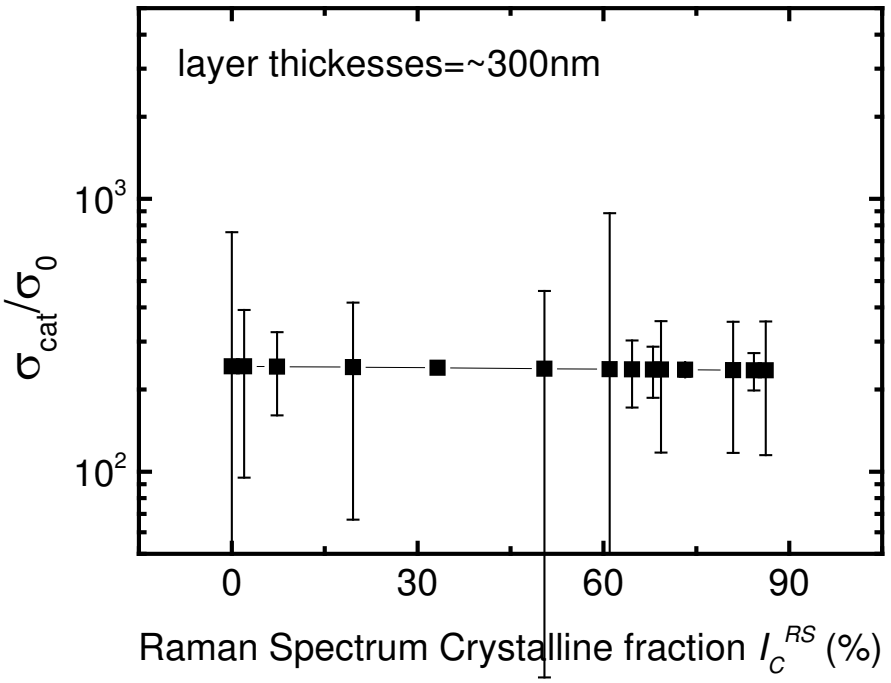
Cat-doping on µc-Si:H(i)

- $T_{wire} = 1300℃,\ T_{sub} = 150℃$
- $f_{PH3} = 20sccm, t = 10min$
- $Pressure = 1Pa,$ Distance $= 90$mm





- Cat-doping → Conductivity ↑
- Considering the doping depth, several orders of magnitude's improvement

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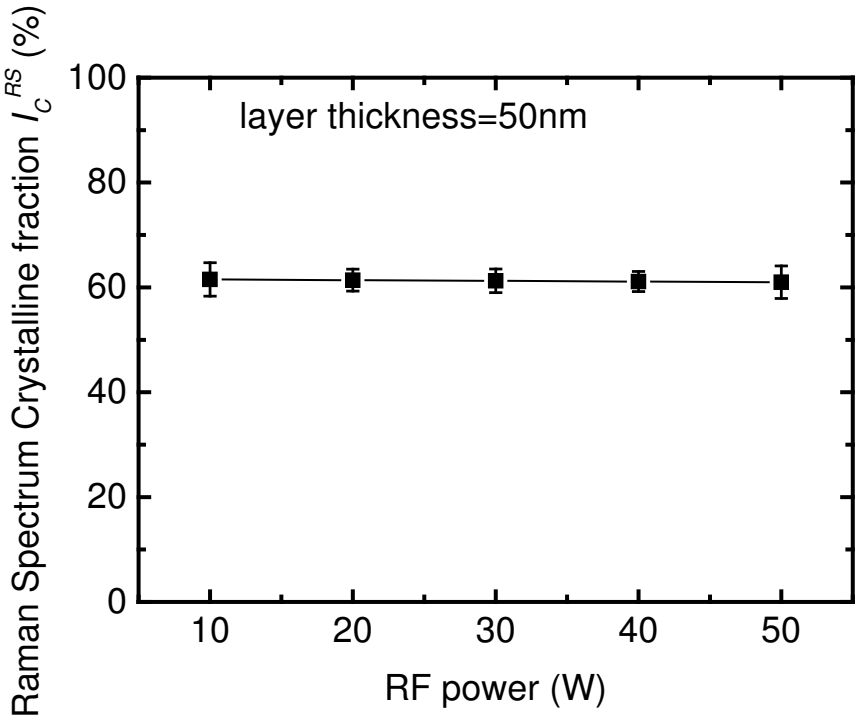
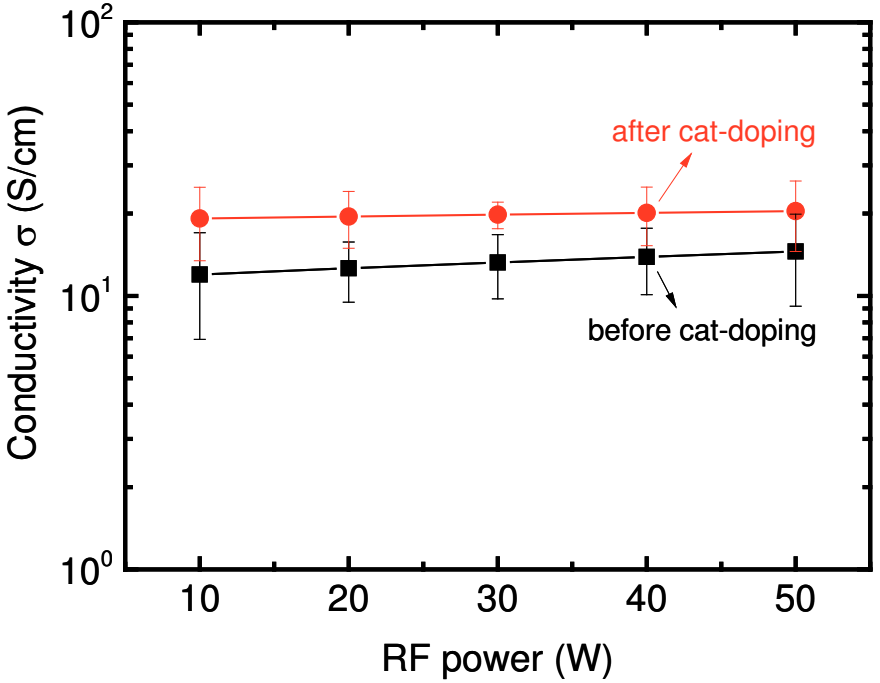
Cat-doping on µc-Si:H(n)

- $T_{wire} = 1300℃,\ T_{sub} = 200℃$
- $f_{PH3} = 20sccm, t = 10min$
- $Pressure = 1Pa,$ Distance $= 90mm$





- Crystallinity stayed in a small range though the RF powers changed in a big range
- Conductivity slightly increased after Cat-doping

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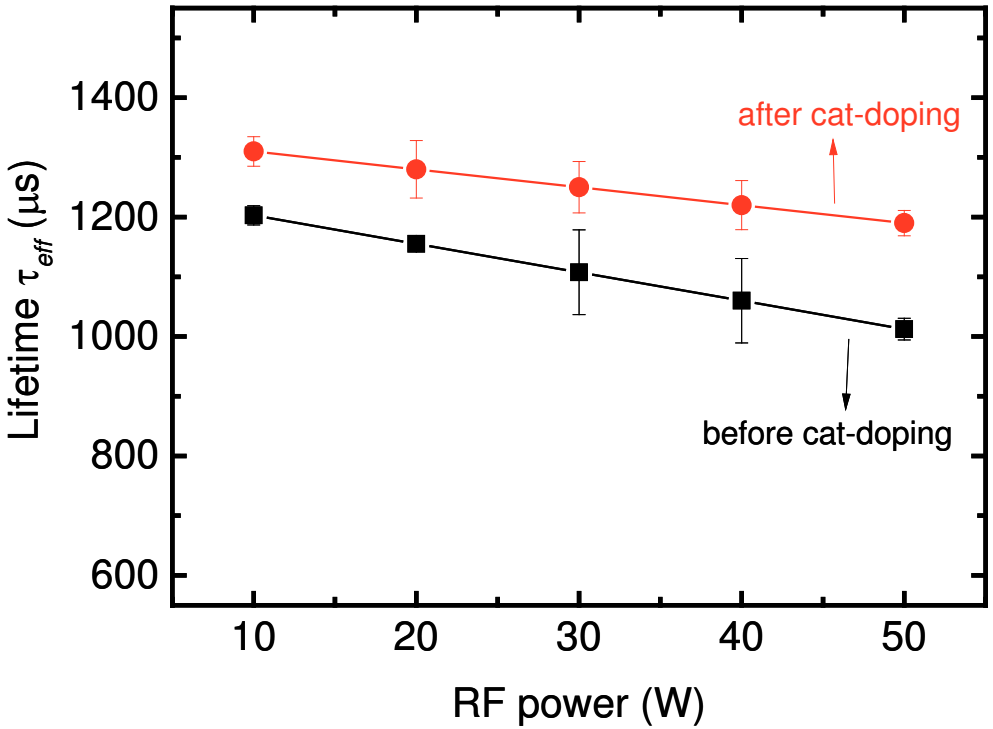
Cat-doping of µc-Si:H(n) on wafers

- $T_{wire} = 1300℃,\ T_{sub} = 200℃$
- $f_{PH3} = 20sccm, t = 10min$
- $Pressure = 1Pa,$ Distance $= 90$mm



- Lifetime decreases with increasing RF power probably due to ion bombardment effect
- Lifetime improved after CAT-doping probably due to the field induced passivation

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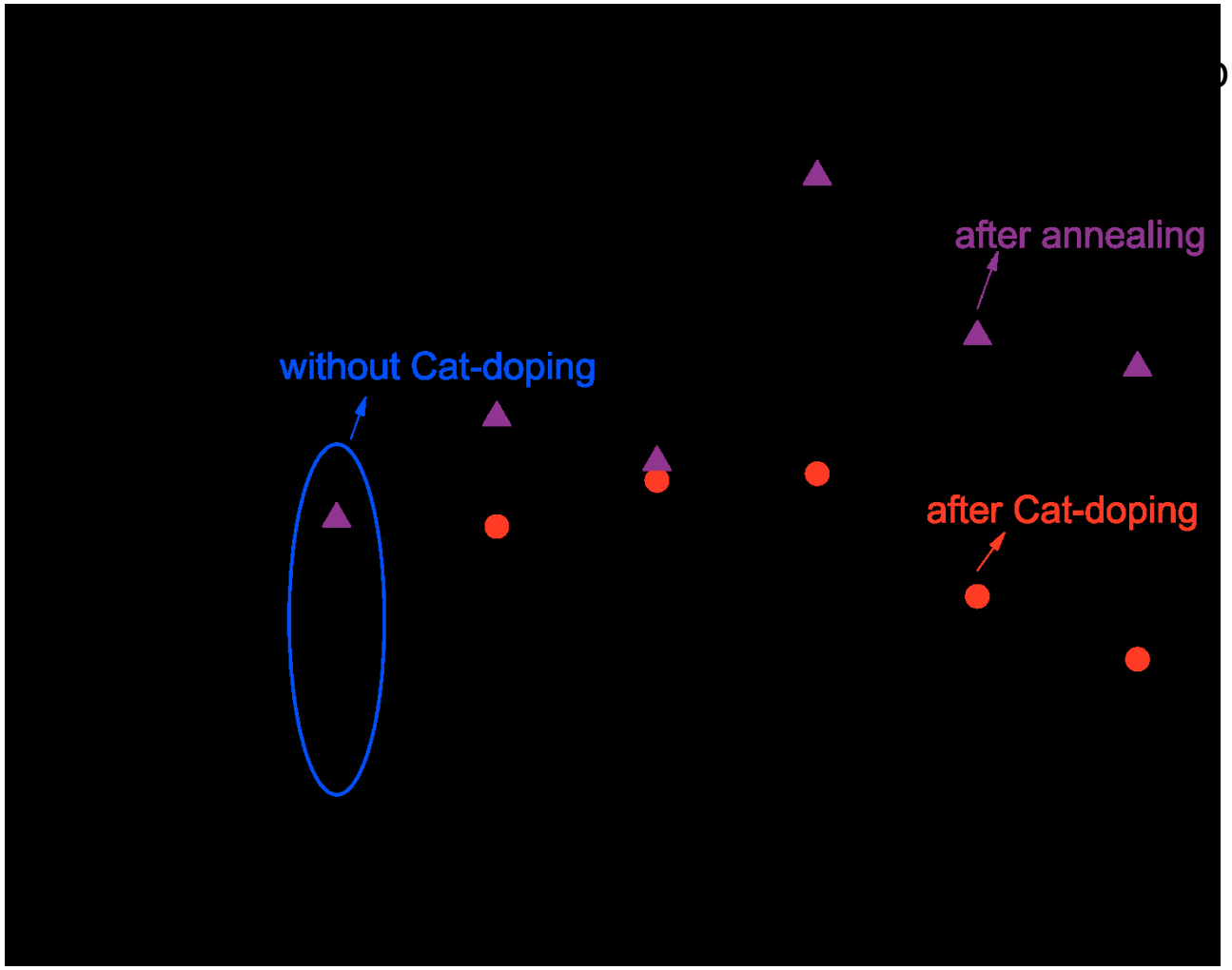
Cat-doping with different T_{wire}



- Cat-doping can improve lifetime by field effect
- After annealing, more P atoms are activated

- $T_{sub} = 200℃$
- $f_{PH3} = 20sccm, t = 10min$
- $Pressure = 1Pa,$ Distance $= 90$mm

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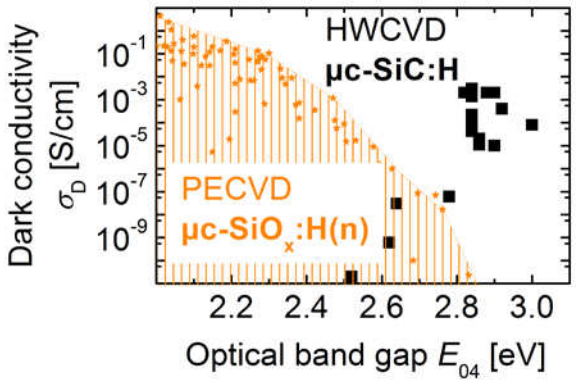
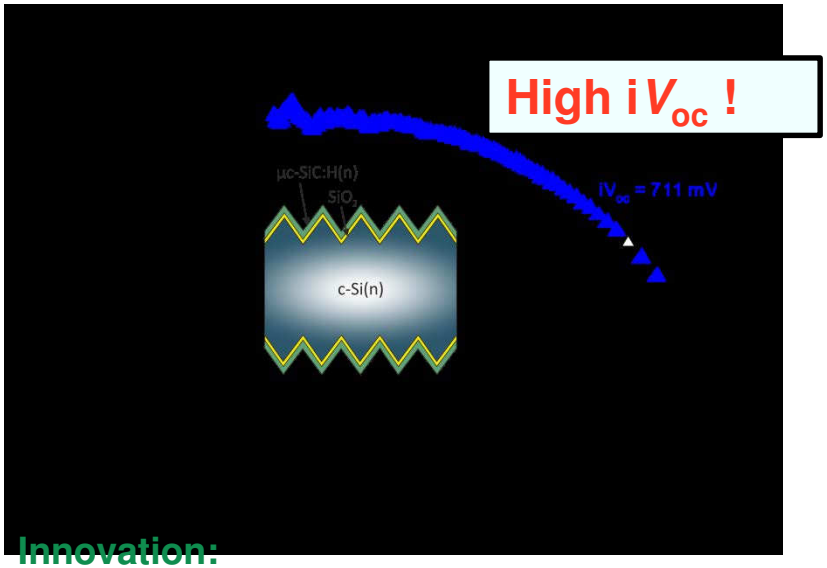
µc-SiC:H(n) using HWCVD





Main material features:

- High transparency (2.6-3.0 eV)
- High refractive index (2.6-3.0)
- High electrical conductivity (up to 14 S/cm)

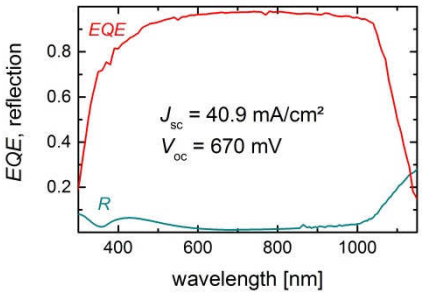
Innovation:

Combine wet-chemical SiO_2 and µc-SiC:H(n) for passivated and transparent front side

Classical SHJ solar cell

Ag/ITO/**µc-SiC:H(n)/SiO$_2$**/
c-Si(n)/
a-Si:H(i)/µc-SiO$_x$:H(p)/ITO/Ag

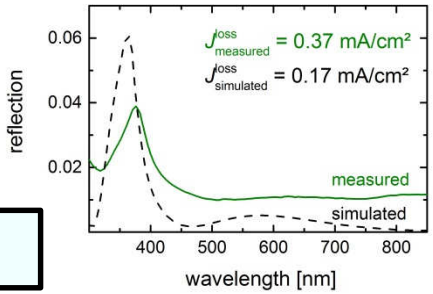
High J_{sc} !



IBC - SHJ solar cell

MgF$_2$/SiN$_x$/**µc-SiC:H(n)/SiO**
c-Si(n)/
a-Si:H(i)/IBC

Low reflection !



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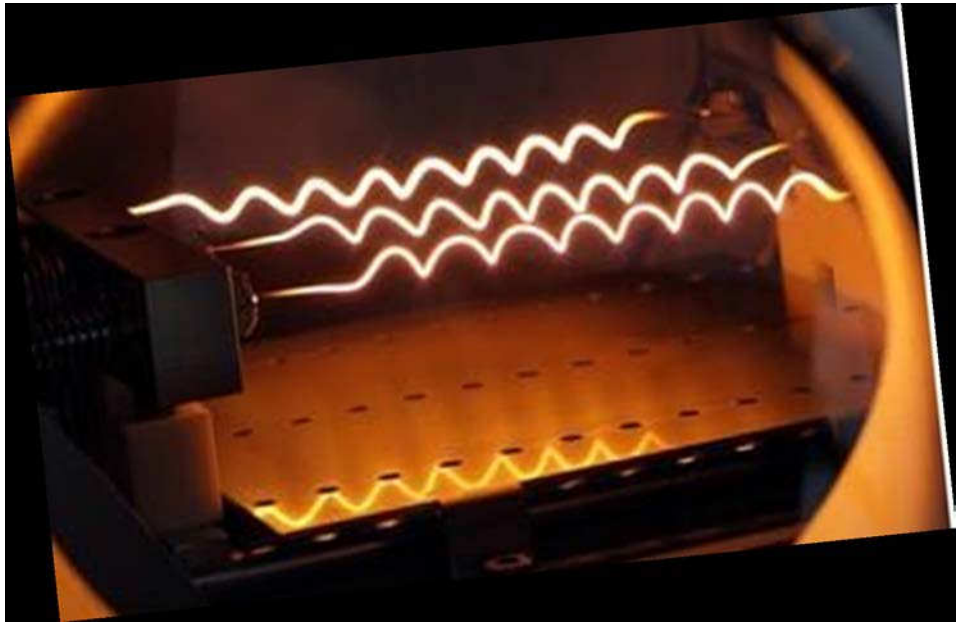
Summary and Outlook

- Cat-doping can dope both intrinsic and n-type µc-Si:H
- Cat-doping can improve the τ_{eff} of SHJ solar cell with µc-Si:H and give the highest τ_{eff} at 900℃~1000℃
- Annealing can activate the P atoms which leads to further improvement

- P type Cat-doping of µc-Si:H
- Performance of cell with Cat-doping
- IBC-SHJ solar cell using Cat-doping



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Thanks

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