

Journal Name

ARTICLE TYPE

Supplementary Information

Table 1 The intensity ratio of the undoped to doped absorbers under different excitation energy(W/cm^2)

Excitation energy	0.212	0.282	0.360	0.445	0.535
Ratio	5.096	4.942	5.071	5.531	5.796

Table 2 The element content of the annealed absorbers detected by EPMA(%)

Temperature	Cu	Zn	Sn	Se	S	Na	K
Undoped							
480°C	24.06	14.40	14.85	44.72	1.32	0.64	0.01
495°C	23.45	14.08	13.44	47.22	0.85	0.96	0.01
510°C	22.89	13.87	12.83	48.56	0.76	1.09	0.01
525°C	22.35	13.54	12.62	49.46	0.93	1.09	0.01
540°C	25.16	15.21	13.17	44.72	0.79	0.94	0.01
Doped							
480°C	23.27	14.22	13.09	48.02	0.32	1.06	0.02
495°C	22.44	13.73	12.82	49.31	0.25	1.43	0.01
510°C	23.34	14.62	13.10	47.07	0.68	1.15	0.04
525°C	22.73	13.67	12.85	49.25	0.25	1.26	0.01
540°C	23.32	14.09	12.65	48.21	0.34	1.35	0.02

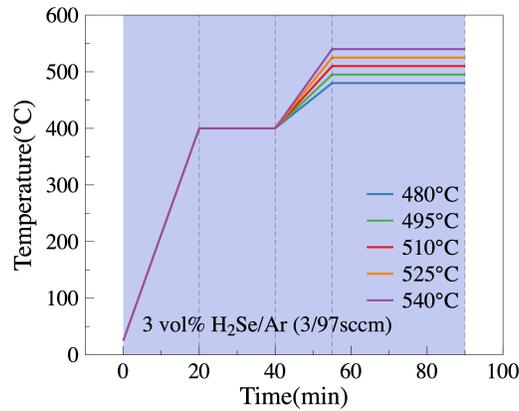


Fig. 1 The annealing temperature versus time in the atmosphere of 3vol.% H_2Se/Ar

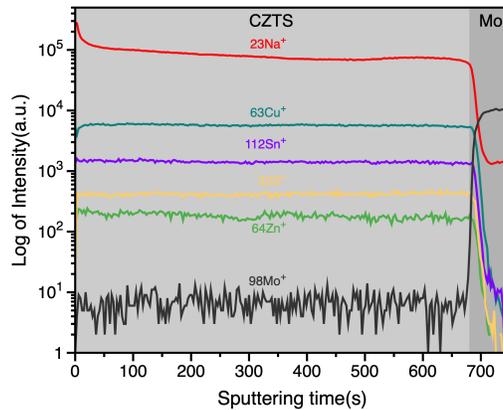


Fig. 2 SIMS depth profiling of in-situ sodium doped precursor, prepared by sputtering the quaternary CZTS ceramic target, in which 0.6at % sodium fluoride was pre-incorporated in.

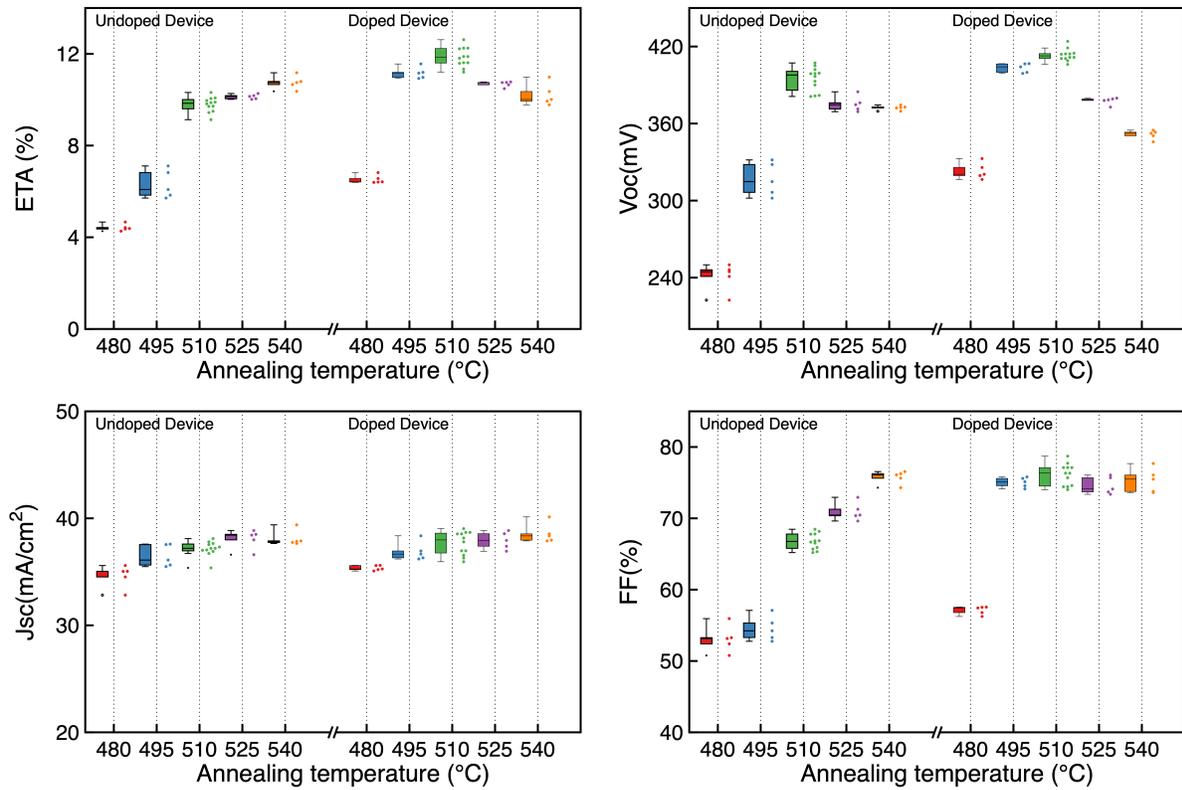


Fig. 3 Statistic box plots of the photovoltaic performance of solar cells with different selenization annealing temperature, respectively. Each group consists of at least 5 individual solar cells. For the optimal temperature (510°C), 12 individual cells were tested.

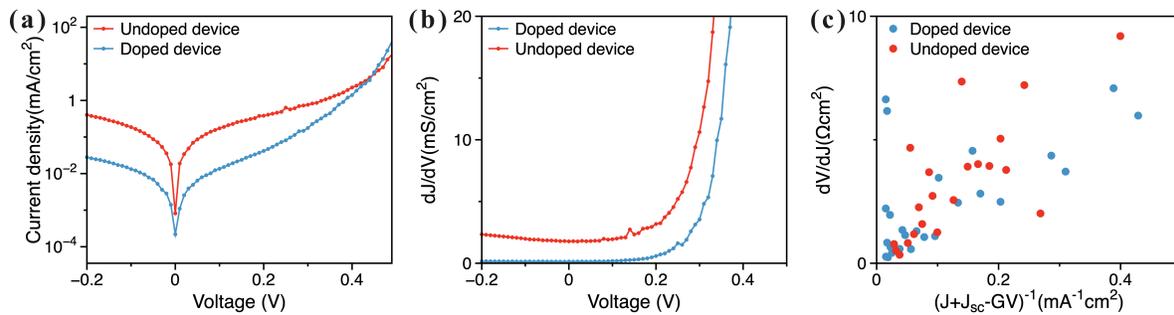


Fig. 4 (a) J-V curves of the undoped and doped devices measured in the dark, (b) Shunt resistance R_{sh} characterization, (c) Series resistance R_s and ideality factor A characterization.

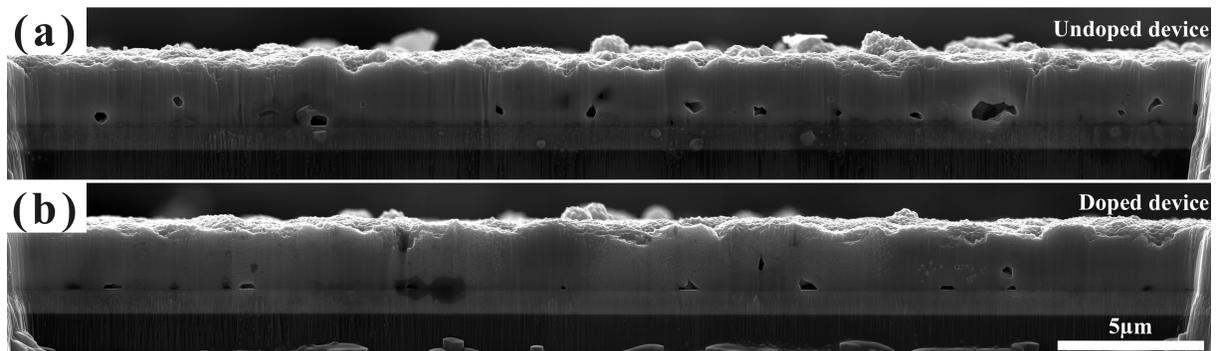


Fig. 5 Another focused ion beam cut cross section image of undoped and doped devices.

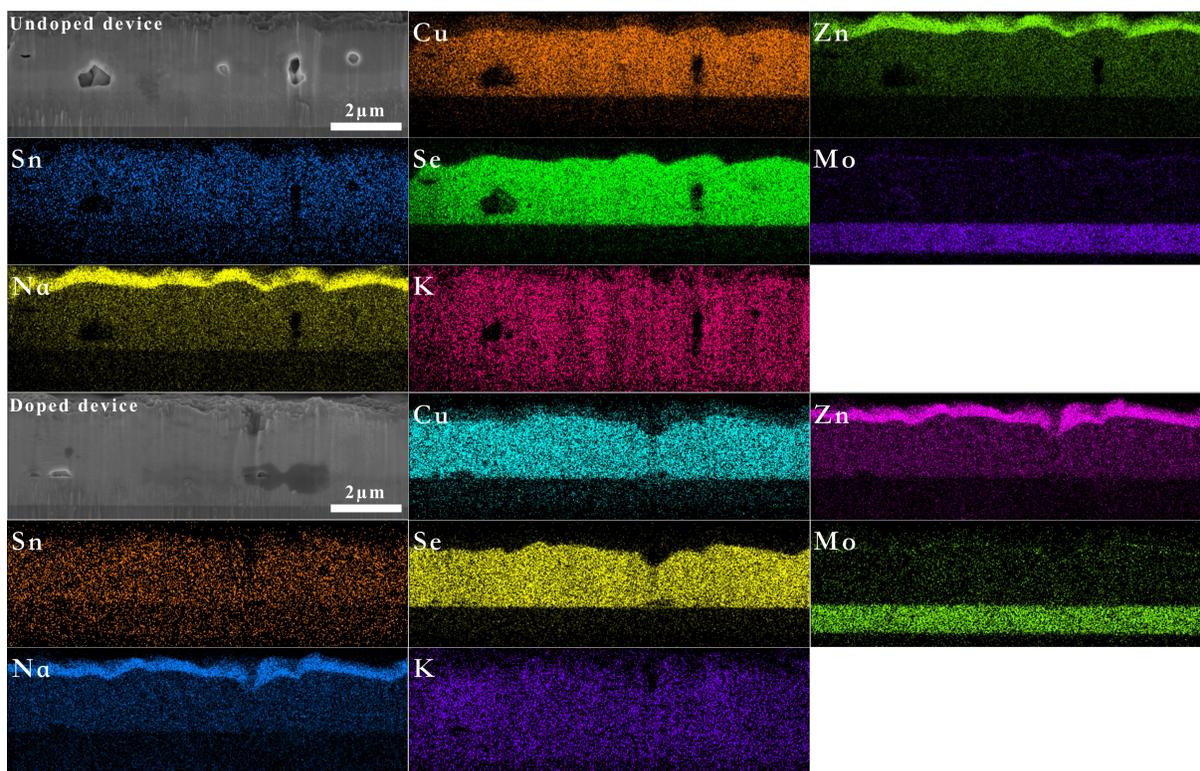


Fig. 6 EDS mapping of copper, zinc, tin, selenium, molybdenum, sodium and potassium on the FIB cut cross section of undoped and doped device. In this work, 5 nm thick platinum coating was applied to enhance the surface conductivity of sample, in order to avoid the charge accumulation on the surface. The dark area in Figure-S5(b) as well as on the surface SEM image of doped absorber could be caused by the different surface conductivity routing in uneven platinum coating.

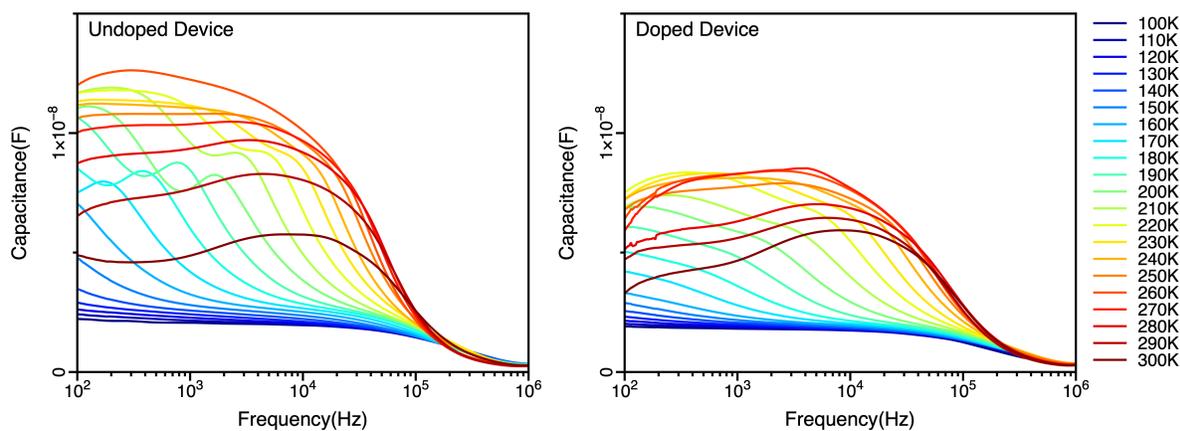


Fig. 7 Admittance spectroscopy(C-f-T) of undoped and doped device at different temperatures, the abnormal increased capacitance of device from 300K to 260K was explained as the enlarged defect capture cross sections as temperature decreased here.



中国认可
检测
TESTING
CNAS L2338

TEST REPORT

Report No: PWQC-WT-P23022421-1R

Sample Name : Photovoltaic cell

Client : Tsinghua University

Client Address : 30 Shuangqing Rd, Hai Dian, Beijing

Type of Project : Consignation

PHOTOVOLTAIC AND WIND POWER SYSTEMS QUALITY TEST CENTER, IEE,
CHINESE ACADEMY OF SCIENCES

February, 28, 2023



PHOTOVOLTAIC AND WIND POWER SYSTEMS QUALITY TEST CENTER, IEE,
CHINESE ACADEMY OF SCIENCES

Report No: PWQC-WT-P23022421-1R

Testing information: Date: February, 24, 2023 Location: No.6 Bei-er-tiao, Zhongguancun, Haidian district, Beijing, China Environmental conditions: 24.6°C, 29.5%RH		
Testing items: Measurement of photovoltaic current-voltage characteristics		
Standards: IEC 60904-1: 2006 Photovoltaic (PV) devices — Part 1: Measurement of photovoltaic current-voltage characteristics		
Equipments:		
Name	S/N	Expired date
Solar simulator	LE106-04	2023-06-15
Source Meter	LE177-01	2023-02-27
Digital millimeter	LE126-01	2024-02-22
Reference cell	J-CH04	2023-11-09

Edited

by(signatory): *Yang lei*

Date: 2023.2.28

Approved

by(signatory): *Jiang Feifei*

Date: 2023.2.28



太阳
检

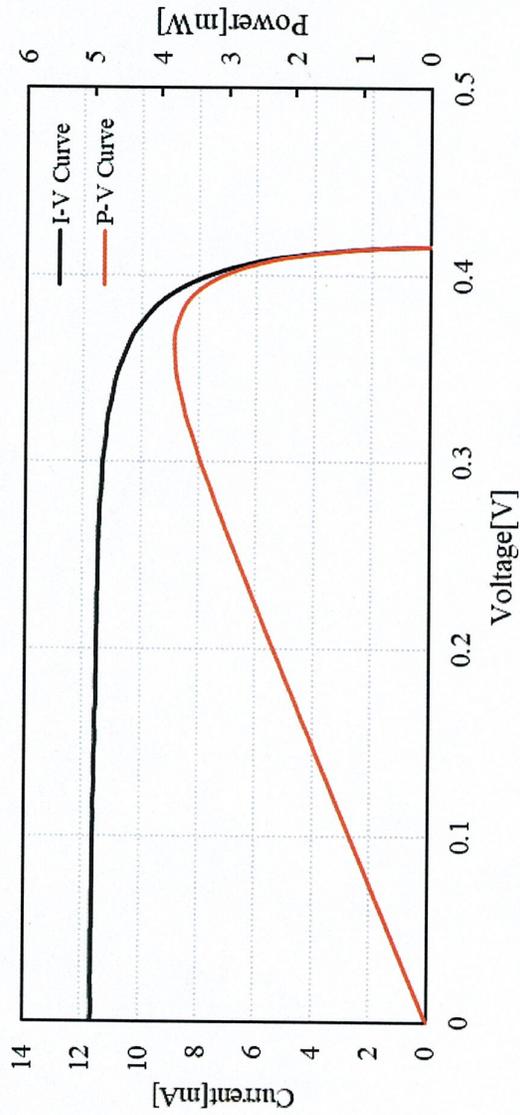
PHOTOVOLTAIC AND WIND POWER SYSTEMS QUALITY TEST CENTER, IEE,
CHINESE ACADEMY OF SCIENCES

Report No: PWQC-WT-P23022421-1R

Sample code	DC2023a007
Sample S/N	K-1
Type	Single Junction Kesterite Solar Cell
Designated area	0.30cm ² The designated area was provided by the client.

Items of testing	Measurement of photovoltaic current-voltage characteristics				
Sample code	DC2023a007				
Results	Isc (mA)	Jsc (mA/ cm ²)	Voc (V)	Pm (mW)	File A202302241 62456
	11.680	38.935	0.415	3.799	
	Ipm (mA)	Vpm (V)	FF (%)	E_{ff} (%)	
	10.409	0.365	78.33	12.66	
Measurement uncertainty:					
U _{95(Isc)} =1.9% (k=2)					
U _{95(Voc)} =1.8% (k=2)					
U _{95(Pm)} =2.5% (k=2)					

Type Single Junction Kesterite Solar Cell
 Ser.No DC2023a007



Area	0.3000 cm ²
Isc	11.680 mA
Jsc	38.935 mA/cm ²
Voc	0.415 V
FF	78.33 %
Pm	3.799 mW
E _{ff}	12.66 %
Ipm	10.409 mA
Vpm	0.365 V
Voltage Sweep	Reverse
Sweep time	1.41 s
Temp	25 °C
Irr	100 mW/cm ²
File	A20230224162456

— End of Report —

系统初

NOTICE

1. The test result in this report relate only to the sample tested.
2. This report is not available without seal of Photovoltaic and Wind Power Systems Quality Test Center, IEE, Chinese Academy of Sciences (PWQTC) . Additionally, Appendix pages are not available without seal of PWQTC.
3. The content of this report may not be changed. The report shall not be as any specific commercial advertisement without written permission of the PWQTC.
4. Any copy of this report is not available without seal of PWQTC.
5. This report may not be reproduced in any form or by any means, without permission in writing from the PWQTC.
6. Client could contact us for any questions within 15 days since the date when you received this report.

Address: No.6 Bei-er-tiao, Zhongguancun, Haidian district, Beijing, China

Post code: 100190

Fax: +86-10-82547052-607

Tel: +86-10-82547051

E-mail: pvcenter@mail.iee.ac.cn