High-performance hematite-integrated perovskite solar cells

Mustafa Kareem[1,2,*], Ethar Yahya Salih[3], Malatesh Akkur[4], Satish Kumar Samal[5], Sridharan Sundharam[6], Sanjeev Kumar[7]

[1]College of Remote Sensing and Geophysics, Al-Karkh University of Science, Haifa St., Baghdad 10011, Iraq
[2]College of Science, University of Warith Al-Anbiyaa, 56001 Karbala, Iraq
[3]College of Energy and Environmental Sciences, Al-Karkh University of Science, Baghdad 10081, Iraq
[4]Department of Physics &Electronics, School of Sciences, JAIN (Deemed to be University), Bangalore, Karnataka, India
[5]Department of Electronics & Communication Engineering Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
[6]Department of physics, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India
[7]Department of Physics, University Institute of Sciences, Chandigarh University, Mohali, Punjab, India

***Corresponding author email:** dr.mustafa@kus.edu.iq

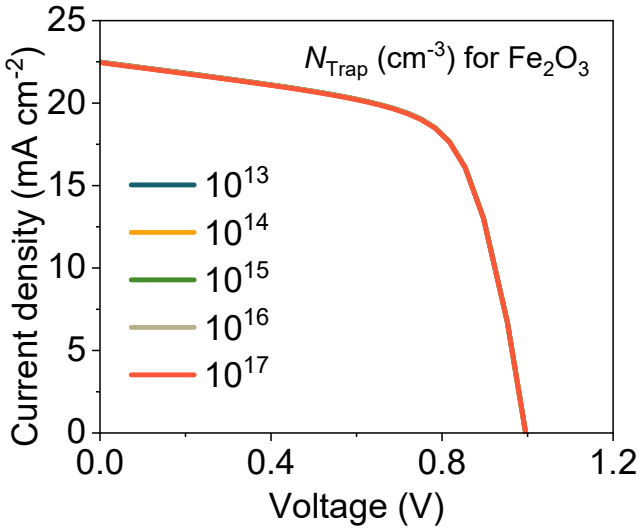

Figure S1: *J-V* curves of PSCs at different N_{Trap} concentrations in Fe_2O_3 ETL.

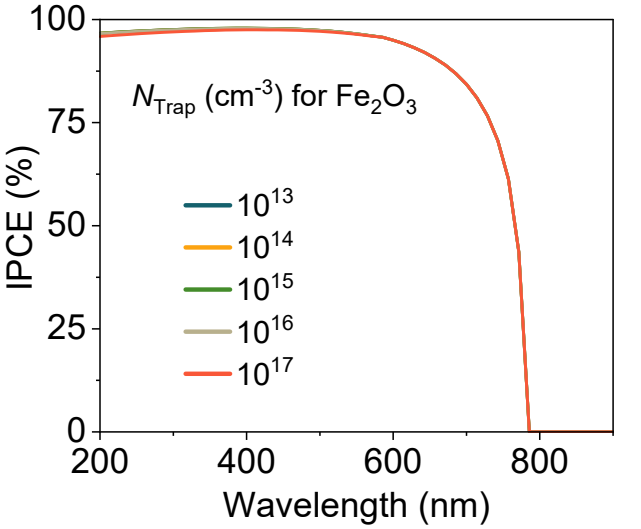

Figure S2: IPCE spectra of PSCs at different N_{Trap} concentrations in Fe_2O_3 ETL.

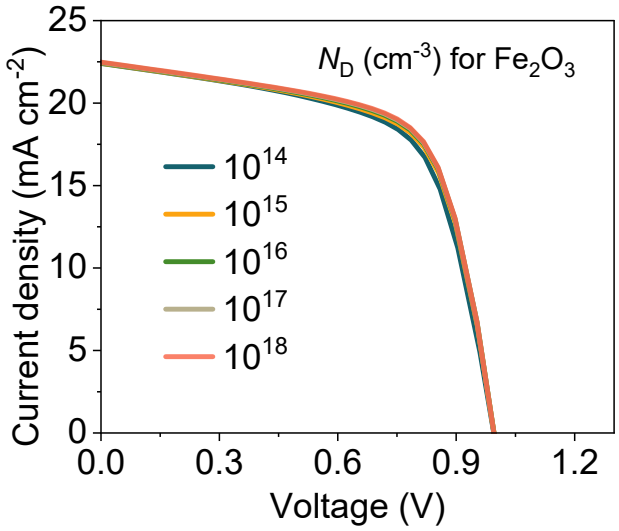

Figure S3: *J-V* curves of PSCs at different donor doping density (N_D) concentrations in Fe_2O_3 ETL.

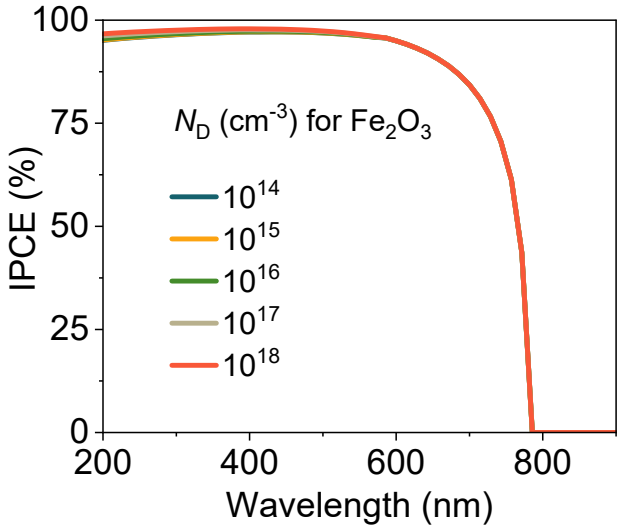

Figure S4: IPCE spectra of PSCs at different N_D concentrations in Fe_2O_3 ETL.

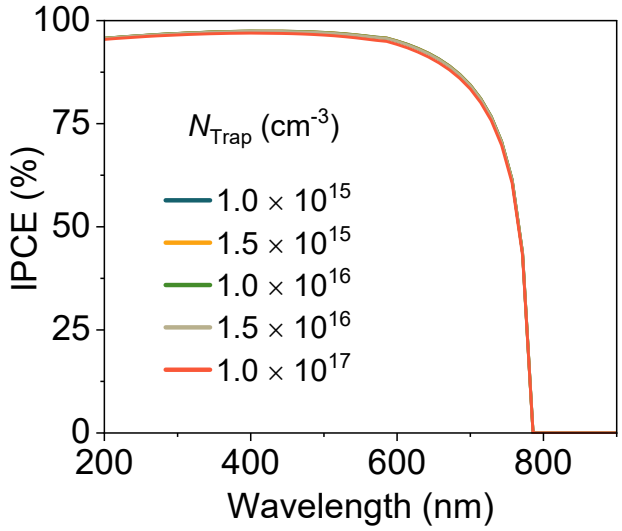

Figure S5: IPCE spectra of PSCs at different N_{Trap} concentrations in $MAPbI_3$ layer.

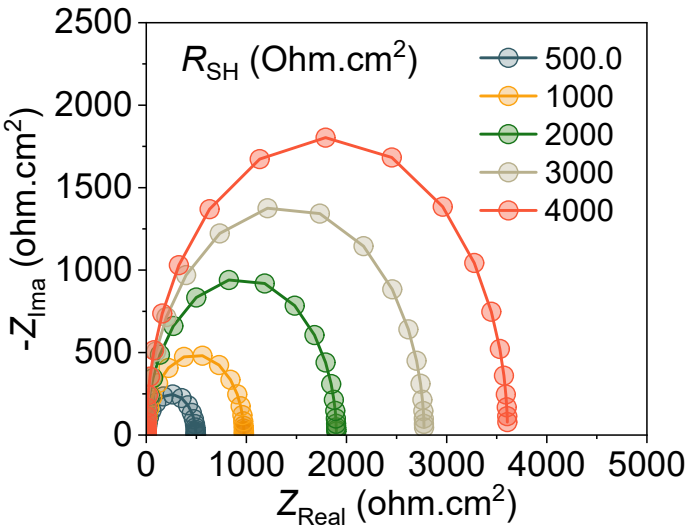

Figure S6: Nyquist plots of PSCs at shunt resistances.

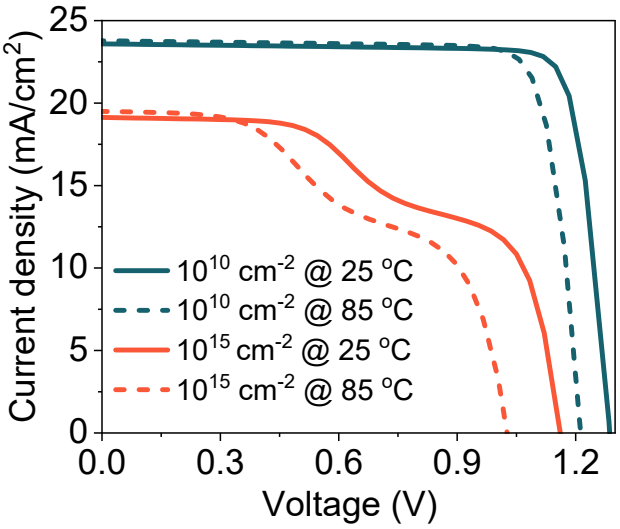

Figure S7: *J-V* curves of PSCs with changing interface defect density and operating temperature.

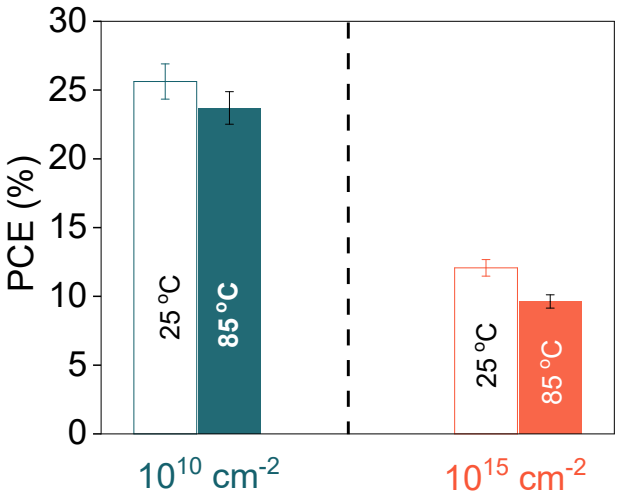

Figure S8: PCEs of PSCs with changing interface defect density and operating temperature.

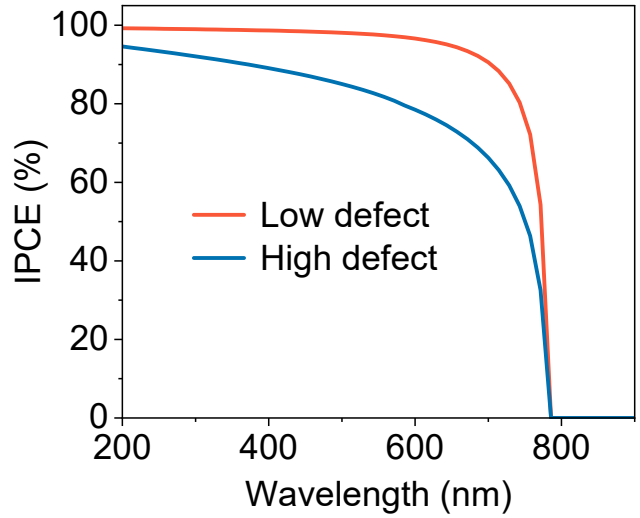

Figure S9: IPCE spectra of PSCs with changing interface defect density at room temperature.

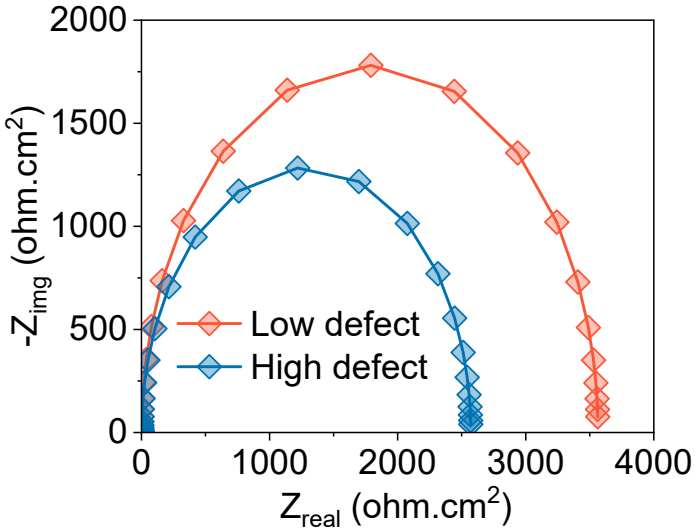

Figure S10: Nyquist plots of PSCs with changing interface defect density at room temperature.

Table S1. Interface parameters of PSC.

Parameters/Interfaces	**α-Fe_2O_3/$MAPbI_3$**	**$MAPbI_3$/spiro-OMeTAD**
Defect type	Neutral	Neutral
Capture cross section for electrons (cm^2)	1×10^{-19}	1×10^{-19}
Capture cross section for holes (cm^2)	1×10^{-19}	1×10^{-19}
Energetic Distribution	Single	single
Reference for defect energy level E_t	Above the highest E_V	Above the highest E_V
Energy with respect to reference (eV)	0.600	0.600
Total defect density ($1/cm^2$)	1.0×10^{10}	1.0×10^{10}