Copper Oxide Nanoarchitectures for Photoelectrochemical Hydrogen Generation

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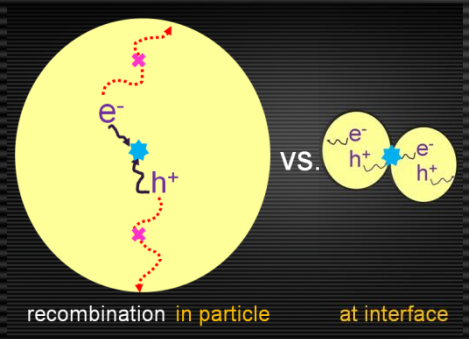
Challenge

Short carrier diffusion length (poor conductivity)

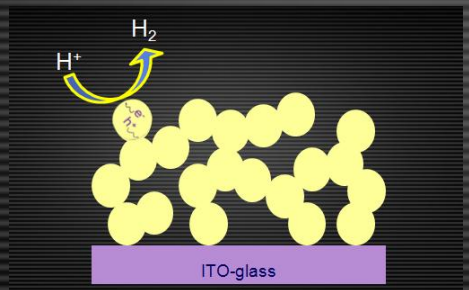
Diffusion length: The average distance traveled by a particle, such as a minority carrier in a semiconductor

(1) Decrease particle size



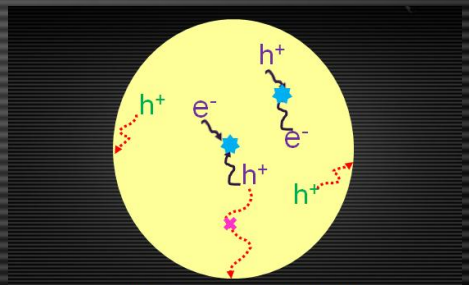
recombination in particle vs. at interface

(2) Increase surface area



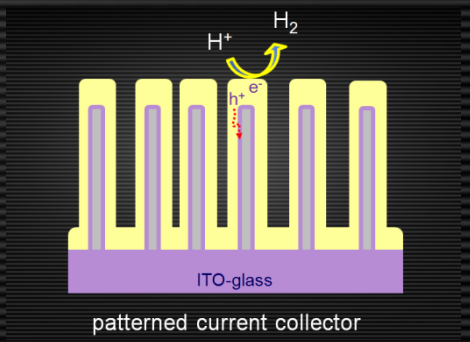
Increase interfacial area/ porosity of the film

(3) Increase conductivity



Increase conductivity by increase charge carrier number

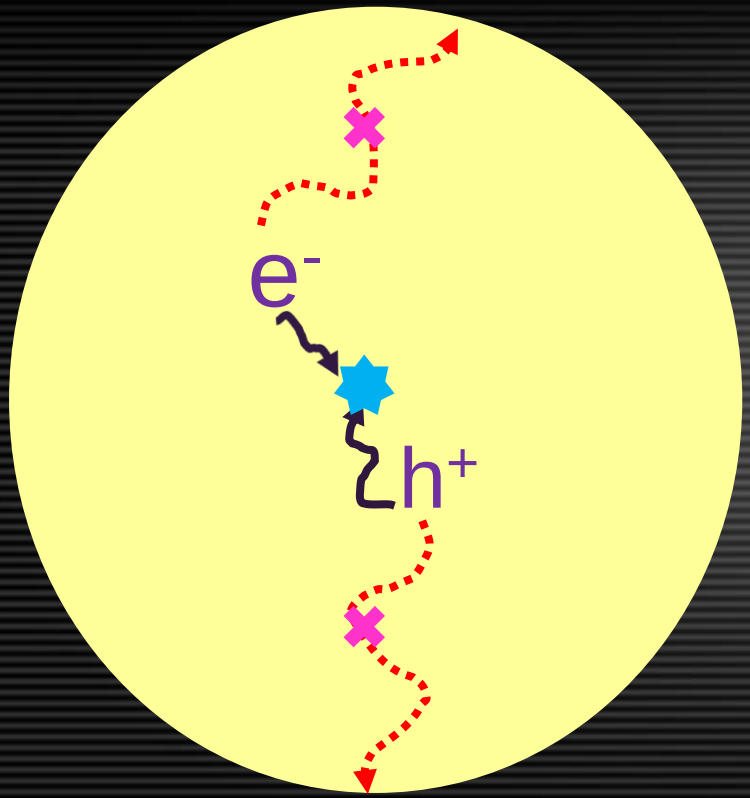
(4) Shorten transport distance



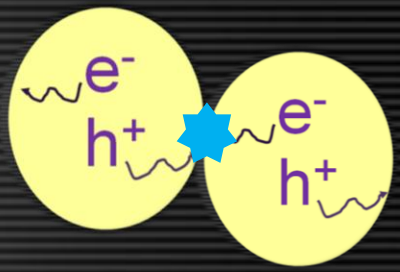
patterned current collector

Approach 1 – Size

Decrease Particle Size



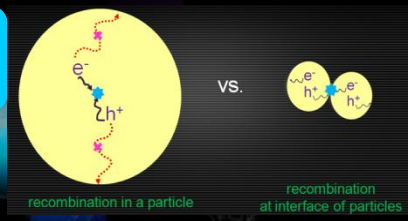
vs.



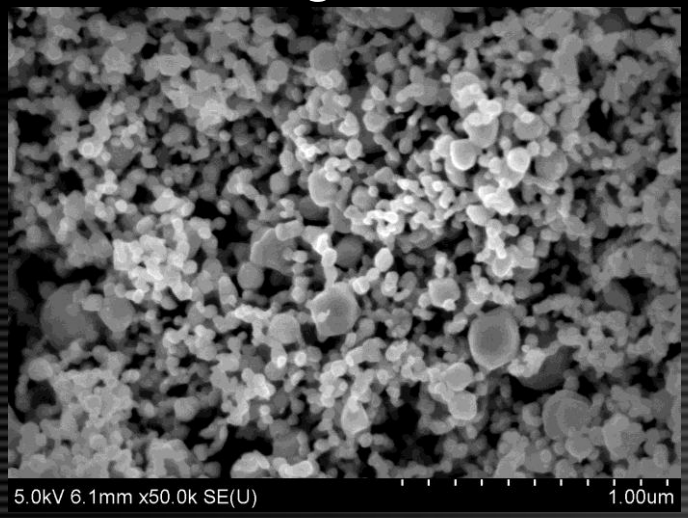
recombination in a particle

recombination
at interface of particles

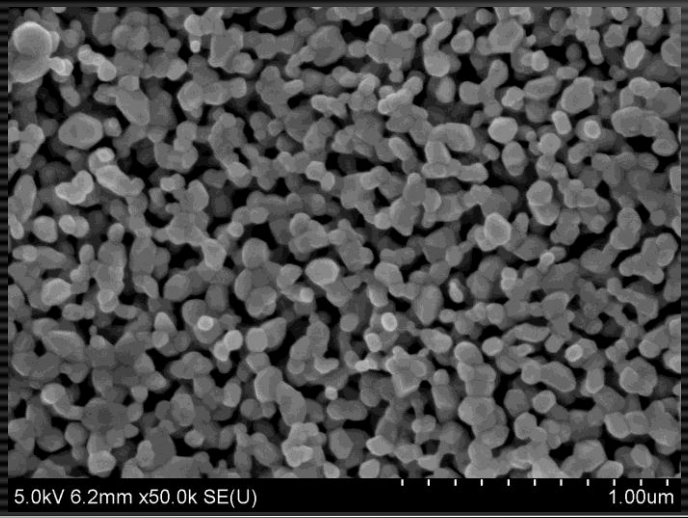
Approach 1 – Size

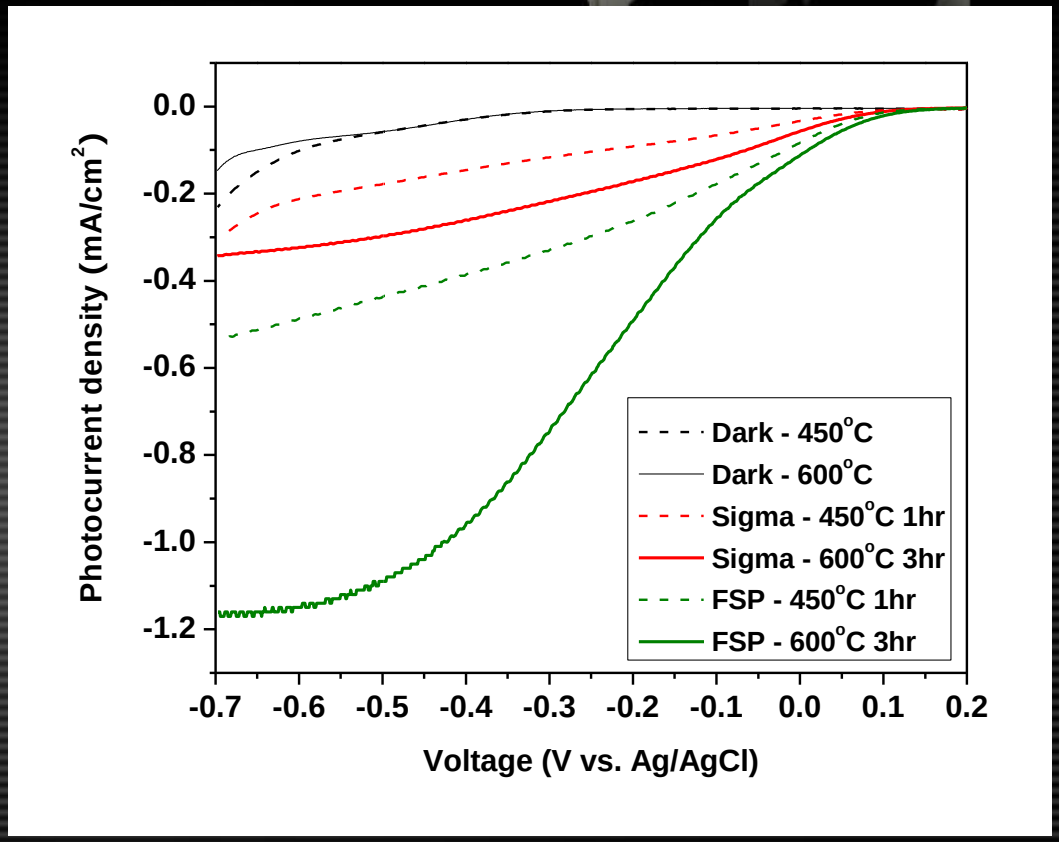


sigma



FSP



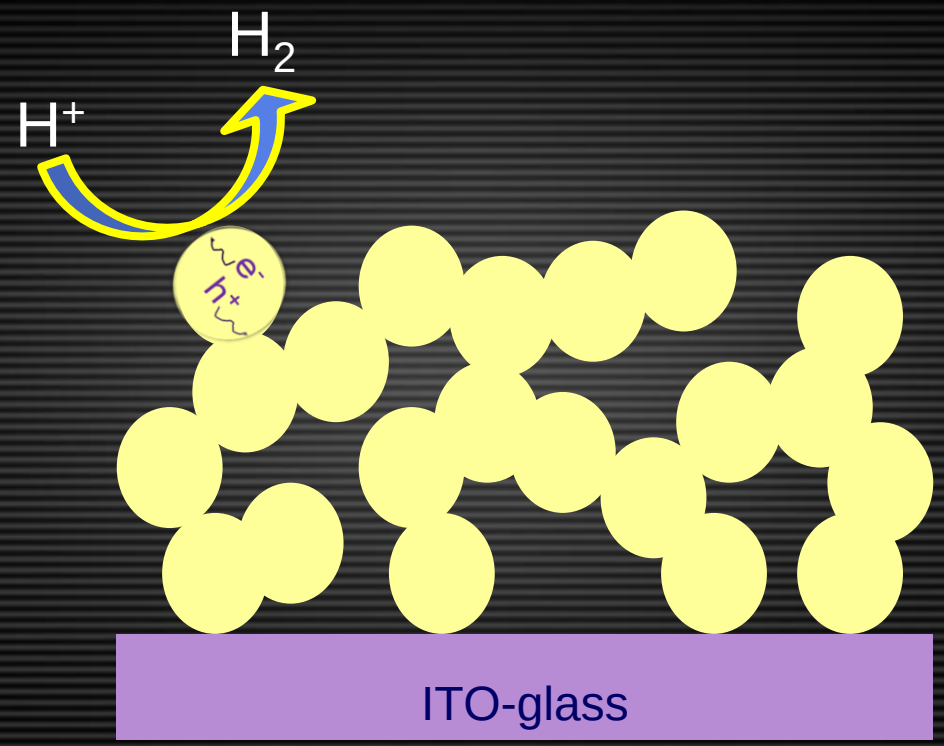


Photocurrent is about
3~4 times higher

Chiang et al., Int J Hydrogen Energ 2012a

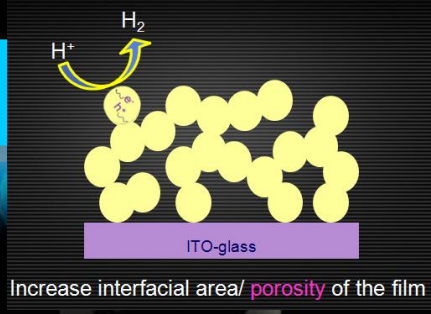
Approach 2 – Film Morphology

Increase Surface Area



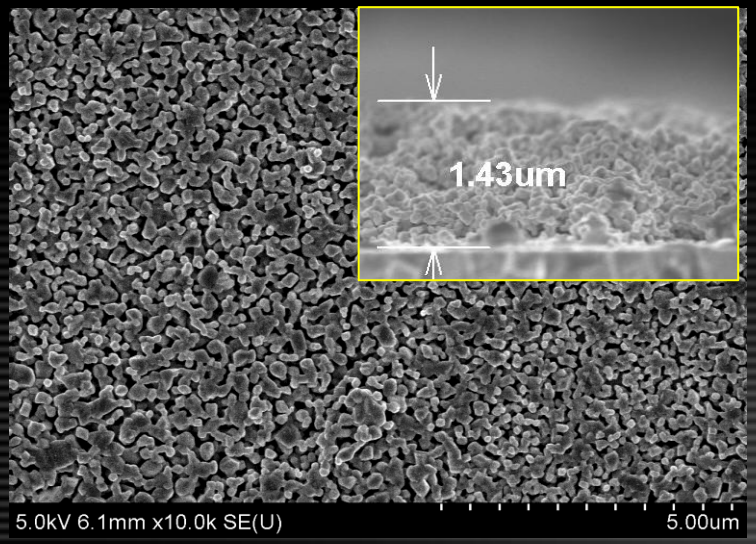
Increase interfacial area/ porosity of the film

Approach 2 – Film Morphology

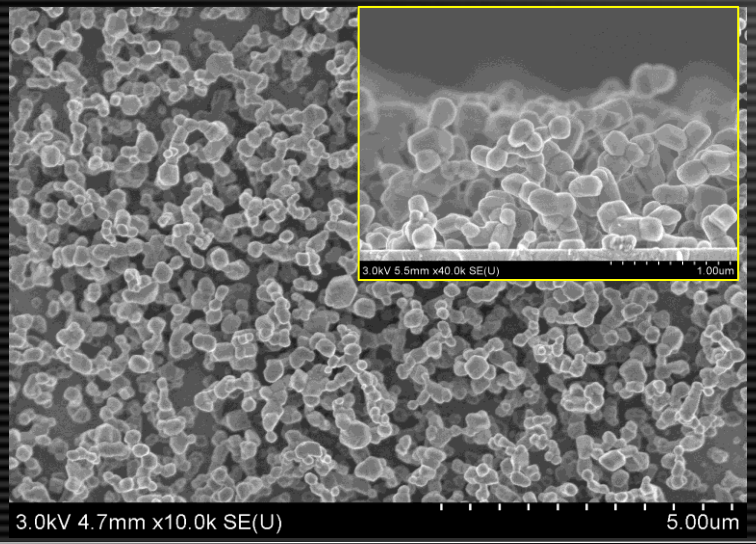


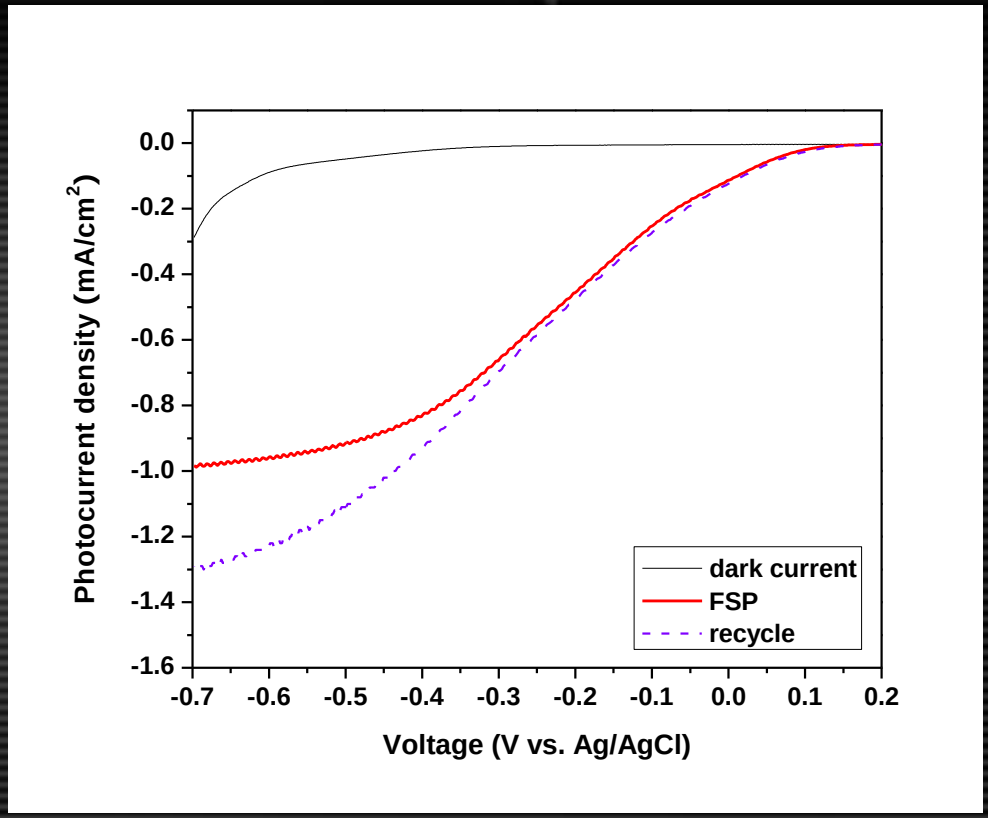
Increase interfacial area/ porosity of the film

FSP



wet chemical



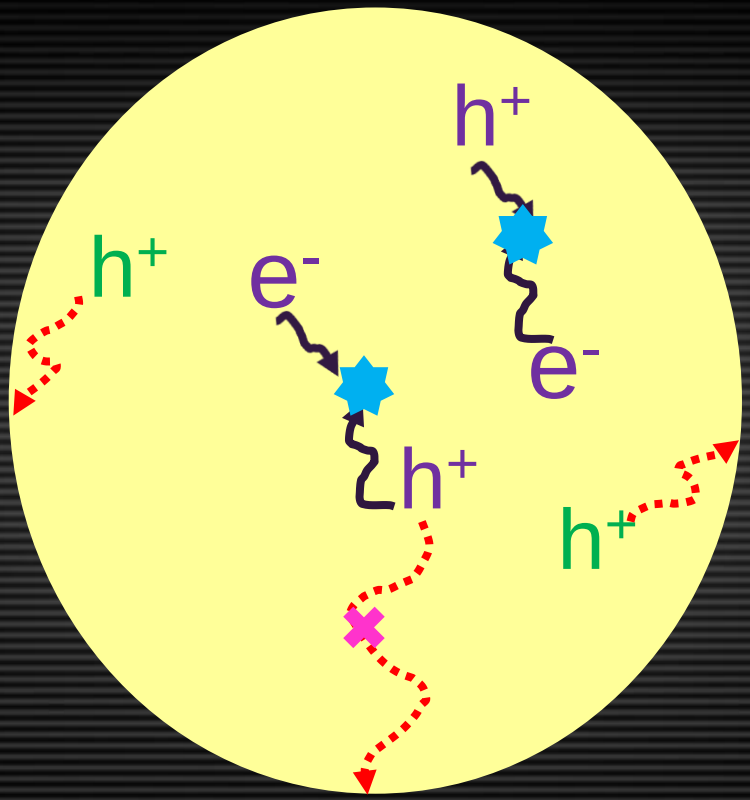


Photocurrent is about 30% more

Chiang et al., Int J Hydrogen Energ 2012b

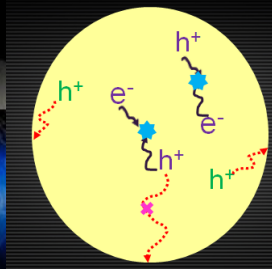
Approach 3 – Dopant

Increase Conductivity

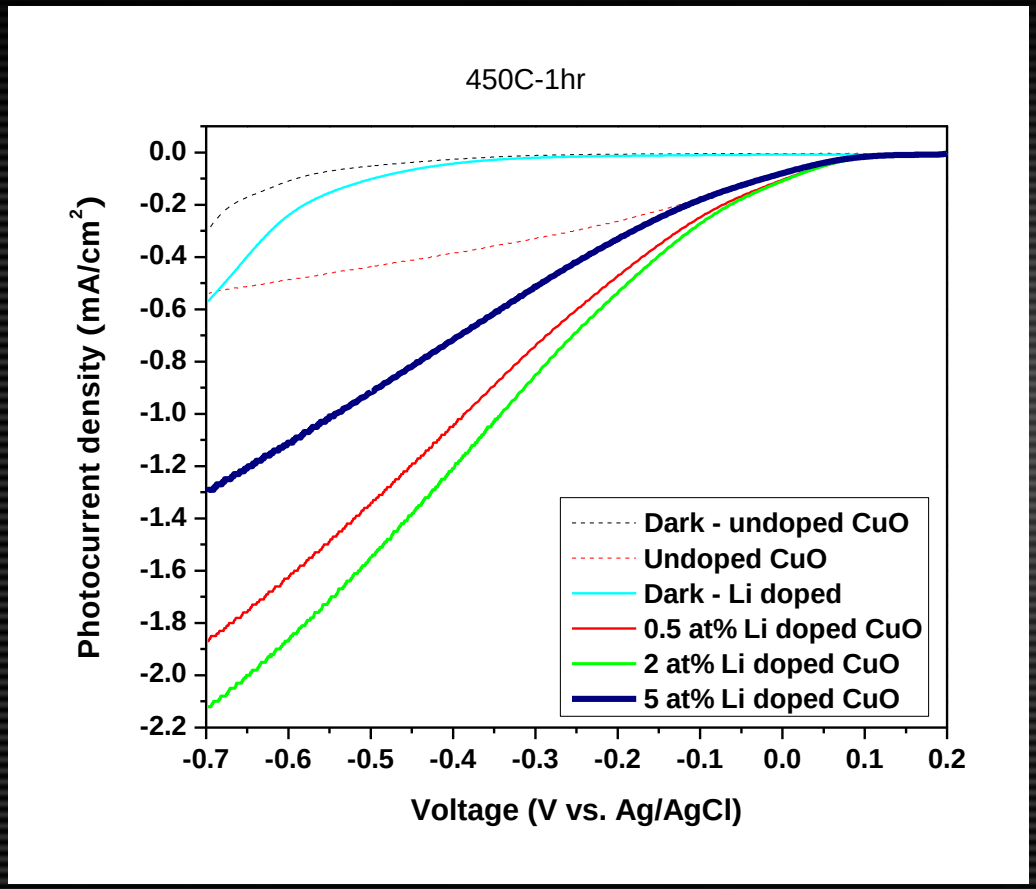


Increase conductivity by
increase charge carrier number

Approach 3 – Dopant



Increase conductivity by
increase charge carrier number

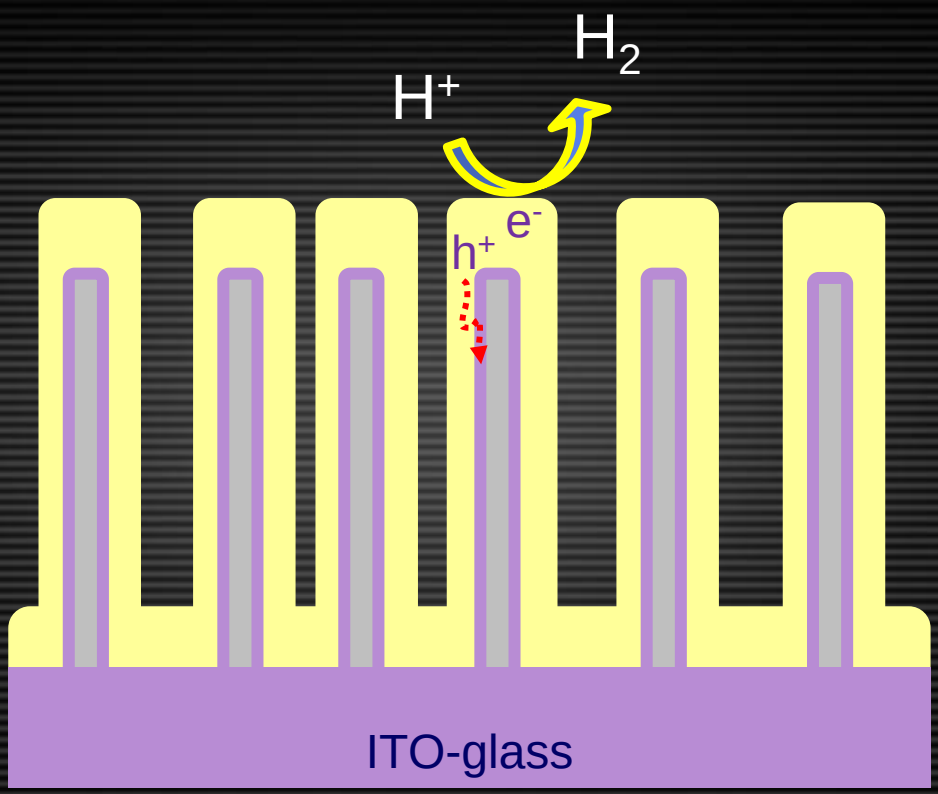


- Li doped CuO can increase the film conductivity about 2 order of magnitudes
- Photocurrent/efficiency is about 4 times higher

Chiang et al., J. Electrochem. Soc., 2012c

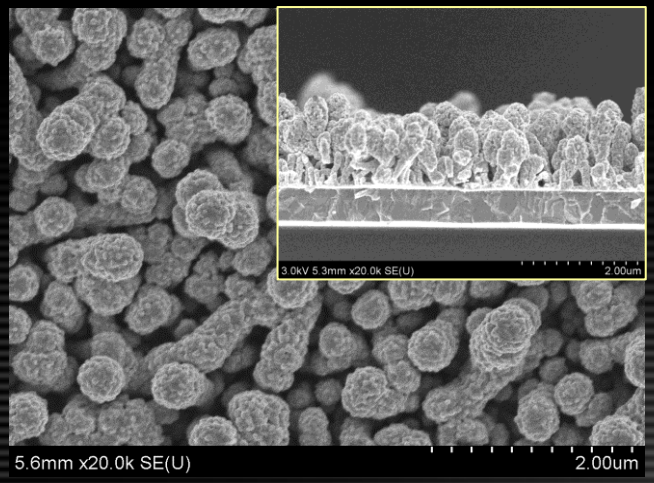
Approach 4 – Patterned

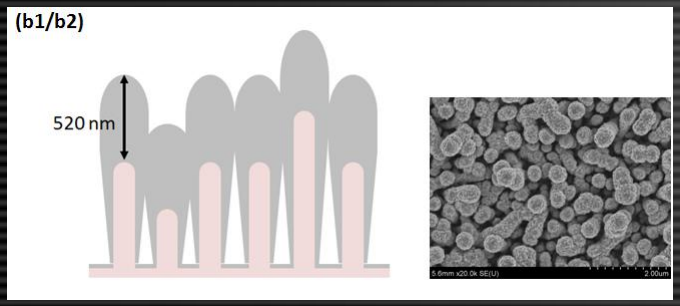
Shorten Transport Distance

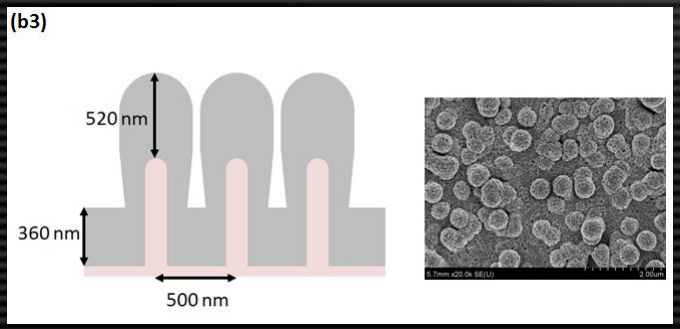


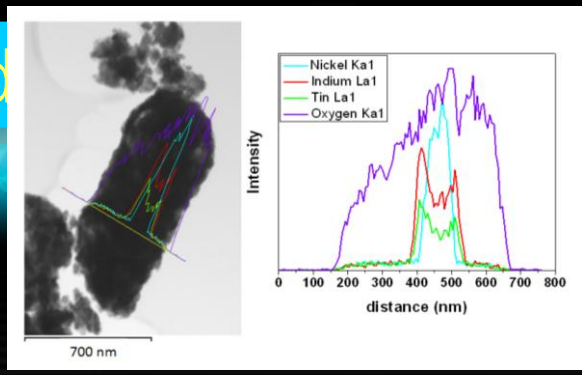
patterned current collector

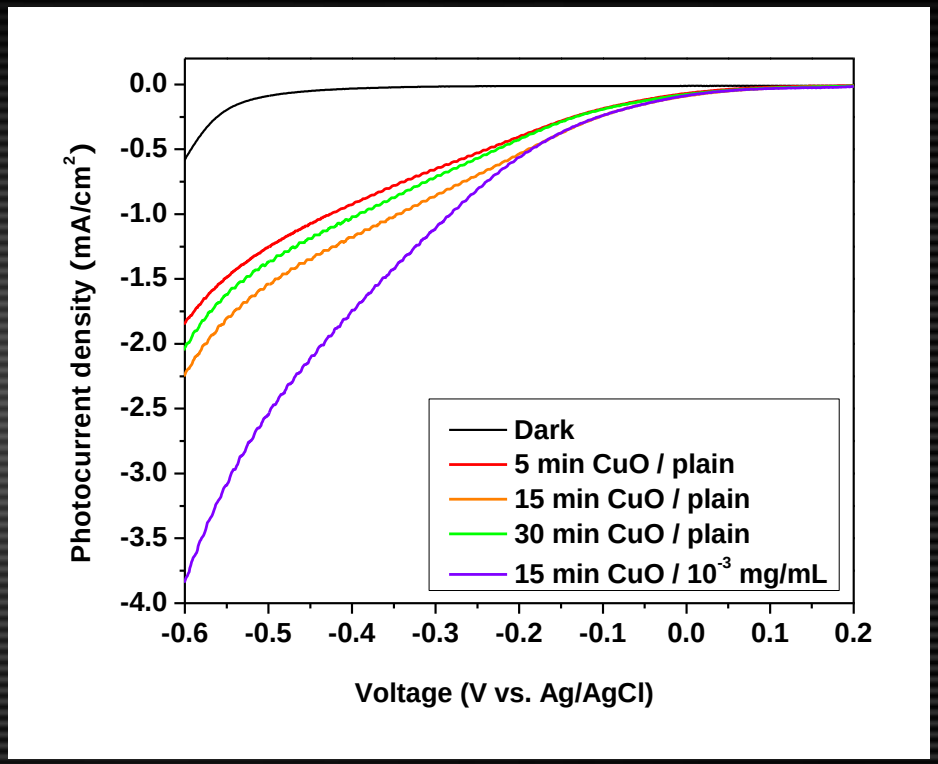
Approach 4 – Patterned











Photocurrent density is about 67% more

Manuscript under preparation

Comparison

System	Light source	Incident power density (W/m^2)	Bias voltage (V)	Photocurrent density (mA/cm^2)	Reference
CuO	500W Xenon		-0.2 vs. Ag/AgCl	0.08	Nakaoka et al., 2004
CuO	150W Xenon Arc		-0.5 vs. SCE	2.2	Chauhan et al., 2006
CuO	150W Solar simulator	1000	-0.55 vs. Ag/AgCl	0.35	Chiang et al., 2011
				1.20	(1) Chiang et al., 2011
				1.20	(2) Chiang et al., 2012
				3.15	(4) unpublished
2% Li-CuO				1.69	(3) Chiang et al., 2012
2% Li-CuO	150W Xenon Arc	8100	-0.4 vs. SCE	0.44	Koffyberg and Benko,1982

Comparison

System	Light source	Incident power density (W/m^2)	Photocurrent density (mA/cm^2)	Solar to H_2 efficiency (%)	Reference
CuO	500W Xenon	1000*	0.08	0.06*	Nakaoka et al., 2004
CuO	150W Xenon Arc	1000*/8100**	2.2	1.59*/0.20**	Chauhan et al., 2006
CuO	150W Solar simulator	1000	0.35	0.26	Chiang et al., 2011
			1.20	0.91	(1) Chiang et al., 2011
			1.20	0.91	(2) Chiang et al., 2012
			3.15	2.38	(4) unpublished
2% Li-CuO			1.69	1.30	(3) Chiang et al., 2012
2% Li-CuO	150W Xenon Arc	8100	0.44	0.05	Koffyberg and Benko,1982

References

- **Chiang, C. Y.**; Aroh, K.; Franson, N.; Satsang, V. R.; Dass, S.; Ehrman, S. "Copper Oxide Nanoparticle Made by Flame Spray Pyrolysis for Photoelectrochemical Water Splitting – Part II. Photoelectrochemical Study" *Int. J. Hydrogen Energ.*, **2011,** 36, 15519-15526.

- **Chiang, C. Y.**; Aroh, K.; Ehrman, S. "Copper Oxide Nanoparticle Made by Flame Spray Pyrolysis for Photoelectrochemical Water Splitting – Part I. CuO Nanoparticle Preparation" *Int. J. Hydrogen Energ*, **2012**, 37, 4871-4879.

- **Chiang, C. Y.**; Shin, Y.; Aroh, K.; Ehrman, S. "Copper Oxide Photocathodes Prepared by a Solution Based Process" *Int. J. Hydrogen Energ.*, **2012**, doi:10.1016/j.ijhydene.2012.02.049

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- **Chiang, C. Y.**; Epstein, J.; Brown, A.; Culver, J.; Ehrman, S. "Use of Biological Scaffolds for High Surface Area Copper Oxide for Photoelectrochemical Applications," under preparation.

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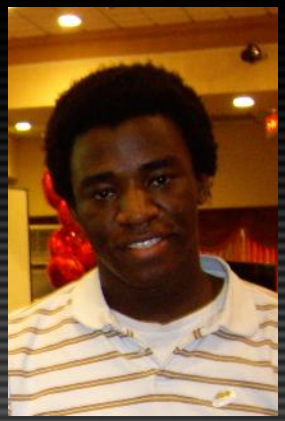

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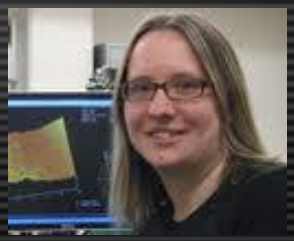

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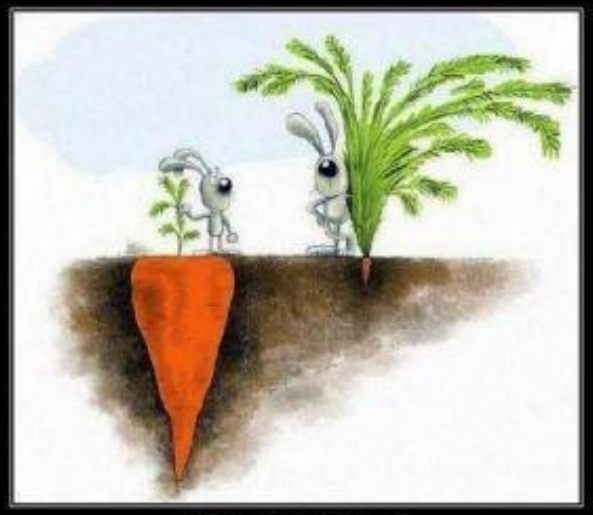

Thanks for your attention!!!