군산대 12월 1일 발표

Preparing Metal Chalcogenide Quantum Dot (QD) Photosensitizers for Photoelectrochemical Applications

(광전기화학적 응용을 위한 금속 칼코게나이드 양자점 광감응제 준비)

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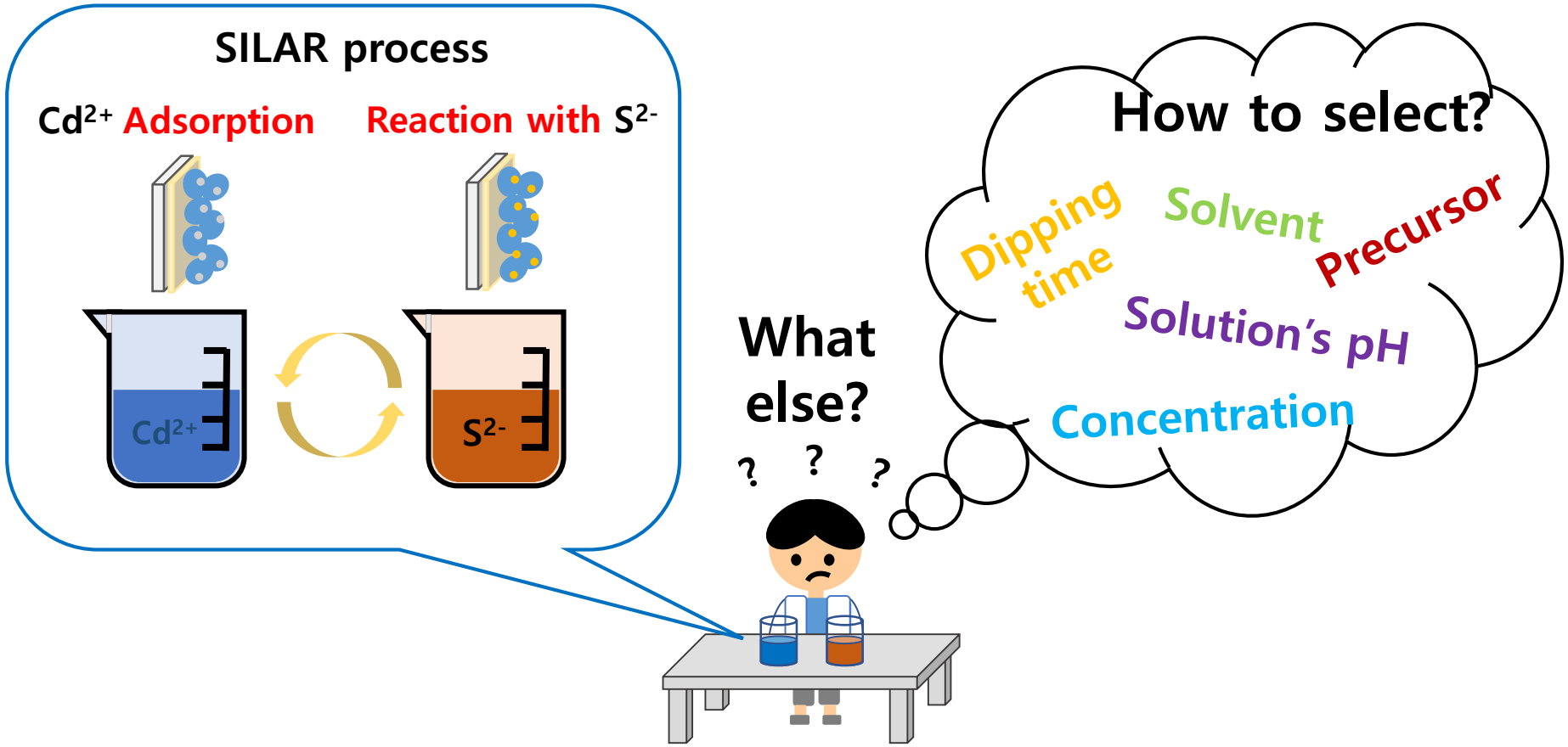
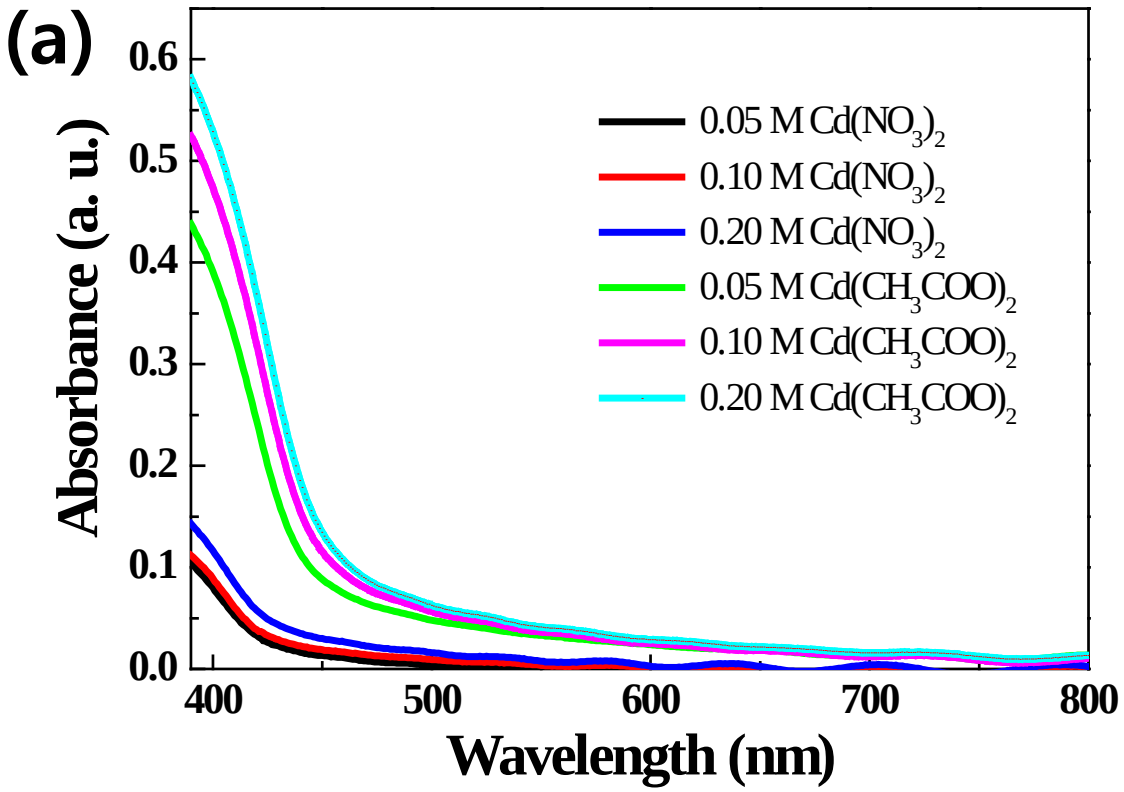
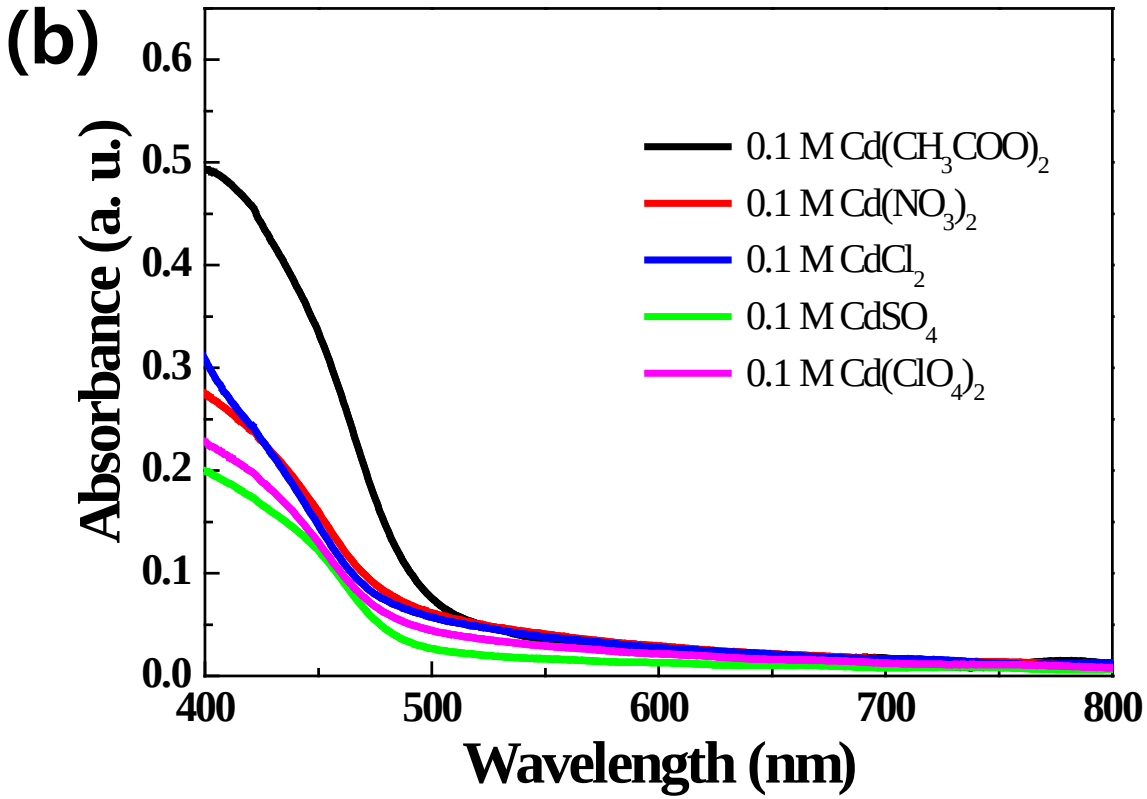
Scheme 1.


SILAR process
Cd2+ Adsorption
Reaction with S2-
Cd2+
S2-
What else?
How to select?
Dipping time
Solvent
Precursor
Solution's pH
Concentration

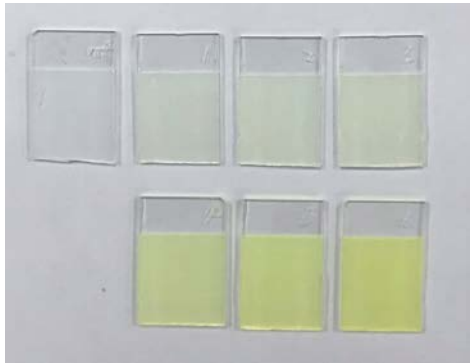
농도

$Cd(NO_3)_2$ vs $Cd(Ace)_2$





SILAR 5



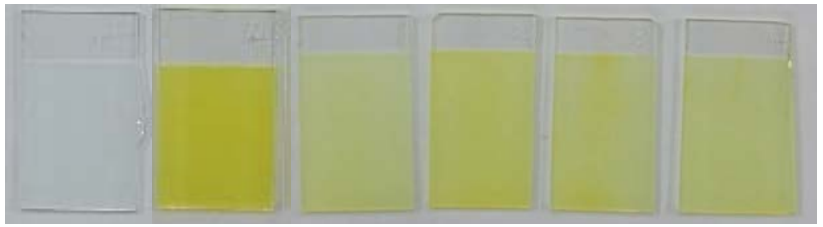
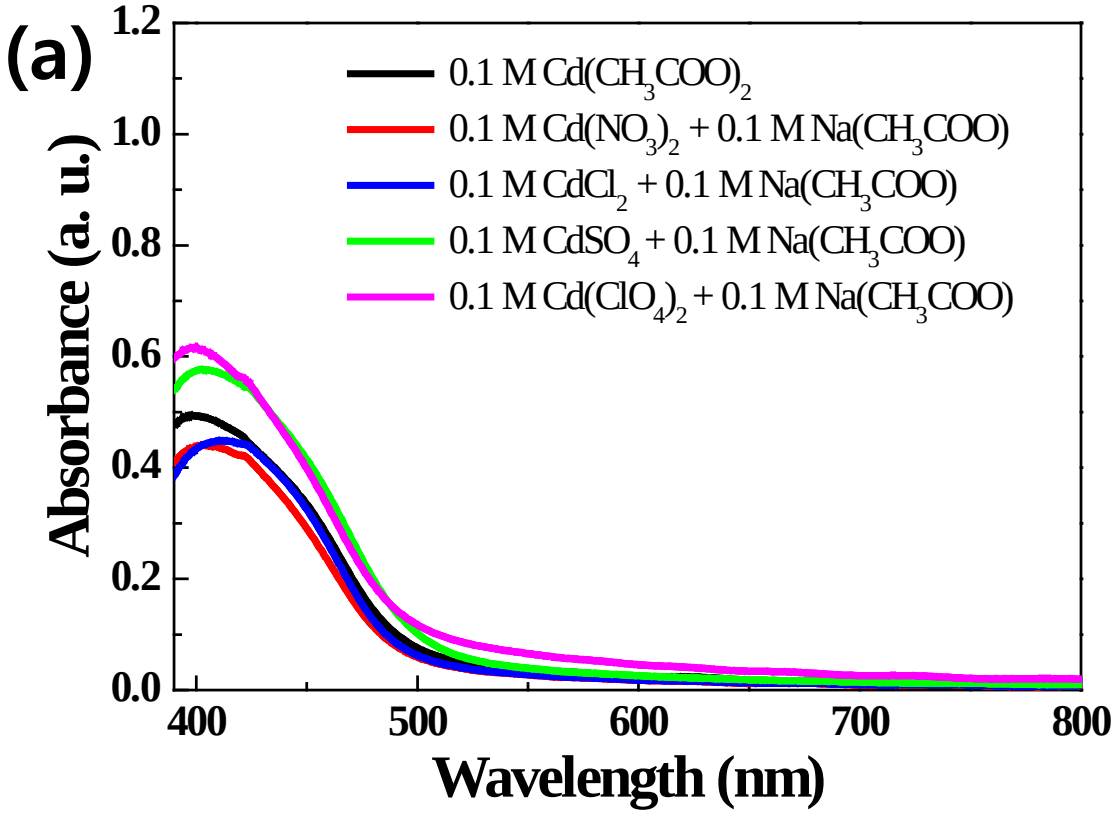
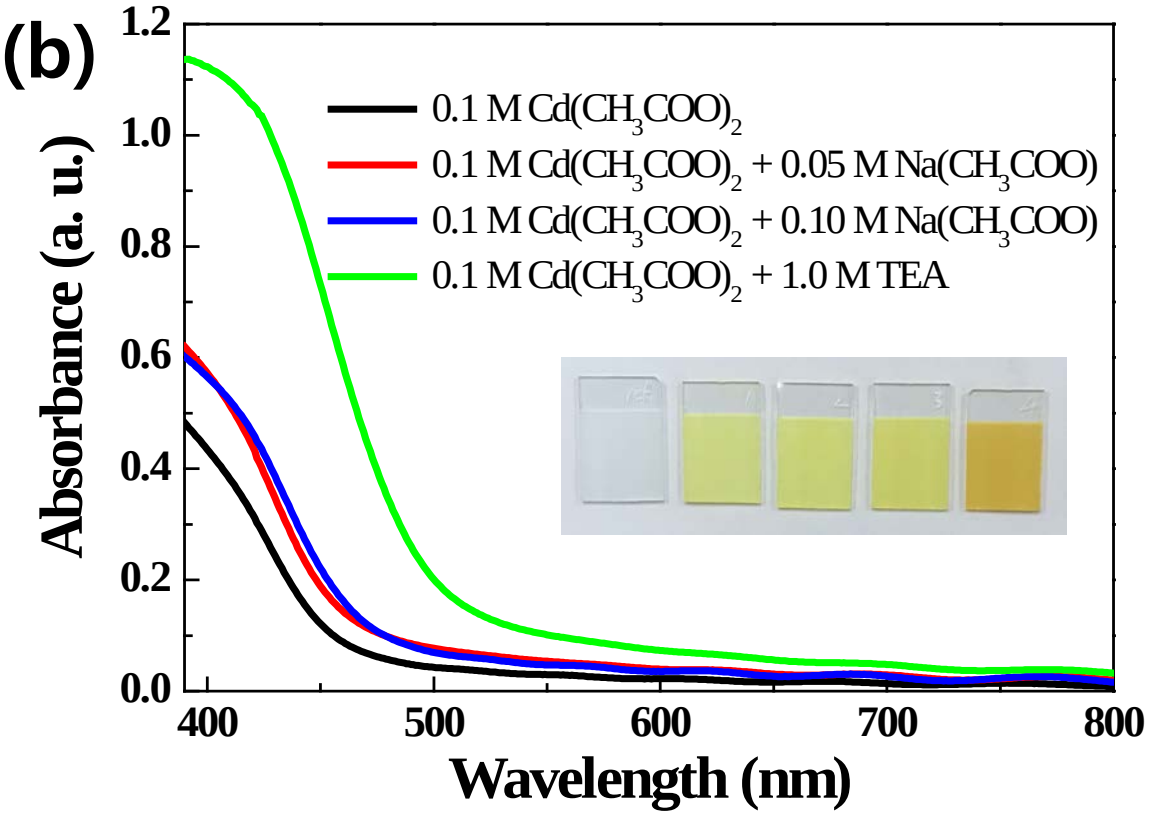
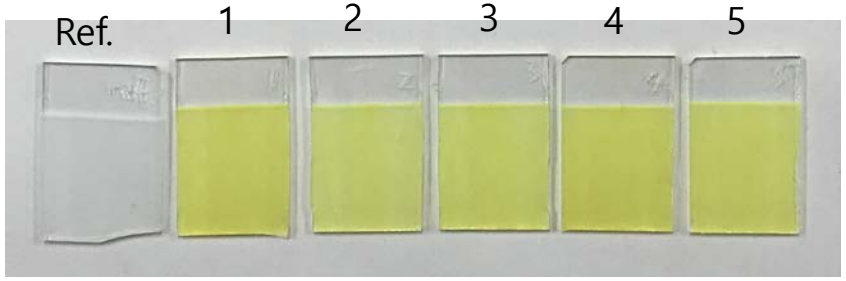


Figure 1(a)

전구체 and pH







4가지의 pH 값 (~6.5 pH)

Dipping time

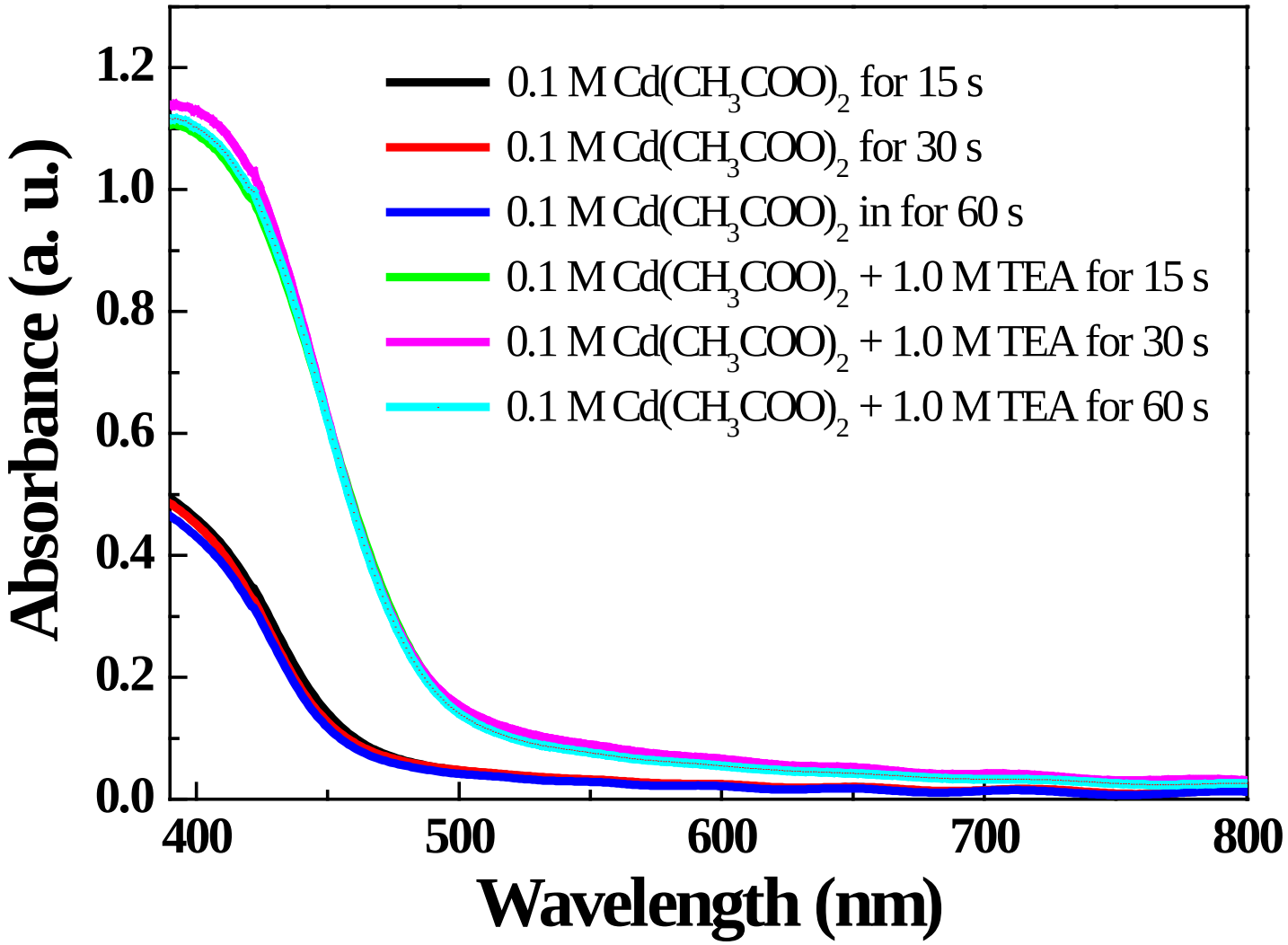


Figure 3

용매 조건-EtOH

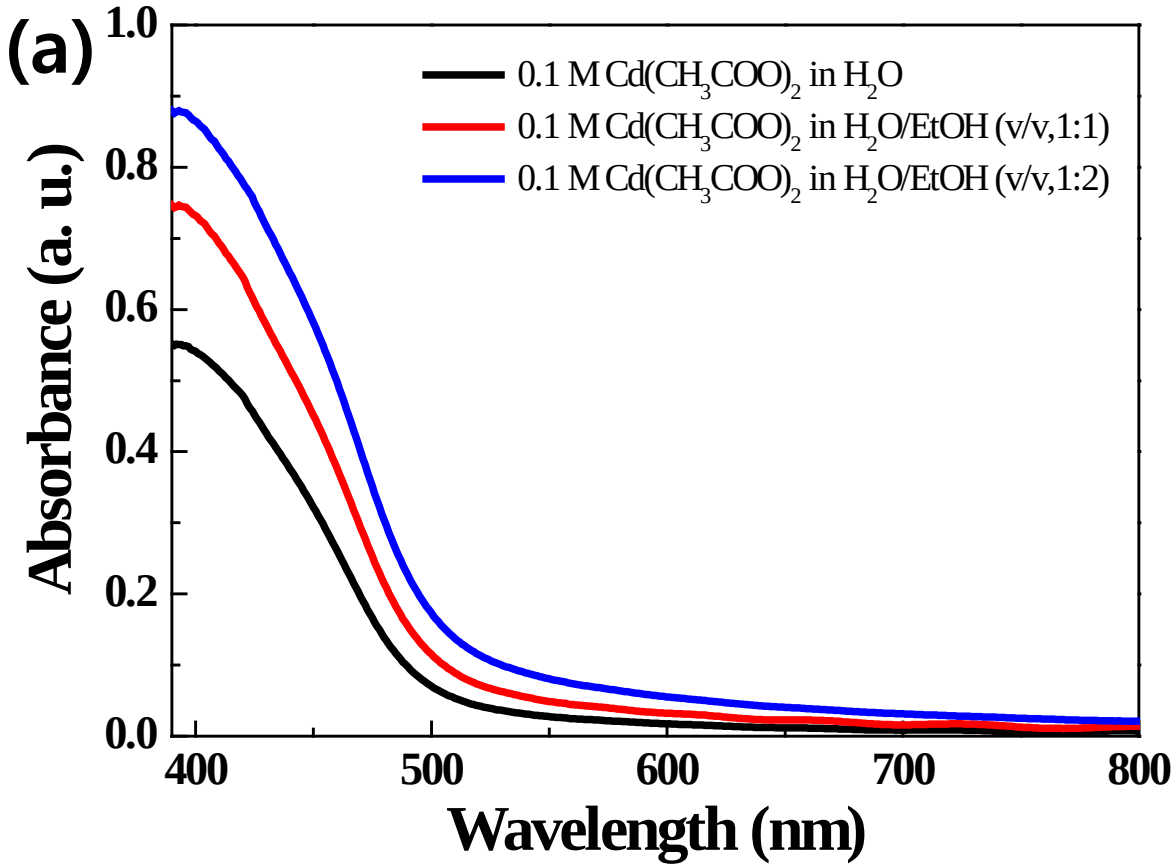


Figure 4(a)

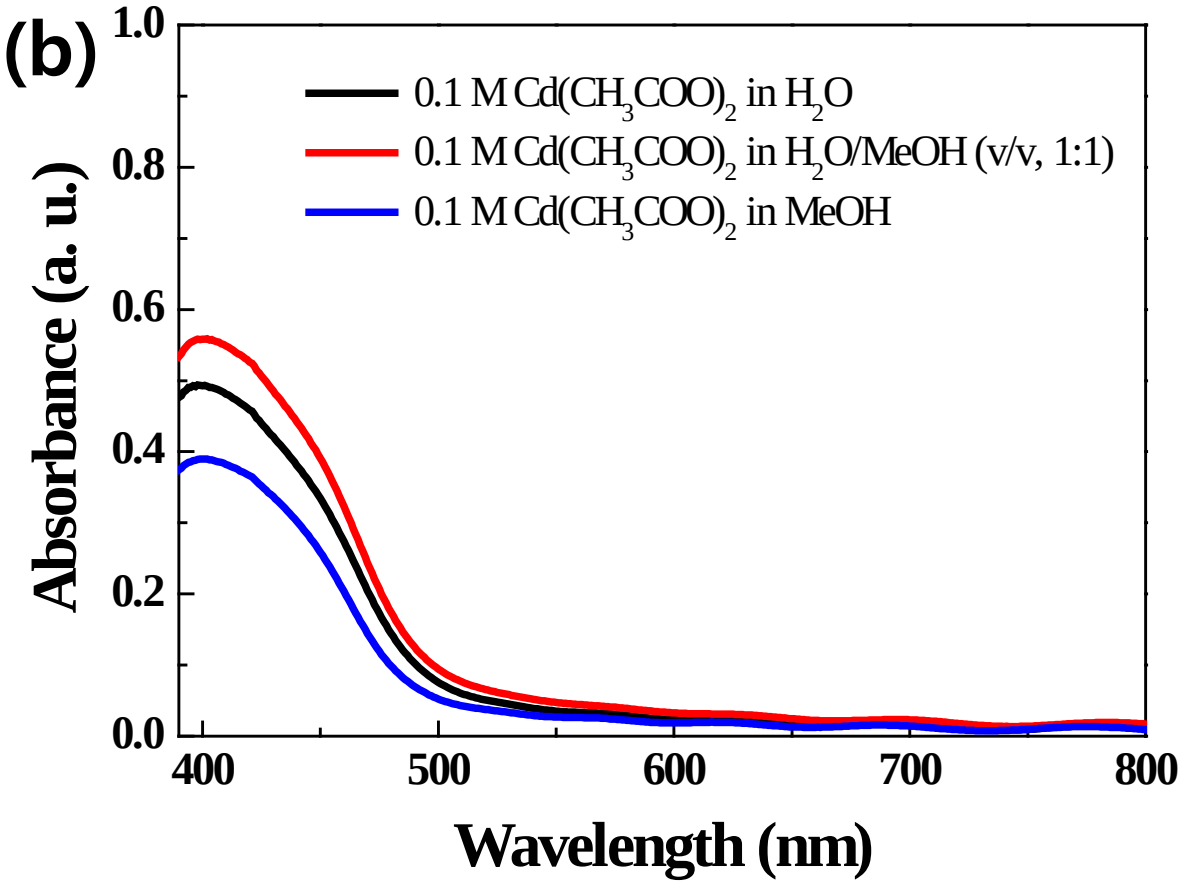


Figure 4(b)

Figure 5

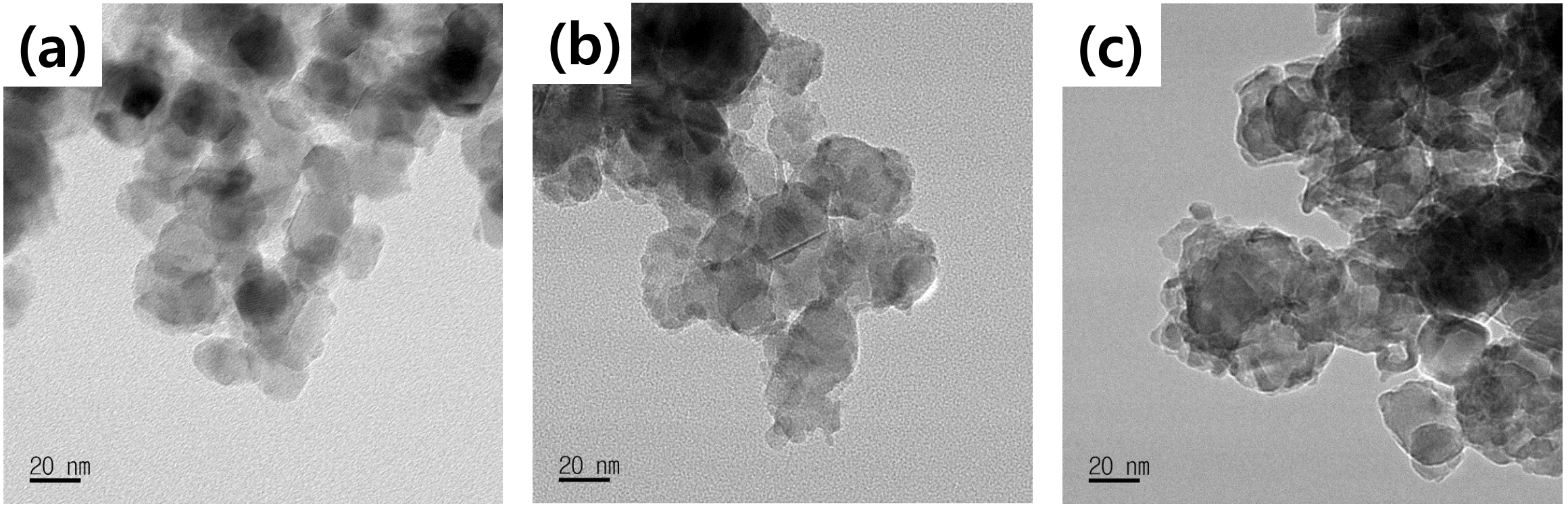


Figure 6

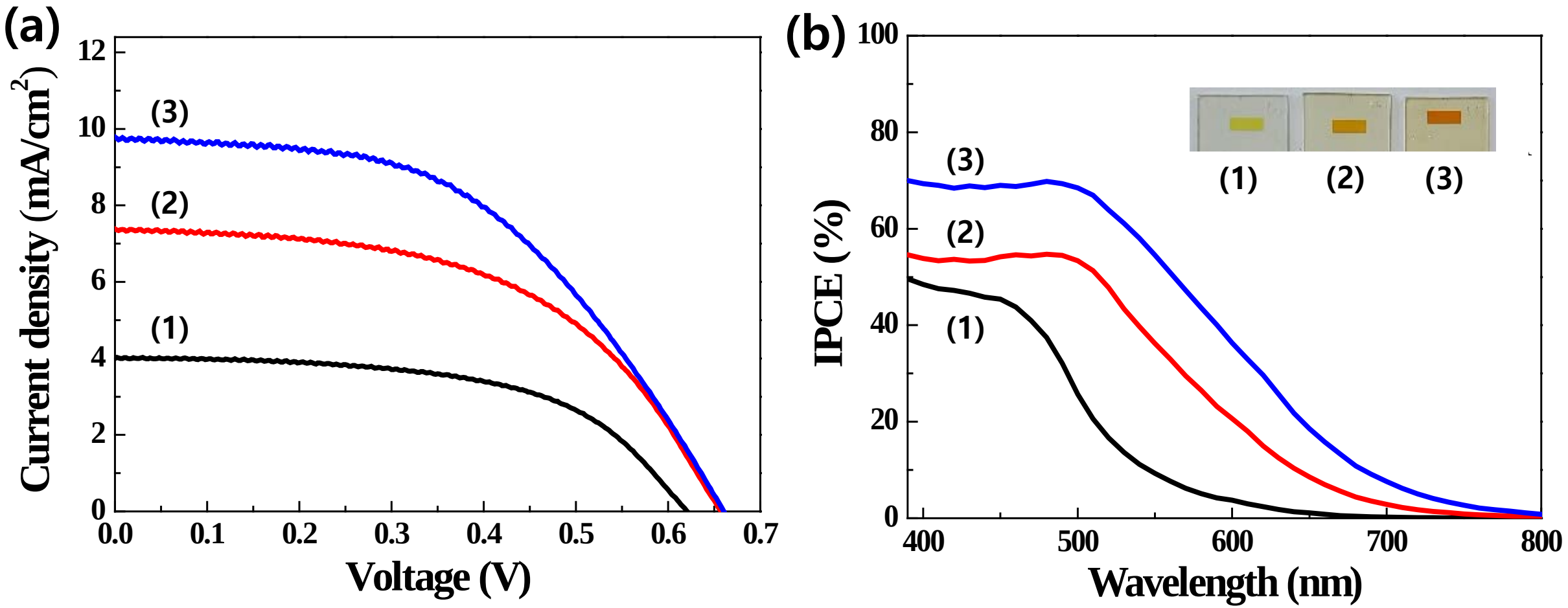
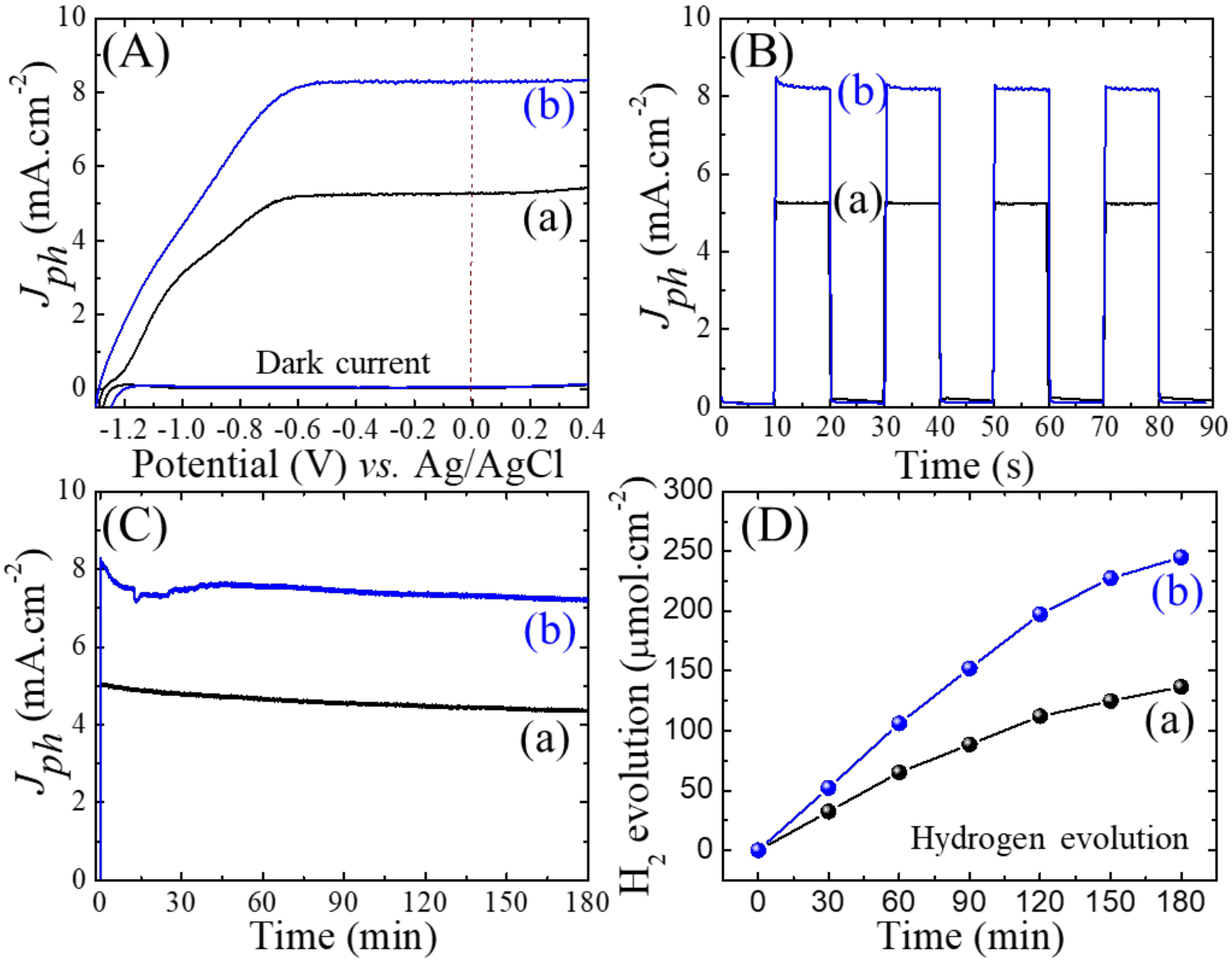

(a)
Current density (mA/cm^2)
Voltage (V)
(1)
(2)
(3)
(b)
IPCE (%)
Wavelength (nm)
(1)
(2)
(3)

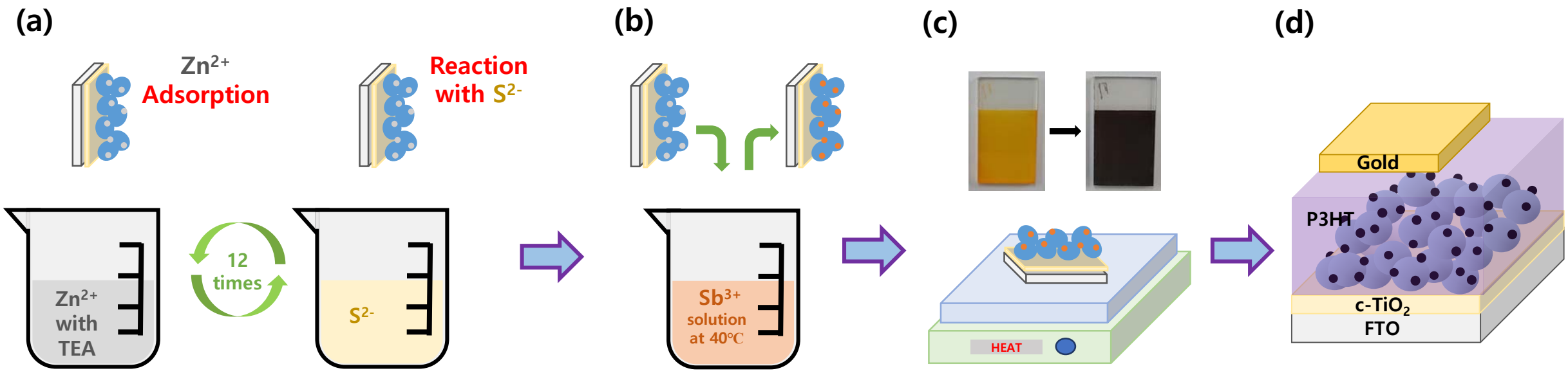
Table 1

J-V 데이터 통계 처리 (평균/표준편차)

	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	PCE (%)
(1) 0.1 M $Cd(NO_3)_2$	4.10 ± 0.26	0.62 ± 0.01	0.55 ± 0.02	1.39 ± 0.07
(2) 0.1 M $Cd(CH_3COO)_2$	7.41 ± 0.41	0.65 ± 0.01	0.51 ± 0.02	2.49 ± 0.27
(3) 0.1 M $Cd(CH_3COO)_2$ with 1.0 M TEA	10.14 ± 0.25	0.63 ± 0.02	0.51 ± 0.01	3.27 ± 0.11


(A)
(b)
(a)
Dark current
J_{ph} (mA.cm^{-2})
Potential (V) *vs.* Ag/AgCl
(B)
(b)
(a)
J_{ph} (mA.cm^{-2})
Time (s)
(C)
(b)
(a)
J_{ph} (mA.cm^{-2})
Time (min)
(D)
(b)
(a)
Hydrogen evolution
H_2 evolution (μmol·cm^{-2})
Time (min)

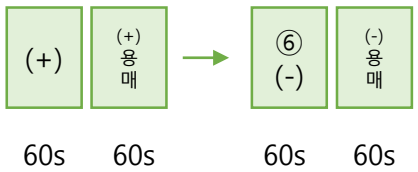
실험 과정 2



Schematic diagram showing how to make the Sb_2S_3-sensitized solid-state cell.

ZnS 최대 흡착 조건 찾기

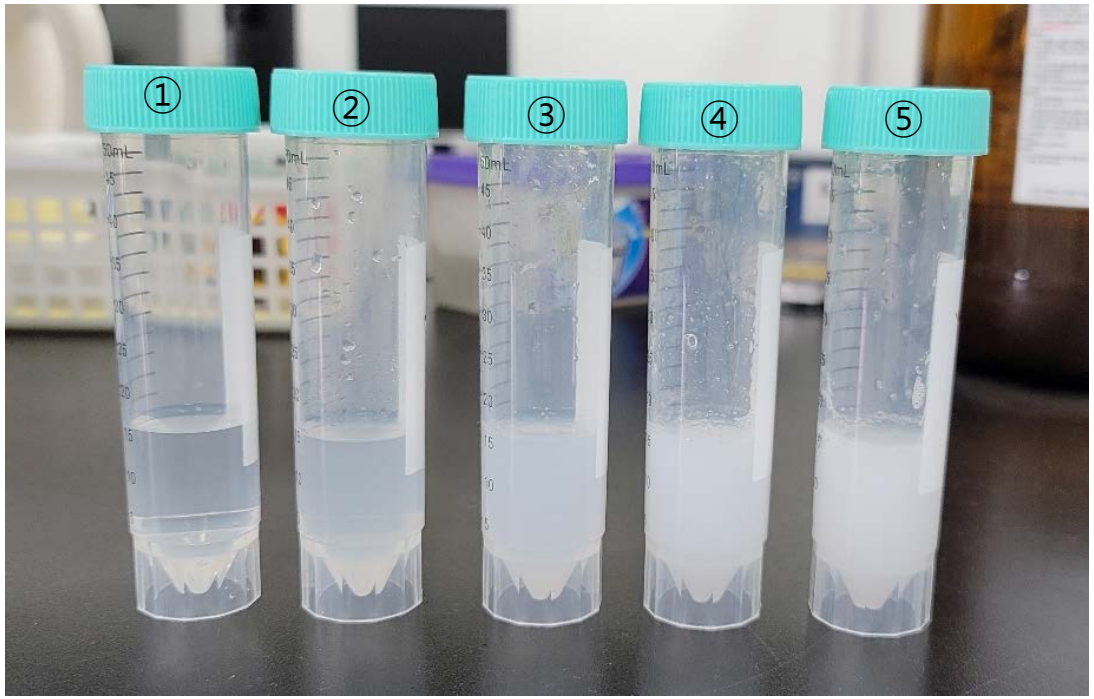
실험 방법

전극	Abs용 TiO_2 전극 (Tape 1 layer)		
	Solution	pH of cationic solution	SILAR (2)
Zn^{2+} 용액	① 0.1M $Zn(ace)_2{\cdot}2H_2O$ in H_2O	6.1	
	② 0.1M $Zn(ace)_2{\cdot}2H_2O$ in H_2O/MeOH (v/v=1:1)	5.8	
	③ 0.1M $Zn(ace)_2{\cdot}2H_2O$ + 0.1M TEA in H_2O	6.4	
	④ 0.1M $Zn(ace)_2{\cdot}2H_2O$ + 0.2M TEA in H_2O	6.8	
	⑤ 0.1M $Zn(ace)_2{\cdot}2H_2O$ + 1.0M TEA in H_2O	9~11	
S^{2-} 용액	⑥ 0.1M $Na_2S{\cdot}9H_2O$ in H_2O		
Pb^{2+} 용액	⑦ 0.1M $Pb(NO_3)_2$ in H_2O		Dipping for 5min and washing (H_2O→EtOH)

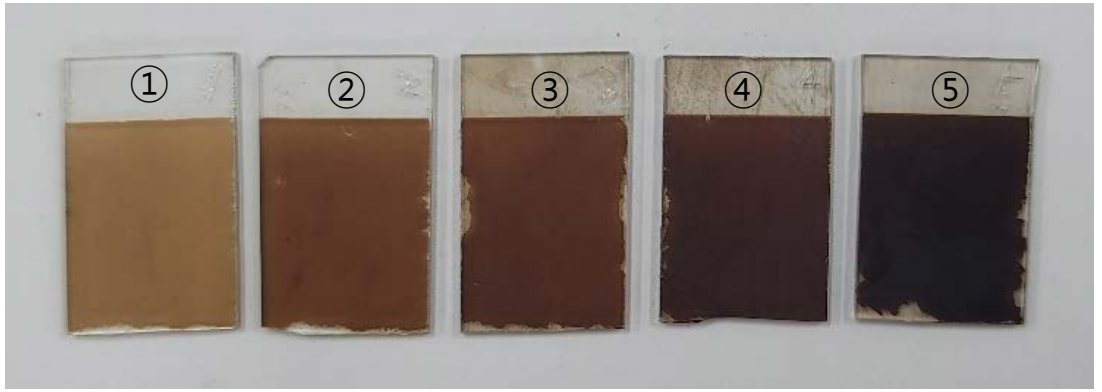
용액 및 흡착 결과

	(+)용액
①	$Zn(ace)_2$ in H_2O
②	$Zn(ace)_2$ in H_2O/MeOH
③	$Zn(ace)_2$ +0.1M TEA in H_2O
④	$Zn(ace)_2$ +0.2M TEA in H_2O
⑤	$Zn(ace)_2$ +1.0M TEA in H_2O

용액



흡착 결과

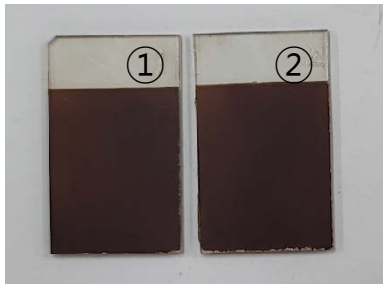


TEA를 많이 첨가할수록 용액이 뿌옇게 변함
그러나 흡착 결과를 보면 SILAR 2회에도 불구하고 1.0M TEA를 첨가한 양이온 용액 사용시 매우 어두운 색을 띠는 것을 확인.
*양이온 용액에 의한 변화를 확인하기 위해 음이온 용액은 동일한 조건으로 사용함.

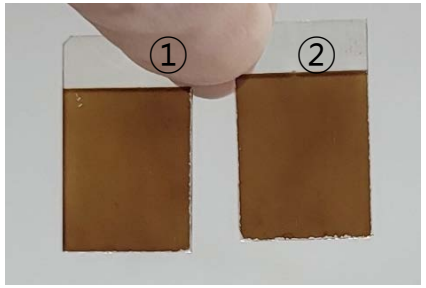
전극	Abs용 TiO_2 전극 (Tape 1 layer)		
	Solution	pH of cationic solution	SILAR (2)
Zn^{2+} 용액	① 0.1M $Zn(ace)_2 \cdot 2H_2O$ + 1.0M TEA in H_2O	About ~9	(+) 60s → (+)용매 60s → H_2O/MeOH (1:1) 10s → ③ (-) 60s → (-)용매 60s
	② 0.1M $Zn(NO_3)_2 \cdot 6H_2O$ + 1.0M TEA in H_2O		
S^{2-} 용액	③ 0.1M $Na_2S \cdot 9H_2O$ in H_2O/MeOH (v/v=1:1)		
Pb^{2+} 용액	④ 0.1M $Pb(NO_3)_2$ in H_2O		Dipping for 5min and washing (H_2O→EtOH)

	(+)용액
①	$Zn(ace)_2$ +1.0M TEA in H_2O
②	$Zn(NO_3)_2$ +1.0M TEA in H_2O

①용액은 뿌옇고, ②용액은 투명하며 가라앉는 것도 없다.



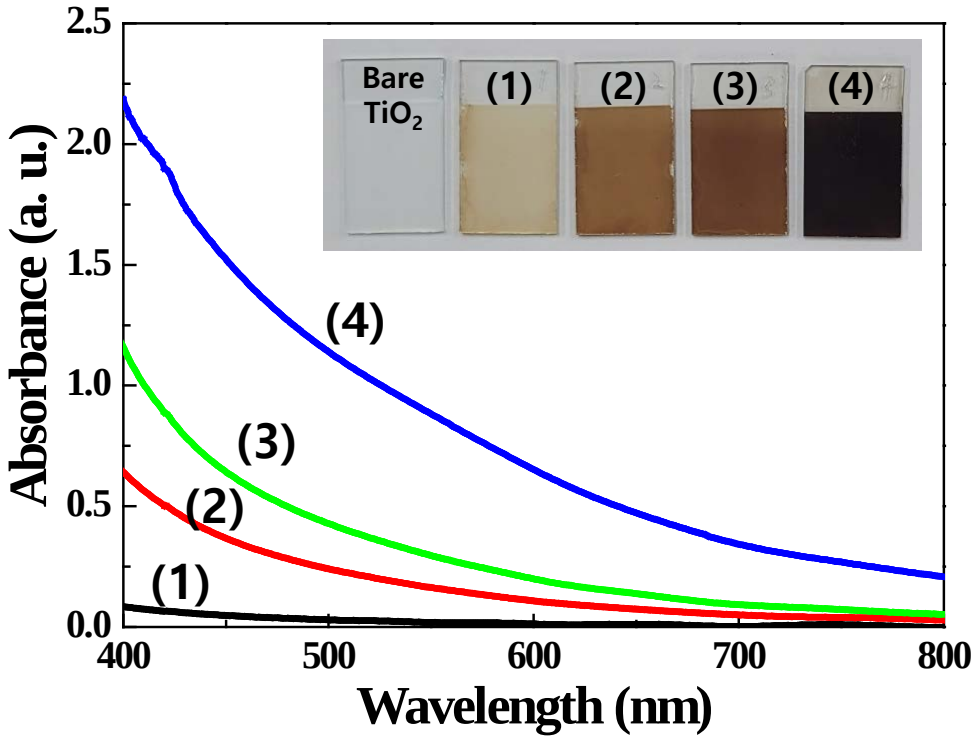
바닥에 대고 찍은 사진



공중에 들어서 찍은 사진

*①, ②용액 모두 비슷한 색을 나타냄

흡수 스펙트럼 (Absorbance)

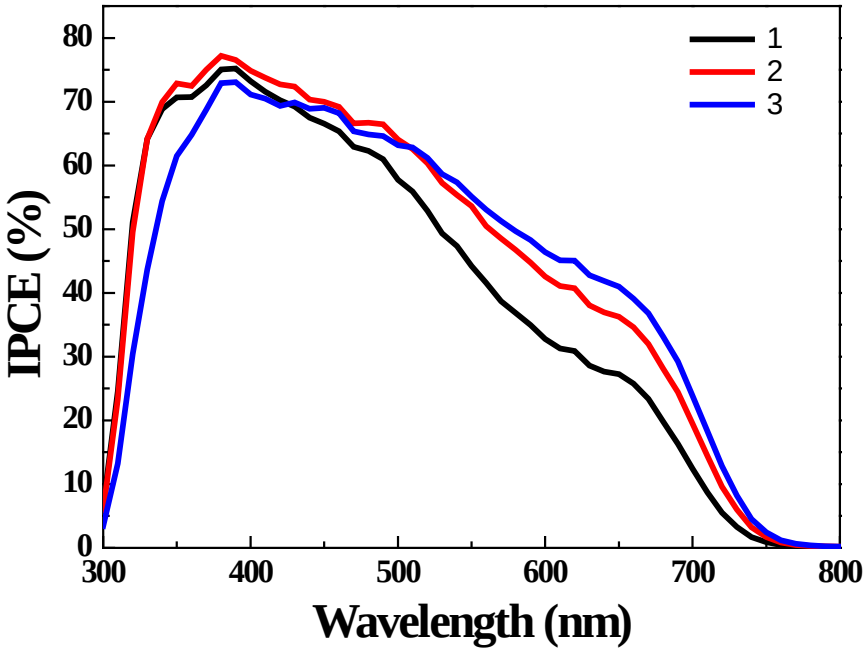


Absorbance spectra of PbS films prepared by cation exchange process between Zn^{2+} and Pb^{2+} after ZnS SILAR process repeated three times using different Zn^{2+} solutions: (1) 0.1 M $Zn(NO_3)_2$ in H_2O, (2) 0.1 M $Zn(CH_3COO)_2$ in H_2O, (3) 0.1 M $Zn(CH_3COO)_2$ in H_2O/MeOH, and (4) 0.1 M $Zn(NO_3)_2$ in H_2O with 1.0 M TEA. The inserted picture shows a bare TiO_2 film and each corresponding film.

전류-전압 곡선 (J-V)

	ZnS SILAR	Sb^{3+}용액 dipping time	Reverse scan with mask			
			Jsc	Eoc	FF	CE
1	8회	5 min	7.677	0.4190	0.4156	1.337
2	10회		9.180	0.4240	0.4240	1.650
3	12회		9.256	0.4350	0.4381	1.764

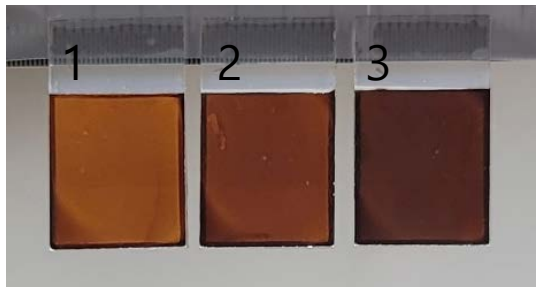
IPCE측정



바닥에 놓고 찍은 사진

~300℃ 가열 전

공중에 들고 찍은 사진



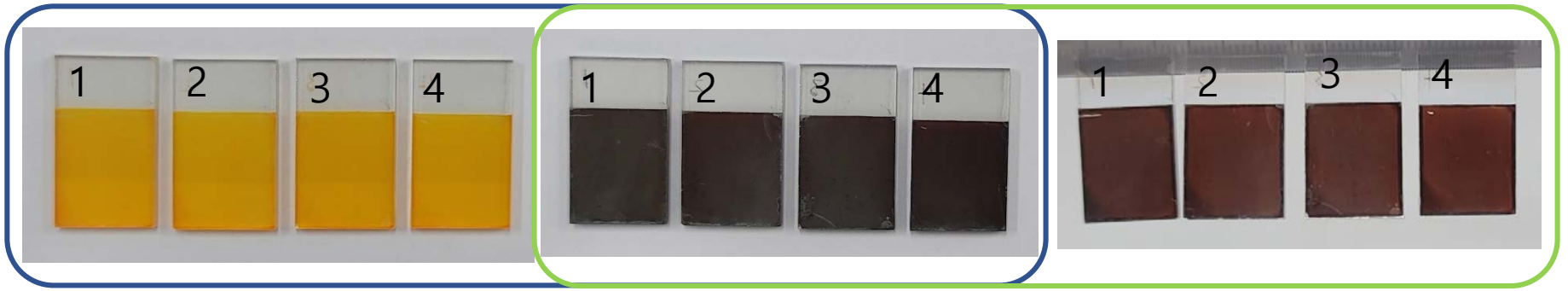
~300℃ 가열 후

양이온 교환 조건

	ZnS SILAR	Sb^{3+}용액 dipping time	Reverse scan with mask			
			Jsc	Eoc	FF	CE
1	12회	5 min	9.036	0.4370	0.3980	1.572
2		10 min	8.529	0.4180	0.4325	1.542
3		3 min at 40℃	9.764	0.4480	0.4330	1.894
4		5 min at 40℃	9.630	0.4540	0.4527	1.979

바닥에 놓고 찍은 사진

공중에 들고 찍은 사진

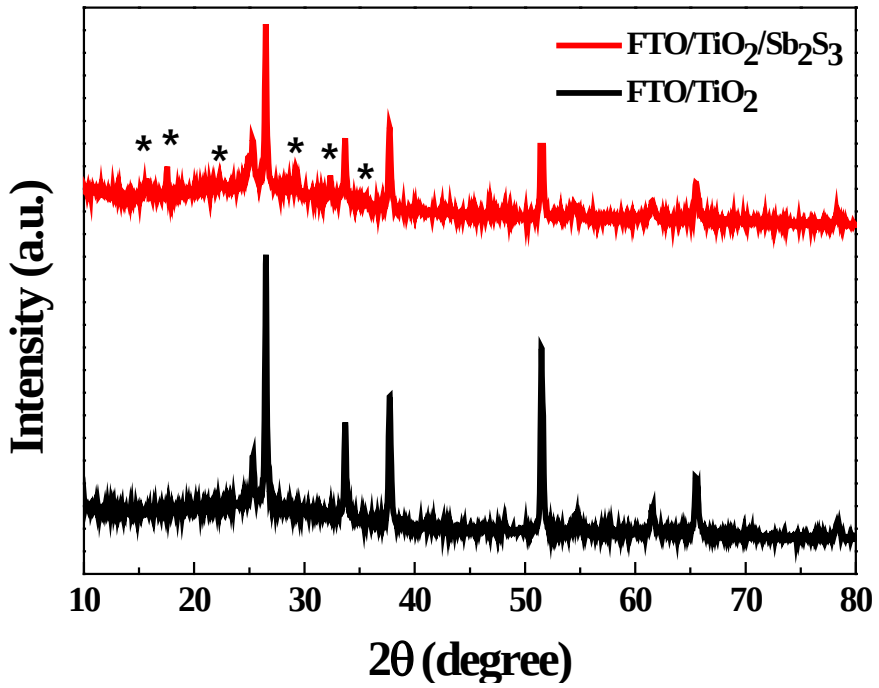


~300℃ 가열 전

~300℃ 가열 후

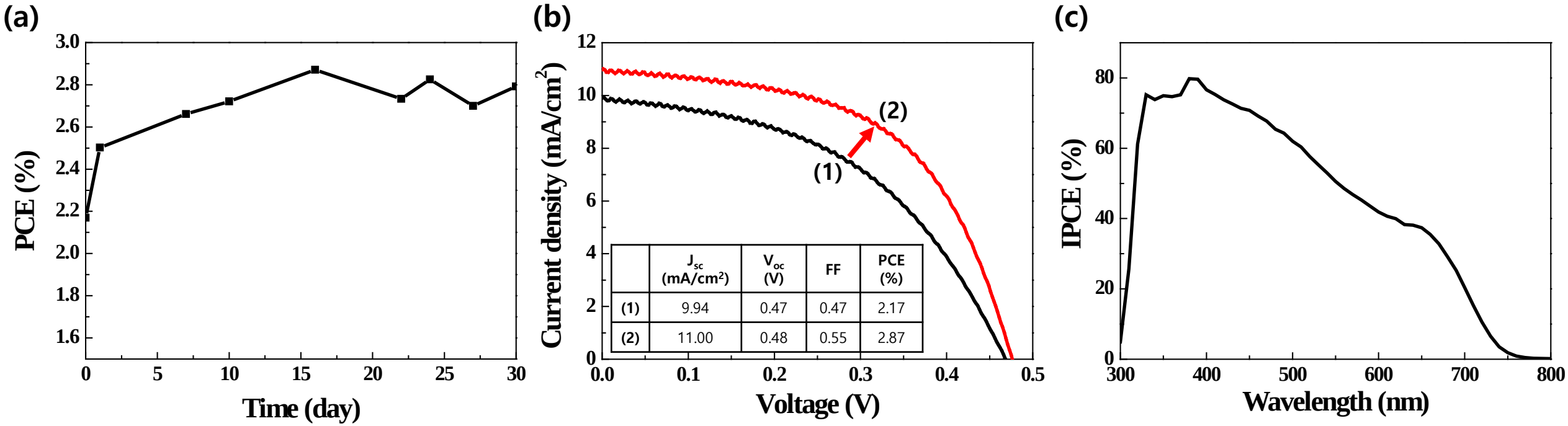
*1~4번 전극 색은 큰 차이가 없으나 1번 전극의 색이 살짝 더 진하게 보임
*Sb^{3+}용액을 40℃로 가열하면서 이온 교환을 시키면 확실히 빠르게 색 변화가 일어남

XRD 데이타



XRD pattern of FTO/TiO_2 and $FTO/TiO_2/Sb_2S_3$ films. The asterisk indicates the main peaks of Sb_2S_3.

효율 추적 및 J-V(처음 vs 최대 효율) & IPCE



	J_{sc} (mA/cm²)	V_{oc} (V)	FF	PCE (%)
(1)	9.94	0.47	0.47	2.17
(2)	11.00	0.48	0.55	2.87

(a) Changes in efficiency tracked for about one month, (b) J-V curves showing enhanced photovoltaic performance compared to initial measurements, and (c) IPCE of a Sb_2S_3-sensitized solid-state cell. The inserted table in part (b) shows (1) initial and (2) enhanced photovoltaic parameters of the solar cell.