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色素増感太陽電池におけるペプチド核酸の利用

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Introduction

Emission-free energy can be produced by converting sun light into electricity using solar cells. Dye-sensitized solar cells (DSSCs) promise to have high efficiencies and low production costs.

Introducing Ag nanoparticles (NPs) into DSSCs is known to improve the conversion efficiency [1,2]. So far, AgNPs with surface modifications of up to 2 nm have been used. In this range, longer surface modifications lead to higher efficiencies [3].

As an oligonucleotide, peptide nucleic acid (PNA) hybridizes with complementary sequences. PNA-DNA duplexes have been reported to conduct electricity similar to double stranded DNA [4].

In this work, we used PNA-modified AgNPs as well as free PNA in DSSCs.

Experimental

DSSCs with a porous TiO₂ working electrode modified with PNA (N^o C: GCCATAGAATCCAGT AAA-Glu), if indicated, AgNPs or PNA (match: N^o C: ACTGGATTCTATGGCAAA-Cys, or mismatch: N^o C: TGACCTAAGATACCGAAA-Cys) and *cis*-diisothiocyanato - bis (2, 2 - bipyridyl - 4, 4 - dicarboxylato) ruthenium (II) bis (tetrabutyl - ammonium) (N719 dye) were fabricated. AgNPs were modified with HS(CH₂)₁₁OH, mercapto-methylpyrimidine and, if indicated, PNA (match or mismatch, as free PNA).

Absorption spectra, IPCE and I-V curves of the DSSCs were measured and evaluated.

The amount of immobilized dye was determined after desorption in aqueous KOH.

Results and Discussion

Six types of DSSCs were fabricated with matching, mismatching or no complementary PNA and with or without AgNPs. The parameters obtained from absorbance spectra, I-V curves and IPCE do vary a lot at this time and cut-off criteria have yet to be found.

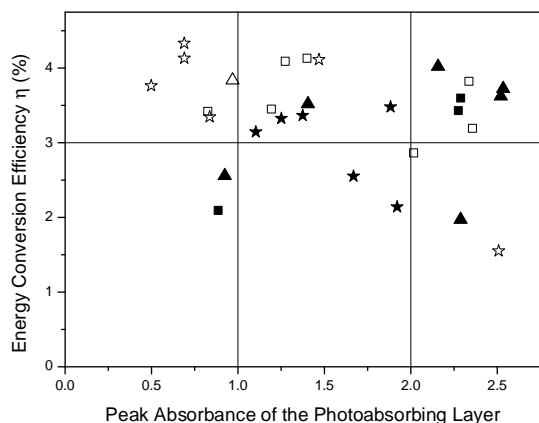


Fig. 1: Energy Conversion Efficiency versus Peak Absorbance (filled symbols: with AgNP, open symbols: no AgNP; square: no complementary PNA, triangle: mismatched complementary PNA, star: matching complementary PNA).

Despite the large variation of the data, the cells including double-stranded PNA seem to have a lower peak absorbance (Tab. 1). This effect does not appear to derive from less N719 in the photoabsorbing layer, though, as all cells seem to have similar amounts of immobilized dye (Tab. 1).

At the same time, no significant decrease in the short circuit current (I_{SC}), the incident photon to current efficiency (IPCE) or the energy conversion efficiency (η) can be observed (Tab. 1).

In a plot of energy conversion efficiency versus peak absorbance (Fig. 1), the cells with dsPNA (stars) therefore are accumulated in the upper left side of the graph ($\eta > 3\%$ and $A_{Peak} < 2.0$), whereas those with single-stranded PNA (squares and triangles) are mostly found in the upper right side ($\eta > 3\%$ and $A_{Peak} > 1.0$).

A possible explanation for this effect is, that even so dsPNA does inhibit the light absorption of the dye it also increases the efficiency of the electron injection into the conduction band of the TiO₂ layer.

This effect of dsPNA on the performance of DSSCs needs to be further investigated. Hopefully, a better understanding of its nature will lead to a higher energy conversion efficiency.

Tab. 1: Parameters obtained from absorbance spectra, I-V curves and IPCE and amount of immobilized dye for exemplary cells.

	A_{Peak}	dye (nmol/cm ²)	V_{OC} (V)	I_{SC} (mA/cm ²)	FF	η (%)	IPCE (%)
ssPNA	2.34		0.69	8.28	0.67	3.81	51
	1.28	35	0.72	9.02	0.62	4.08	59
ssPNA + AgNP	2.29		0.70	7.69	0.66	3.59	
	2.28		0.69	7.84	0.64	3.42	46
ssPNA + ssPNA	0.97	37	0.73	8.41	0.63	3.84	53
ssPNA + ssPNA-AgNP	2.53		0.67	8.66	0.64	3.72	56
	2.52		0.66	8.61	0.63	3.62	55
dsPNA	0.69	35	0.72	9.72	0.62	4.33	60
	0.69	33	0.72	9.24	0.62	4.13	57
dsPNA-AgNP	1.25		0.68	7.56	0.64	3.32	51
	1.37		0.70	7.14	0.67	3.37	

References

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Acknowledgement

We thank the Japan Society for the Promotion of Science (JSPS) for financial support.

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