

Photoelectrochemical Energy Conversion: from Efficient Planar Structures to Nanotopographical Devices

H.J. Lewerenz

Joint Center for Artificial Photosynthesis
California Institute of Technology
1200 E. California Blvd, Pasadena, CA 91125, USA

Abstract

In this overview, the development of photoelectrochemical energy conversion devices is presented, emphasizing development routes, the role of interfaces and device structural aspects. Photoelectrochemical energy conversion devices are predominantly based on the principle of rectifying junction formation between redox electrolytes and semiconductors, introduced by Gerischer [1]. The early efficient (planar) systems have been introduced by the Heller group at Bell Laboratories using III-V semiconductors [2-4]. High efficiencies and stability were achieved by selective, mostly *in-situ*, surface modification. Interfacial oxidic layers, formed during (photo)electrochemical processing, have been employed as stabilizers, resulting in long-term stability at high current densities [5]. Whereas these first half cells operated in the photovoltaic mode, InP has also been used as a photoelectrocatalytic hydrogen evolving system where the photocathode was made by surface functionalization with interfacial layers and electrocatalysts [6]. Subsequently, efficient ternary chalcopyrite solar cells have been developed [7, 8]. They, too, were stabilized by *in-situ* prepared interfacial films. The next development step was the inception of the dye sensitization cell which operates as an excitonic solar cell [9], representing the first efficient nanotopographic system. Besides the use of PV tandem structures for photoelectrocatalysis [10], cells were developed based on current oscillations on Si electrodes where a nanoporous thick oxide layer was formed [11]. Metal electrodeposition into the nanopores forms rectifying Schottky-type junctions which resulted in efficient photovoltaic cells, coined nanoemitter solar cells [12]. Early applications as photocathode using p-Si showed reduced efficiency due to the comparably low contact potential difference [13]. Recently, this limitation has been overcome by introducing a novel electrode architecture [14]. Interestingly, the early InP photocathode cell introduced by Heller et al. has found renewed interest as a nanotopographic system [15] and, also, as a buried junction thin film epitaxial structure [16] thereby demonstrating the legacy of experiments reaching from the late 1970-ies into today's work at the Joint Center for Artificial Photosynthesis where micro- and nanowire structures are explored for scalable solar fuel generating prototypes.

References

1. H. Gerischer, J. Electroanal. Chem. Interfac. Electrochem. **58** (1975) 263
2. B. A. Parkinson, A. Heller, and B. Miller, J. Electrochem. Soc. **126** (1979) 954
3. A. Heller, H.J. Lewerenz, B. Miller, Ber. Bunsenges. Phys. Chem. **84** (1980) 592
4. B. Miller, A. Heller, S. Menezes, H.J. Lewerenz, Farad. Disc. Chem. Soc. **70** (1981) 223
5. A. Heller, B. Miller, H.J. Lewerenz, K.J. Bachmann, J. Am. Chem. Soc. **102** (1980) 6555
6. A. Heller, R.G. Vadimsky, Phys. Rev. Lett. **46** (1981) 1153
7. S. Menezes, H.J. Lewerenz, K.J. Bachmann, Nature **305** (1983) 615
8. H.J. Lewerenz, H. Goslowky, K.-D. Husemann, S. Fiechter, Nature **321** (1986) 687
9. B. O'Regan, M. Graetzel, Nature **353** (1991) 737
10. O. Khaselev, J. A. Turner, Science **280** (1998) 425
11. M. Aggour, M. Giersig, H.J. Lewerenz, J. Electroanal. Chem. **383** (1995) 67
12. M. Aggour, K. Skorupska, T. Stempel Perreira, H. Jungblut, J. Grzanna, H.J. Lewerenz, J. Electrochem. Soc. **154** (2007) H794-H797
13. A.G. Munoz, H.J. Lewerenz, J. Electrochem. Soc. **156** (2009) D 242
14. D.V. Esposito, I. Levin, T.P. Moffat, A.A. Talin, Nature Mat. DOI 10.1038/NMAT3626 (2013)
15. M.H. Lee, J. Ager et al., Angew. Chem. Internat. Ed. **51** (2012) 10760
16. H.J. Lewerenz, C. Heine, K. Skorupska, N. Szabo, T. Hannappel, T. Vo-Dinh, S.A. Campbell, H.W. Klemm, A.G. Munoz, Energy & Environment. Sci. **3** (2010) 748