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Conversion of solar energy to electricity by saline/semiconductor interface

Przemiana energii słonecznej w elektryczną przy zastosowaniu interfejsu solanka/półprzewodnik

When a semiconductor comes into contact with a liquid (redox species), to maintain electrostatic equilibrium, there will be a charge transfer between the n-type or p-type semiconductor and liquid phase if formal redox energy level of redox species lies inside semiconductor band gap [1-5]. We have considered one dimensional particle energy bands for the nearly free particle model at a saline/semiconductor interface structure [6]. With the help of Schrodinger equation and Bloch's theorem, it is possible to formulate a general approach to derive both the band bending and direct band gap in the interface structure. The Bloch's theorem shows that translational symmetry in real space leads to translational symmetry in k-space. The model was introduced to account for the effects of band bending at the interface structure.

To obtain better insight into the mechanism of the photovoltaic effect, we have performed detailed electric investigations on interfaces of a 5-μl drop of saline with ZnO and with Cu_2O with fixed irradiations of 250 W/m^2 and fixed temperatures of 50°C, respectively. The Cu_2O and ZnO thin layers were prepared similarly to the previously published method [3,4]. A measurement method of photovoltaic effect permits the resistor's calibration value, which is specific for the output electric power of interface.

Results and discussion

Band diagrams of two occupied and unoccupied bands separated by the energy gap at the semiconductor are illustrated in Figure 1.

Figure 2 shows the time evolution of electric power for saline/ZnO and saline/Cu_2O interfaces. From two shapes of the curves, we see that, immediately following the partial wetting of drops on the semiconductor surface, they change their shapes very quickly. It should be noted that the quick jumps are due to the instability of band bending in the interface structure. At the end of the evaporation process, the exponential behaviour of electric power relaxes back to equilibrium. Experimental efficiency in the range of 0.5%-3.2% can be achieved. The simula-

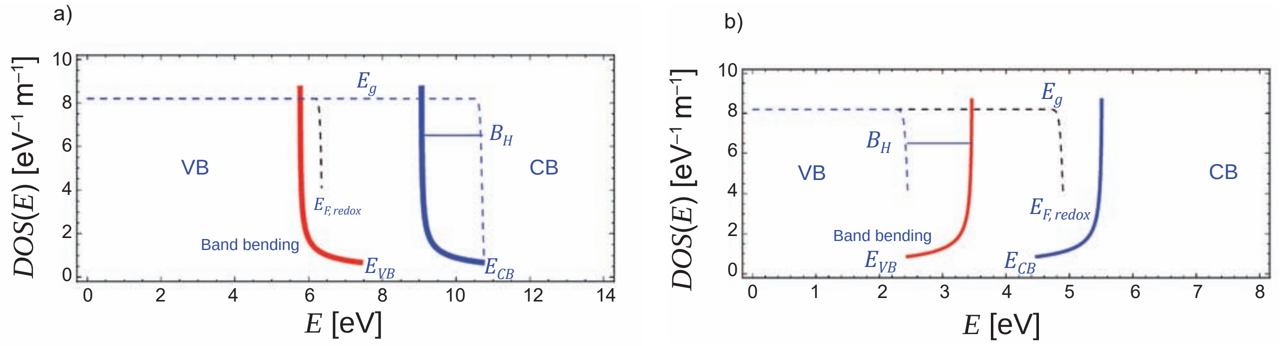

Fig. 1. The density of states in various types of materials
a) the 5 μL saline/ZnO semiconductor interface, b) the 5 μL saline/Cu_2O semiconductor interface
DOS(E) denotes the density of states, and E_{VB} is the maximum energy of the valence band, E_{CB} is the characteristic energy of the conduction band and B_h is the energy barrier height. E_g is the energy gap, $E_{F,redox}$ is the redox Fermi level of interfaces

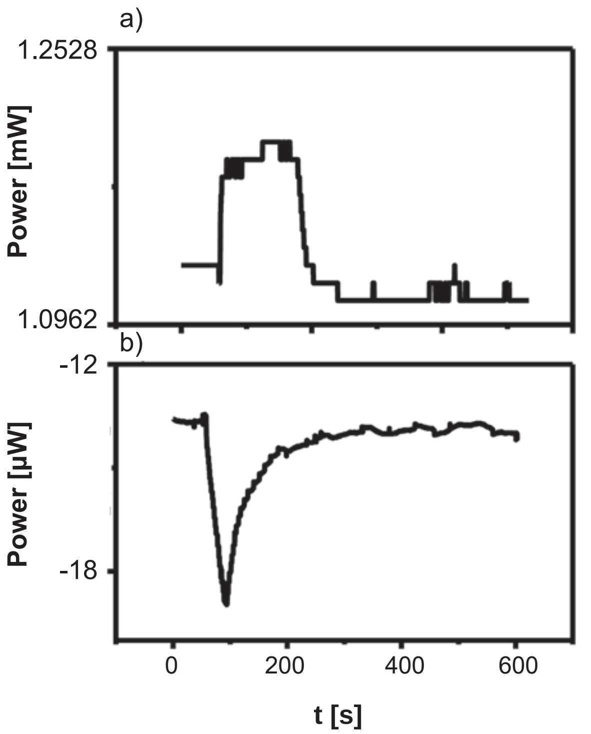

Fig. 2. Time evolution of the electric power of the 5-μl saline drop/ n-ZnO interface a), and the 5-μl saline drop/ n-ZnO interface, b) during isothermal photovoltaics (50°C and 250 W/m²)

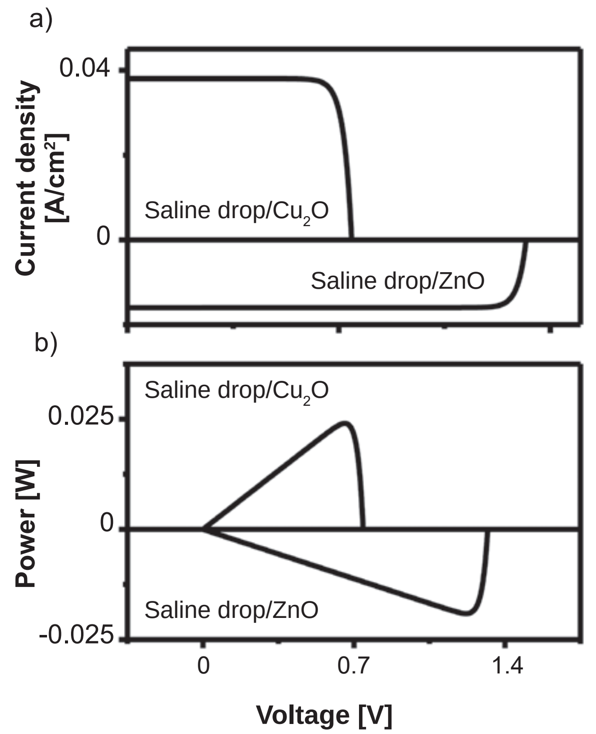

Fig. 3. Theoretical current density-voltage and power-voltage curves for the saline drop/ n-ZnO interface (a) and the saline drop/ n-ZnO interface (b)

tions of illuminated current density-voltage curves are plotted in Figure 3 using the analytical model as in work [3]. The electric power predicted by simulation and experimental results has a similar behavior. Theoretically, the efficiency limit can be raised from 19% at saline/ZnO interface to 24% at saline/Cu_2O if their structures are perfect.

Conclusion

Our study reveals the photoactive interfaces, which can convert sunlight into electricity. The nearly free particle model explains the interface structures. The simulations describe behaviour for the electric power as a function of voltage. Therefore, it is possible to extract correct information about the studied interfaces.

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