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Editorial: Physical Model and Applications of High-Efficiency Electro-Optical Conversion Devices

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Editorial on the Research Topic

Physical Model and Applications of High-Efficiency Electro-Optical Conversion Devices

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MODELING OF HIGH-EFFICIENCY ELECTRO-OPTICAL CONVERSION DEVICES

To improve the performances of an electro-optical conversion device, a physical model of the same is needed. In fact, once an appropriate model is built, the optimization of the device design is possible. In particular, electrochemical properties are very relevant to the efficiency of electro-optical conversion devices. It has been shown that impurity doping is an effective method of improving electrochemical performance [1–4]. An Al-doping ternary cathode material model based on first principles density functional theory is proposed to improve the electrochemical performance of the device (Gao et al.). In this model, Al doping provides the ternary cathode material with better electrical conductivity and cycling ability, therefore results in a significant improvement in the rate performance of the material. On this basis, considering that Li-rich Mn-based oxides are also commonly used cathode materials for battery modules of electro-optical conversion devices, a similar model is established to simulate the effects of changing sodium doping amounts on the electrochemical properties of the oxide (Gao et al.). The results show that the conductivity is larger when the sodium doping amount is 0.1 mol. In addition, a model is developed to prepare n^{-}-n^{+} photodiodes by growing Bi-doped MAPbCl3 epitaxial layer on MAPbCl3 single crystal substrate (Zhao et al.). Specifically, impurity doping can improve the physical and electrochemical properties of conventional materials, leading to an increase in the efficiency of electro-optical conversion devices [5, 6].

At the same time, high self-heating and low heat dissipation are the critical issues needed to be addressed during the operation of electro-optical conversion devices. Heat is generated during devices operation, resulting in higher device temperature and thermal droop. Building some specific models to reduce the thermal droop can effectively boost the efficiency of the devices and promote the energy saving [7–9]. A model based on thermal transport effects is proposed to study electron transports and transport efficiency of LEDs under high and low bias voltages. When the applied voltage is lower than the photon voltage, heat generated in the circuit is exchanged and absorbed by carriers. This allows to improve the efficiency of the whole system through energy recovery and heat collection (Lu et al.). The new model can act as the research prototype to design high-efficient LED arrays for better energy recycling and thermal control. Based on the concept of heterostructure, a model is proposed to obtain a new type of nanowire (NW) photoanode by strong enhancement of the photocurrent in solar water splitting.

A heterostructure with correct staggered band arrangement greatly enhances the separation and transmission of photogenerated carriers. It not only improves the efficiency of n-type photoanode, but also solves the problem of p-type doping that has a great impact on the device (Zhao et al.).

The presence of Majorana bound states (MBSs) in the circuits can greatly affect the value of the currents. Therefore, accurate detection of MBSs is one of the core issues addressed by modeling electro-optical conversion devices [10]. In the framework of the nonequilibrium Green's function, a new model is established to investigate electronic transport in a quantum dot (QD) which is coupled to a phonon bath and MBSs simultaneously (Wang et al.). With a certain bias voltage, by selecting correct parameters, heating can be suppressed even if the current is increased. This permits to eliminate the waste heat generated by the current through the low dimensional circuit. Properties of spin Seebeck effect in a quantum dot coupled to topological superconductor hosting a pair of MBSs are theoretically studied by nonequilibrium Green's function method (Sun et al.). This model may have practical applications in the detection of MBSs and be used in highly efficient spin-thermal devices. It is an ideal choice for designing energy-saving devices. Based on the characteristics of MBSs in photon-assisted tunneling (PAT) process, it is valuable to study the influence of MBSs on thermoelectric properties by using optical technology [11–14]. Considering the irradiation of photon field, conductivity and thermoelectric properties of a QD coupled to MBSs are studied (He et al.). As the coupling strength between the QD and MBSs increases, the combined action of MBSs and PAT can significantly improve the thermoelectric energy. Meanwhile, a sign change of the thermopower induced by changing either dot-MBSs coupling or temperature is analyzed. This can be used as the evidence of the existence of MBSs. In spintronic devices, a key quantity is the relative change of current called tunnel magnetoresistance (TMR). A model of double quantum dots in series is established, and the properties of electrical current and TMR in the model are studied theoretically (Tang et al.). The magnitude of currents can be changed by adjusting the sign of spin polarization and the arrangement of magnetic moments. When two spin polarizations are the same in sign, a negative TMR emerges which is useful in detection of the MBSs. This tunable current and TMR can also be used for efficient spintronic devices or information processing. The properties of local heat originated from energy exchange are studied theoretically in a quantum dot (QD) (Wang et al.). A dual negative differential of heat generation (NDHG) effect is found in the model. In addition, the simulation results show that the dual NDHG effect is robust against the variation of intradot Coulomb interaction strength, and may remedy some limitations of tunneling spectroscopy technique.

The previous physical models can determine the properties of electro-optical conversion, electrochemistry and heat generation, etc. Selecting right parameters to optimize models can lead to higher efficiency in electro-optical conversion devices. As electro-optical devices continue to shrink in size, increasing the conversion efficiency of devices will not only allow for better performance, but also expand their application in new materials and structures.

APPLICATIONS OF HIGH-EFFICIENCY ELECTRO-OPTICAL CONVERSION DEVICES

The development of new materials and structures is needed for the application of electro-optical conversion devices [15, 16]. III-V multijunction solar cells are widely used in space applications due to their super high electro-optical conversion efficiency and radiation resistance (Li et al.). The need of a tradeoff between bandgap matching and lattice matching promotes the development of new structures and materials of solar cells (Li et al.). The conversion efficiency can be effectively improved by crystalline silicon heterojunction solar cell. Furthermore, latticematched GaInP/GaAs/Ge triple junction solar cell fabrication technology is mature and can be used in large-scale production. A polychromic macromolecular dye system using azopyrazolone as chromophore is proposed (Deng et al.). The dye system is constructed with azopyrazolone dye as the chromogenic matrix. The binding effect of the bridge group in space is used to reduce the dipole moment of the entire molecule and the backflow effect of oil with external electric field. This method can effectively improve the solubility, absorption coefficient and light stability of dyes. In addition, an ultrafast modulation effect on local magnetization orientation in the GdFeCo layer is obtained when it is triggered by the femtosecond laser pulse and driven by the effective exchange field (Xie et al.). This method is conducive to the development of exchange-coupled composites.

The optimization of algorithms is of great significance to promote the application of high-efficiency electro-optical conversion devices (Liu et al.). In order to measure the actual driving distance of vehicle ahead, an improved sum of squared difference (SSD) algorithm is proposed (Lin et al.). Gaussian blur and gray conversion are used to optimize images, and then the improved SSD is used for stereo matching and disparity calculation to obtain the corresponding distance value of each point. This method can effectively improve the accuracy of stereo matching and disparity calculation, and can be applied to license plate recognition and other fields. A novel generation and transmission method of 400G signal is demonstrated with single discrete Fourier transform-spread (DFT-spread) band to avoid multi-band inter-sub-band interference (Liu et al.). The problem of increasing bandwidth brings about by the development of mobile Internet can be solved by this technology. The optimization of algorithms can also be used to improve the performance of electro-optical conversion devices, such as electrophoretic displays (EPDs) and electrowetting displays (EWDs) (Tian et al.) [17, 18]. A driving waveform based on driving process fusion and black reference gray scale is proposed to improve the performance of EPDs (Wang et al.). In this driving waveform, the DC balance rule is used to prevent the display breakdown caused by charge trapping, and the black state is used as the reference gray scale to reduce the driving time. Similarly, some driving waveforms are proposed to reduce contact angle hysteresis, response time and charge trapping, and improve the aperture ratio of EWDs (Yi et al.) [19]. A driving scheme for EWDs using alternating current (AC) voltage is proposed and the inhibitory effect of AC voltage on contact angle hysteresis is proved (Wang et al.). As for reducing response time, a driving waveform based on overdriving voltage is proposed to increase the response speed of oil (Zeng et al.). The influence of different overdriving voltages on response time is tested. The experimental results show that overdriving the voltage can effectively reduce the response time. The charge trapping of EWDs also needs to be solved. A method shows that charge trapping can be reduced by a periodic reset signal, and the oil backflow can also be reduced by the reset signal (Zhang et al.). In a previous study, it has been proven that oil splitting is one factor which can lead to the decrease of aperture ratio [20]. A driving waveform with a narrow falling ramp, low-voltage maintenance, and a rising ramp is proposed to reduce oil splitting (Lai et al.). The low voltage maintenance stage in this driving waveform can effectively suppress the oil splitting. In addition, the inhibitory effect of rising gradient voltage on oil splitting is shown in another driving scheme (Tian et al.).

The latest progress of applications of electro-optical conversion devices was discussed in this section. Study on new materials, structures and algorithms can effectively improve the electro-optical conversion efficiency and increase the various possible applications of electro-optical conversion devices, which may enable new technologies to facilitate people's lives and promote further industrialization.

CONCLUSION

The latest technology developments impose tighter requirements for the conversion efficiency of electro-optical conversion devices. In this reserch topic, new high-efficiency electro-optical conversion devices are described. At first, the impact of the latest models of electro-optical conversion devices on their performance is introduced. Then, the new materials, structures and algorithms of electro-optical conversion devices are classified and summarized, which provides reference value for increasing their performance and application scenarios. In the future, the rapid development of electro-optical conversion devices is expected to bring technological breakthroughs in the fields of solar cells and new displays.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

1. Jian J, Jiang G, van de Krol R, Wei B, Wang H Recent Advances in Rational Engineering of Multinary Semiconductors for Photoelectrochemical Hydrogen Generation. *Nano Energy* (2018) 51:457–80. doi:10.1016/j.nanoen.2018.06.074
2. Cho S, Jang J-W, Lee K-H, Lee JS Research Update: Strategies for Efficient Photoelectrochemical Water Splitting Using Metal Oxide Photoanodes. *Apl Mater* (2014) 2:010703. doi:10.1063/1.4861798
3. Chi F, Liu L, Sun L Photon-mediated Spin-Polarized Current in a Quantum Dot under thermal Bias. *Chin Phys. B* (2017) 26:037304–94. doi:10.1088/1674-1056/26/3/037304
4. Chi F, Fu Z-G, Liu L, Zhang P Enhanced Spin-dependent Thermopower in a Double-Quantum-Dot Sandwiched between Two-Dimensional Electron Gases. *Chin Phys. B* (2019) 28:107305. doi:10.1088/1674-1056/ab3f98
5. Sarkar P, Srivastava A, Tripathy SK, Baishnab KL, Lenka TR, Menon PS, et al. Exploring the Effect of Ga3+ Doping on Structural, Electronic and Optical Properties of CH3NH3PbCl3 Perovskites: an Experimental Study. *J Mater Sci Mater Electron* (2020) 32:12841–55. doi:10.1007/s10854-020-04019-w
6. Xiong Y, Xu L, Wu P, Sun L, Xie G, Hu B Bismuth Doping-Induced Stable Seebeck Effect Based on MAPbI 3 Polycrystalline Thin Films. *Adv Funct Mater* (2019) 29:1900615. doi:10.1002/adfm.201900615
7. Meneghini M, De Santi C, Tibaldi A, Vallone M, Bertazzi F, Meneghesso G, et al. Thermal Droop in III-Nitride Based Light-Emitting Diodes: Physical Origin and Perspectives. *J Appl Phys* (2020) 127:211102. doi:10.1063/5.0005874
8. Lei QQ, Aierken A, Sailai M, Heini M, Shen XB, Zhao XF, et al. 150 KeV Proton Irradiation Effects on Photoluminescence of GaInAsN Bulk and Quantum Well Structures. *Opt Mater* (2019) 97:109375. doi:10.1016/j.optmat.2019.109375
9. Shen D-F, Guo J-J, Lin G-S, Lin J-Y Content-aware Specular Reflection Suppression Based on Adaptive Image Inpainting and Neural Network for Endoscopic Images. *Comput Methods Programs Biomed* (2020) 192:105414. doi:10.1016/j.cmpb.2020.105414
10. Karzig T, Knapp C, Lutchyn RM, Bonderson P, Hastings MB, Nayak C, et al. Scalable Designs for Quasiparticle-Poisoning-Protected Topological Quantum Computation with Majorana Zero Modes. *Phys Rev B* (2017) 95:235305. doi:10.1103/physrevb.95.235305
11. Li Y, Kundu A, Zhong F, Seradjeh B Tunable Floquet Majorana Fermions in Driven Coupled Quantum Dots. *Phys Rev B* (2014) 90:121401. doi:10.1103/PhysRevB.90.121401
12. Väyrynen JI, Rastelli G, Belzig W, Glazman LI Microwave Signatures of Majorana States in a Topological Josephson junction. *Phys Rev B* (2015) 92:134508. doi:10.1103/PhysRevB.92.134508
13. Chen H, Zhu K All-optical Scheme for Detecting the Possible Majorana Signature Based on QD and Nanomechanical Resonator Systems. *Sci China Phys Mech Astron* (2015) 58:1–14. doi:10.1007/s11433-014-5637-4
14. Tang H-Z, Zhang Y-T, Liu J-J Photon-assisted Tunneling through a Topological Superconductor with Majorana Bound States. *AIP Adv* (2015) 5:127129. doi:10.1063/1.4939096
15. Jin M, Shen S, Yi Z, Zhou G, Shui L Optofluid-based Reflective Displays. *Micromachines* (2018) 9:159. doi:10.3390/mi9040159
16. Yi Z-C, Chen Z-B, Peng B, Li S-X, Bai P-F, Shui L-L, et al. Vehicle Lighting Recognition System Based on Erosion Algorithm and Effective Area

Separation in 5g Vehicular Communication Networks. *IEEE Access* (2019) 7: 111074–83. doi:10.1109/access.2019.2927731

17. Yi Z, Shui L, Wang L, Jin M, Hayes RA, Zhou G A Novel Driver for Active Matrix Electrowetting Displays. *Displays* (2015) 37:86–93. doi:10.1016/j.displa.2014.09.004
18. Yi Z-c., Bai P-f., Wang L, Zhang X, Zhou G-f. An Electrophoretic Display Driving Waveform Based on Improvement of Activation Pattern. *J Cent South Univ* (2014) 21:3133–7. doi:10.1007/s11771-014-2285-9
19. Yi Z, Huang Z, Lai S, He W, Wang L, Chi F, et al. Driving Waveform Design of Electrowetting Displays Based on an Exponential Function for a Stable Grayscale and a Short Driving Time. *Micromachines* (2020) 11:313. doi:10.3390/mi11030313
20. Luo Z, Fan J, Xu J, Zhou G, Liu S A Novel Driving Scheme for Oil-Splitting Suppression in Electrowetting Display. *Opt Rev* (2020) 27:339–45. doi:10.1007/s10043-020-00601-z

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