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# Electric and Thermal Effects on Mach-Zehnder Interferometer Optical Modulator

広島大学ナノデバイス・バイオ融合科学研究所, ° サナ アムリタ クマル, 古谷 竜一, 雨宮 嘉照, 横山 新
Research Institute for Nanodevice and Bio Systems, Hiroshima University
°Amrita Kumar Sana, Ryuichi Furutani, Yoshiteru Amemiya, and Shin Yokoyama
E-mail: yokoyama-shin@hiroshima-u.ac.jp

## Introduction

Silicon industry is reaching its limit in size, device integration and complexity, as the physical limitations of metallic interconnects. Existing metallic interconnect technology is facing a severe challenges due to ever-increasing bandwidth demand for next generation high performance computing. Light modulation in silicon, is the challenging aspects to change the refractive index, because silicon does not show any Pockel's effect [1]. Light modulation in silicon is achieved by varying the carrier density to change the local index of refraction [2]. We demonstrate Mach-Zehnder Interferometer modulator with cascaded p/n junctions which are arranged as shown in Fig. 1, along the arms of modulator and operated at forward biased mode.In the slow switching mode, both the thermal and electric field effects are important, while in the high speed modulation only the electric effect is considered. We discuss about these two effects.

## Fabrication process

The MZI optical modulator was fabricated on silicon-on-insulator (SOI) wafer. An oxidation layer of 100 nm is formed on the SOI wafer. The $SiO_2$ layer is deposited by atmospheric pressure chemical vapor deposition (APCVD) and this layer acts as an insulator as well as upper cladding layer. Finally, Al electrodes are fabricated after contact hole wet etching, by the DC magnetron sputtering and $H_2$+$N_2$ annealing is carried out. Optical micrograph of our fabricated device is shown in Fig. 2.

## Results Discussion and Conclusion

Modulation behavior is shown in Fig. 3(a) for 3V and 3(b) for 6V. Simulation is carried out, the output intensity is proportional to $\cos^2\theta/2$ where θ is phase shift and θ= θ(electric) + θ(thermal). Electrical effect decreases refractive index change, $\Delta n<0$ and thermal effect increases refractive index change, $\Delta n>0$. Simulation results (Fig. 3(c) and 3(d)) show at different applied bias both electrically and thermally phase change has increased. Phase change by injected current may depends on injected current density as well as thermal phase change depends on amount of power. Figure 4(a) and 4(b) shows that optical phase change increasing by increasing the bias voltage.

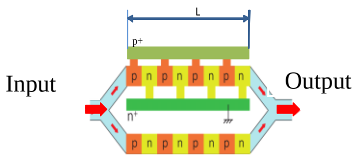


Fig. 1 Structure of Si MZI optical modulator with cascaded p/n junctions [3].

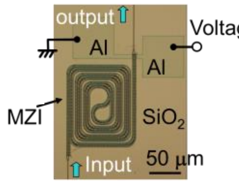


Fig. 2 Optical micrograph of the fabricated MZI (arm length is 5 mm) [3].

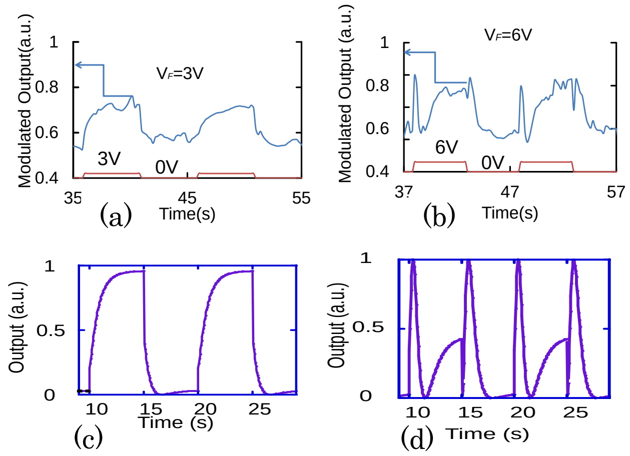


Fig. 3 (a), 3(b) measured are results and 3 (c), 3(d) are simulation results at 3V and 6V respectively.

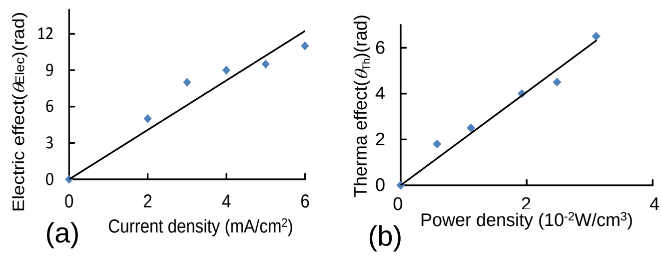


Fig. 4 (a) Phase change ($\theta_{Elec}$) versus current density (b) Phase change ($\theta_{Th}$) versus power.

## References

1. M. R. Watts *et al.*, IEEE Journal of Selected Topics in Quantum Electronics**16** (2010) 159.
2. Zhi-Yong Li *et al.*: OPTICS EXPRESS **17** (2009) 15948.
3. R. Furutani *et al.*: Proceedings of SPIE,Silicon Photonic Integrated Circuits III **8431** (2012) 84310W