

# Reversible and Precisely Controlled p/n type Doped Method for van der Waals MoTe<sub>2</sub> Device and Its Application of Logical Circuits

Shih-Hsien Yang\*

Yuan-Ming Chang#, Yen-Fu Lin#, Chen-Hsin Lien\*

\*Department of Electrical Engineering & Institute of Electronic Engineering, National Tsing Hua University, Hsinchu 300, Taiwan

# Department of Physics, National Chung Hsing University Taichung 40227, Taiwan

Sh.yang@gapp.nthu.edu.tw

A simple and effective doping method is very difficult for two-dimensional materials, which greatly limits the application of two-dimensional materials in logic devices.[1-3] In this study, a method of reversible and precisely controlled p/n-type doping for molybdenum ditelluride (MoTe<sub>2</sub>) is successfully achieved by electrothermal doping (E-doping) processes, which includes two main processes as shown in figure 1A, one is electrothermal annealing treatment by drain bias voltage in a vacuum chamber, oxygen or water molecules, which adsorbed on MoTe<sub>2</sub> will be excluded by high temperature, results in n-type electron doping of the transistors and the transfer curve is as Figure 1B. The other one is adsorption of oxygen or water molecules by applying a gate voltage on transistors in air (p-type hole doping), the transfer curve is as Figure 1C. Since E-doping method has no irreversible chemical reaction in the doping process, E-doping method is reversible (shows in Figure 1D), simple and highly efficient.

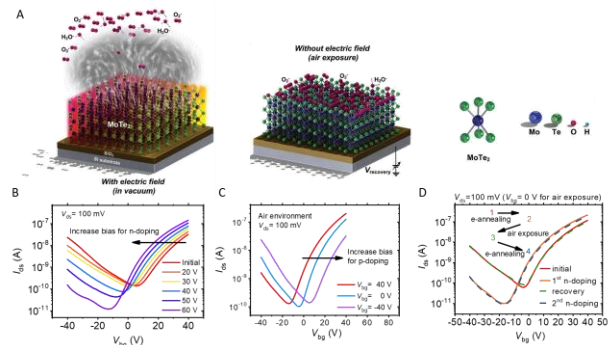
Furthermore, through precise combination of p/n-doped MoTe<sub>2</sub> transistors, a series of logical circuits, such as inverter, NOR gate and NAND gate, are successfully realized in Figure 2.

Based on the experimental results, in this study undoubtedly provides a efficient doping method to create a high performance electronic device.

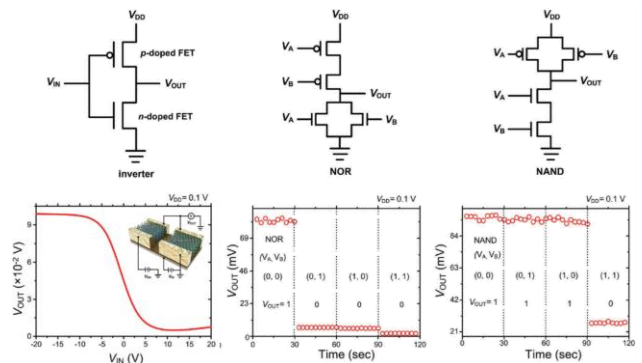
## References

- [1] Gong, Yongji, et al., Nano letters 14.2 (2013) 442-449.
- [2] Duan, Xidong, et al., Nano letters 16.1 (2015) 264-269.
- [3] Zhang, Siyuan, et al., Advanced Materials 30.36 (2018) 1802991.

## Figures



**Figure 1:** A. Schematic of E-doping processes for MoTe<sub>2</sub> channels. B. Transfer characteristics of the MoTe<sub>2</sub> transistor treated by E-annealing for n-doping process. C. Transfer curve of MoTe<sub>2</sub> transistors, which exposed in air for p-type doping process. D. Transfer curve for reversible doping process by E-doping.



**Figure 2:** Schematic of logical circuit composed of E-doping n/p-type MoTe<sub>2</sub> transistor.