2023「中技社科技獎學金」

2023 CTCI Foundation Science and Technology Scholarship

境外生研究獎學金

Research Scholarship for Overseas Students

Manipulation of piezotronic effect for development of piezotronics transistors and various sensors

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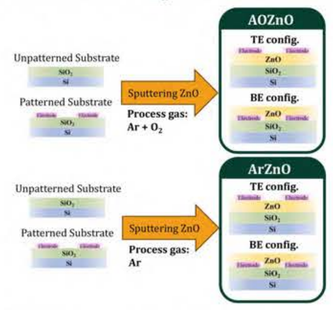
Abstract

The development of nano devices, smart sensors, and advanced electronics demands compliance with the concern of energy efficiency in the era of increasing awareness of green energy and environmental sustainability. Therefore, development of energy efficient sensors and devices catches more intention throughout the research community. Here, we present the development of Piezo-gated Transistor and shown the dual operation (depletion & accumulation) modes on a piezotronic device. We investigated the reduction in carrier concentration by one order could enhances the piezo-gating effect by ~156% and also identify the underlying non-dominated piezoresistive effect could further enlarge the Gauge factor of strain sensitivity. After that, we combined the piezo-gating effect with thermoelectric effect and obtain an enormous enhancement(~400 times) in thermoelectric power factor (PF) by simultaneous contribution of piezo-gating effect. Finally, we developed Multi-dimensional Piezo-gated Flexible Transistor (M-PGFT) , which not only detect strain but also identifies the type of strain. Further, we performed three valued/ternary logic operation employing the Multi-dimensional Piezo-gated Flexible Transistor (M-PGFT) based sensor, operating as a standard ternary inverter (STI) logic and a standard ternary NAND (ST-NAND) logic unit. This trajectory of innovation ushers in energy-efficient prospects, spanning domains from human-machine interaction to soft robotics and structural health monitoring, shaping a future enriched by mindful engineering and sustainable technology.

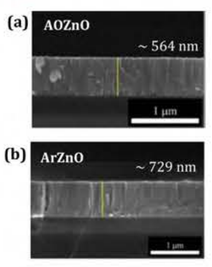
Keywords: Piezo-gating effect, Transistor, flexible sensor, ZnO, Piezotronic Strain Sensor , Ternary Logic Device

Results and Discussion

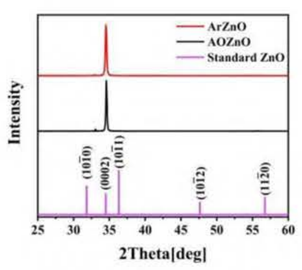
❑ Part 1: Development of Piezo-gated Transistor



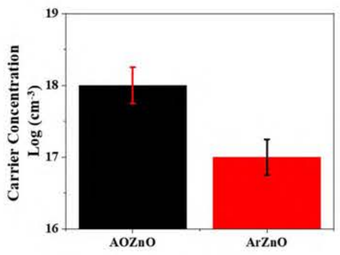
F 1.1 Schematic diagram of device fabrication



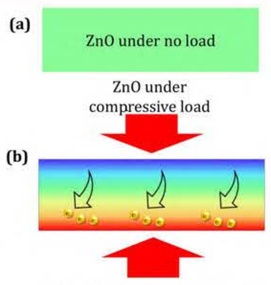
F 1.2 Cros-section SEM images of AOZnO and ArZnO samples



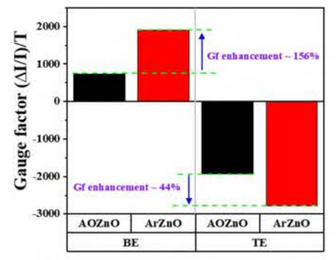
F 1.3 XRD data of AOZnO and ArZnO samples



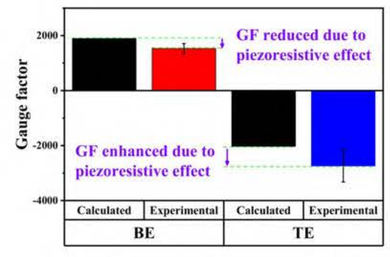
F 1.4 Hall measurement data showing carrier concentration of AOZnO and ArZnO samples.



F 1.5 Schematic mechanism of piezo-gating effect.

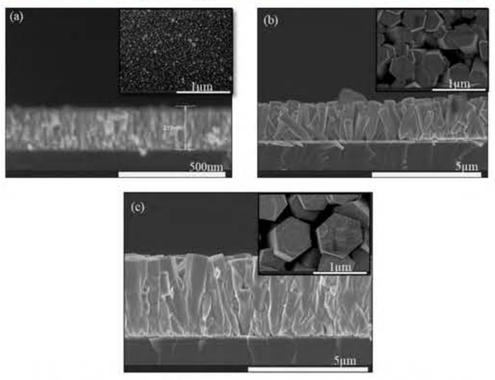


F 1.6 Comparison of the Gauge Factor of Piezo-gating effect between Top and Bottom electrodes of AOZNO and ArZnO samples.

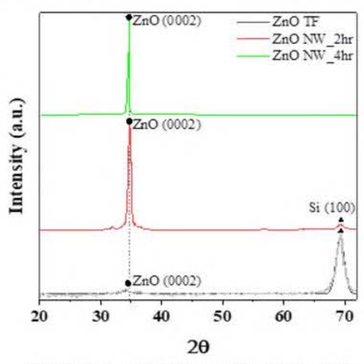


F 1.7 Comparison of the Gauge Factor of Piezo-gating effect between Theoretical and experimental data of Top and Bottom electrodes.

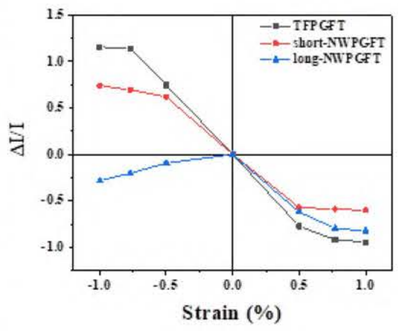
❑ Part 2: Synergistic effect of Piezo-gating and thermoelectric effects



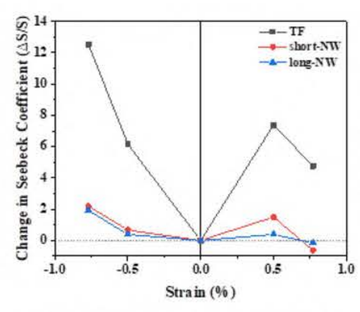
F 2.1 Cros-section SEM images of TF, Short-NW and Long-NW samples



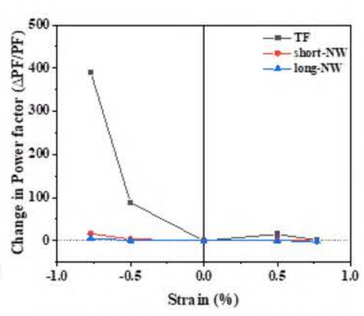
F 2.2 XRD data of TF, Short-NW and Long-NW samples



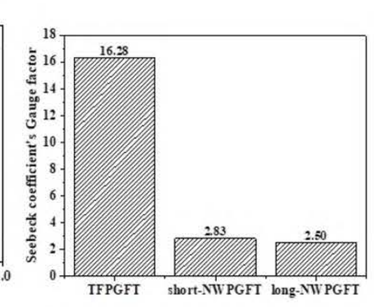
F 2.3 Change in conductivity under different strain conditions on different samples.



F 2.4 Change in Seebeck Coefficient under different strain conditions on different samples.

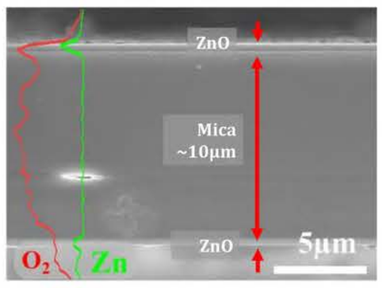


F 2.5 Change in Power Factor under different strain conditions on different samples.

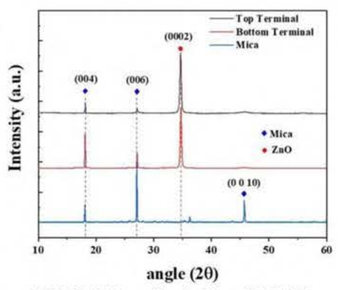


F 2.6 Comparison of the Gauge Factor of Seebeck co-efficient for self powered strain sensor.

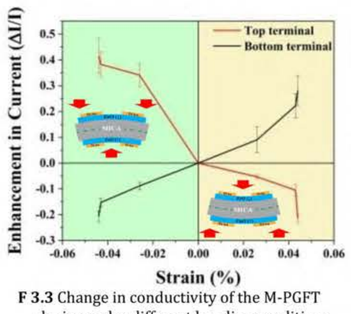
❑ Part 3: Development of Multi dimensional Piezo-gated flexible Transistor



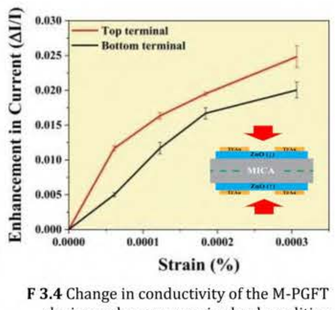
F 3.1 Cros-section SEM images of M-PGFT device.



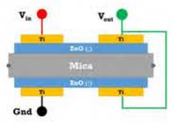
F 3.2 XRD data of both sides of M-PGFT device.



F 3.3 Change in conductivity of the M-PGFT device under different bending conditions, which shows asymmetric pattern on top and bottom terminals.

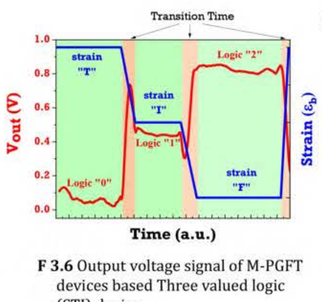


F 3.4 Change in conductivity of the M-PGFT device under compressive load condition, which shows symmetric pattern on top and bottom terminals.

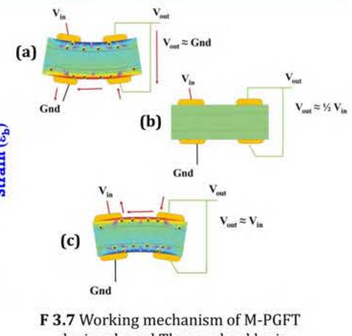


Strain Input	Logic Output
T (2)	0
I (1)	1
F (0)	2

F 3.5 Schematic diagram of M-PGFT devices based Three valued logic (STI) device and the output truth table.



F 3.6 Output voltage signal of M-PGFT devices based Three valued logic (STI) device.



F 3.7 Working mechanism of M-PGFT devices based Three valued logic (STI) device.

Conclusions

In this study, we have proposed and successfully investigate the internal working mechanism of a piezo-gated transistor-based strain/tactile sensor. We have also successfully explored the possibility of such effect to be work synergistically with other effects. Finally, we have developed a smart flexible strain sensor which could open up new dimensions to the human machine interface systems and advanced robotics.

Selected Publication and Patent

- **Dutta, Jit**, and Chuan-Pu Liu. "Piezo-gated flexible transistors: A path to energy-efficient multi-functional piezotronic devices." Nano Energy 114 (2023): 108663.
- **Dutta, Jit**, Zhe-Yong Gong, Arijit Mitra, and Chuan-Pu Liu. "Enormous enhancement of thermoelectric properties via piezo-gating effect." Nano Energy 108 (2023): 108246.
- **Dutta, Jit**, and Chuan-Pu Liu. "Analytical and experimental investigation of dual-mode piezo-gated thin film transistor for force sensors." Nano Energy 95 (2022): 106985.
- **Dutta, Jit**, and Chuan Pu Liu. "MULTI-DIMENSIONAL STRAIN SENSING DEVICE, METHOD FOR SENSING TYPES OF EXTERNAL MOTIONS AND FOR FORMING TERNARY VALUED LOGIC DEVICE BY THE SAME, AND TERNARY VALUED LOGIC SYSTEM", US Patent, Application Number: 18/219,300, File Date 2023/07/07.

Acknowledgement

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