L.4: Zinc oxide based triboelectric nano generator for vibration energy harvesting

A triboelectric nano generator (TENG) is an energy harvesting device that converts external mechanical energy such as vibration, rotation, wind, human motion, and water wave energy into electricity by conjunction of triboelectric effect and electrostatic induction. TENG generally consists of positive and negative triboelectric materials, which in contact initiate the transfer of surface charges. When these positive and negative triboelectric materials separate, generated surface charges are induced to the corresponding electrodes and result in the flow of current through external load. Since the output performance of TENG depends primarily on the ability of the positive/negative triboelectric materials to lose/gain electrons i.e., their effective work function difference, hence positive triboelectric material should have enough electrons in the conduction band for transferring to negative triboelectric material, and vice-versa. ZnO owing to its wide and direct bandgap, tuneable n-type conductivity, low cost and matured nanofabrication methodologies has emerged as potential positive triboelectric material for TNEGs.

We have developed TENGs based on ZnO nanowires as positive triboelectric material. ZnO nanowires of mean diameter ~ 100 nm and density ~ 8 μm^{-2} were deposited on ITO/Quartz substrates via vapour-phase transport method using two-zone tubular furnace. High purity Zn dust (source) was heated in quartz crucible at different temperatures in the range of 400-700 °C, while the substrate was kept at 600 °C and ~ 35 mm away from the source. Argon flowing at 100 sccm was used as the carrier gas and growth was performed for one hour duration. As grown ZnO nanowires on ITO/Quartz substrates were used as the positive triboelectric material and spin casted PDMS film on ITO/PET substrate served as the negative triboelectric material. For the fabrication of TENGs, the ZnO/ITO/Quartz and PDMS/ITO/PET were packed face to face, while maintaining a gap of ~ 2 mm using scotch tape as shown in Figure L.4.1(a). The ITO electrodes of both the ZnO and PDMS films were connected to an external circuit via fine copper wire.

The electrical output characteristic viz., open-circuit voltage (V_{OC}), and short circuit current (I_{SC}) of ZnO-TENGs were measured using an oscilloscope and a low noise current preamplifier by applying 30 N force vertically at different tapping frequencies in the range of 1-10 Hz. The V_{OC}, I_{SC}, and power density of ZnO-TENGs were found to increase with increasing growth temperature up to 600 °C and frequency up to 6 Hz for fixed applied force and thereafter decreased. Figures L.4.1(b) and L.4.1(c) show the output characteristics of ZnO-TENG fabricated with ZnO grown at 600 °C for which the work-function difference with PDMS was maximum, as measured by ultraviolet photoelectron spectroscopy. The maximum V_{OC} ~ 210 V (peak-peak) and I_{SC} ~ 95 µA (peak) were observed when 30 N force was applied at 6 Hz.

Output characteristics of ZnO-TENG were recorded across different load resistances as shown in Figure L.4.1(d) and the maximum power density of ~ 8.8 mW/cm^2 was observed across 10 MΩ load resistance.

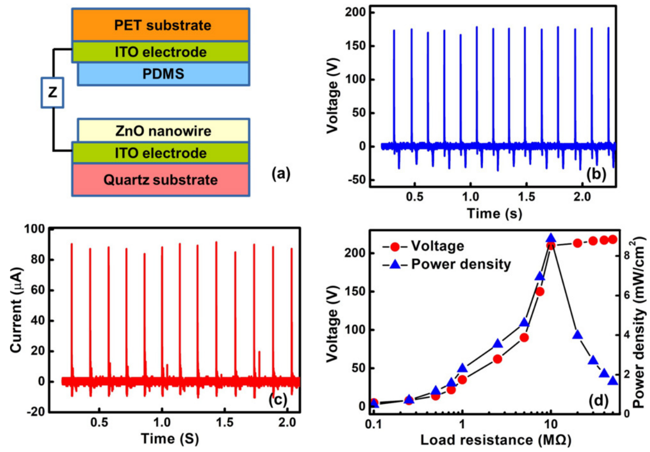

Figure L.4.1: (a) Schematic of ZnO-TENG, (b) open-circuit voltage, (c) short circuit current, and (d) power density with the load resistance.

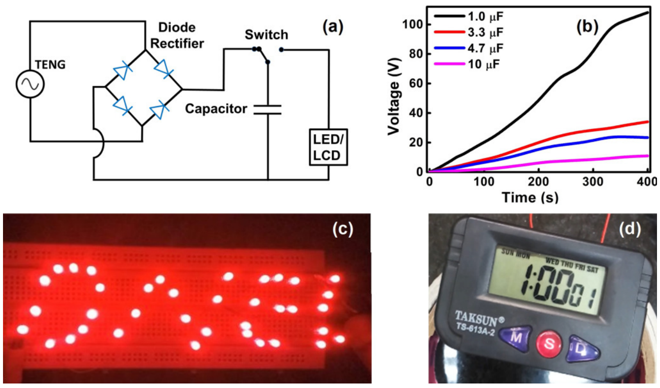

Figure L.4.2: (a) Circuit diagram for storing the harvested energy by ZnO-TENG in a capacitor, (b) temporal profile of charging of capacitors, (c) flash lighting of LEDs, and (d) flash lighting of LCD.

ZnO-TENG was used to power commercial LEDs and LCD. Figure L.4.2(a) shows schematic diagram of the circuit used for rectifying the output of ZnO-TENG, charging capacitors and powering LEDs and LCD display. Figure L.4.2(b) shows the charging curves of capacitors of different capacitance (1-10 µF). In 300 s, the 1 µF capacitor was charged up to ~81 V, while the 10 µF capacitor could be charged up to ~8.5 V. The energy stored in the capacitor was used to flash a matrix of 38 commercial LEDs connected in series (Figure L.4.2(c)) and LCD of a stop watch (Figure L.4.2(d)). The results demonstrate potential application of ZnO-TENG as portable power source for microelectronic devices, displays and sensors.

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