Non-volatile Ferroelectric Mechanical Memory

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A new type of non-volatile ferroelectric mechanical memory has been developed by combining the functions of a piezoelectrically actuated micro-electromechanical (MEMS) switch and the remanent polarization data state storage of a ferroelectric capacitor. This novel non-volatile memory device is unique because it integrates the actuation mechanism and the non-volatile data storage in the same element, viz., the ferroelectric capacitor that exhibits hysteretic strain. Additionally the fundamental memory cell constitutes a 1C1R architecture that allows for data state interrogation that is not limited by the ferroelectric polarization magnitude. The combination of the MEMS switch with the non-volatile memory allows for applications in non-volatile relays, logic and switching networks.

An initial demonstration of a ferroelectric mechanical memory (FEMM) was successfully shown by utilizing a piezoelectric MEMS cantilever switch using a PZT(52/48) thin film actuator similar to the device shown schematically in Fig. 1. The PZT layer acts as both the switch actuator and the non-volatile data storage element because it displays hysteretic strain that depends on hysteretic polarization. A schematic of the hysteretic strain shown in Fig. 2 provides for a description of one of the operating methods for the non-volatile FEMM device. The data state of the memory cell is first written by applying a voltage between terminals A and B shown in Fig. 1. Either a positive voltage for a 1-state, following path 1 or 4 of Fig. 2, or a negative voltage for a 0-state, following path 2 or 3 of Fig. 2 can be applied. This write operation sets the polarization direction of the ferroelectric capacitor and additional determines the direction of cantilever displacement that will occur during the application of a subsequent unipolar read operation. When a positive read voltage is applied between terminals A and B, the cantilever tip will bend downward for a stored 0-state, following path 4, and will bend upward for a stored 1-state, following path 1. For the example shown in Fig. 2, the read voltage is limited to a magnitude below the ferroelectric coercive voltage in order to avoid depolarization of the ferroelectric and loss of the stored data state during the read operation. The gap between the capacitor bottom electrode connected to terminal A and the switch contact electrode connected to terminal C is designed such that the switch is closed when a read voltage is applied and the device is written in the 1-state. Hence the FEMM switch will be open during a 0-state read and will be closed during a 1-state read operation. The open or closed state of the switch is determined by applying a voltage between terminals A and C that will induce a current flow when the switch is closed, i.e. when the memory cell is in the 1-state. Since the data state is detected by the current flow during the time of switch closure and the current is induced by an external voltage source, the read signal margin is decoupled from the ferroelectric switch polarization that determines the signal margin in standard ferroelectric random access memory. The example described here employs a non-destructive read operation and the memory state relies on the memory of the direction of cantilever tip displacement. A variety of read and write operation methods based on non-destructive read, destructive read, displacement direction memory and remanent displacement will be presented.

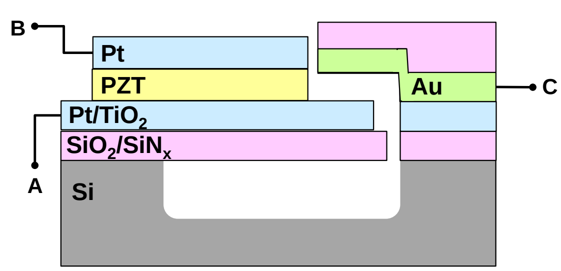

Fig. 1 – Schematic of cantilever type, three terminal FEMM device used to demonstrate non-volatile switch behavior.

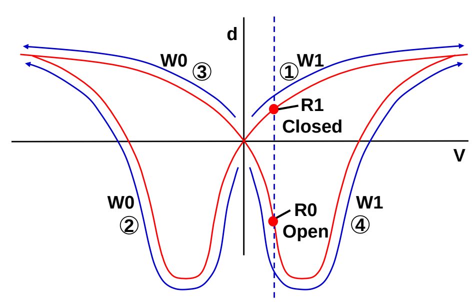

Fig. 2 – Schematic of displacement hysteresis used for writing and reading non-volatile FEMM devices.