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2000s
Development of new types of memory
~ Integrated Circuit ~

In flash memories, which are representative nonvolatile memories today, it is said that the number of stored electrons for recording information decreases along with miniaturization, and that it will soon reach the operation limit as memory. Therefore, various types of nonvolatile memories having new structures to replace the flash memories have been proposed.

In Magneto-resistive Random-Access Memory (MRAM), a magnetic tunnel junction is formed, consisting of a ferromagnetic layer (movable layer) - insulating film - ferromagnetic layer (fixed layer), and data is written as the magnetization direction of the movable layer, and read is performed by the tunnel current modulated with the magnetization direction. Fe, Mo, Co or the like are used for the magnetic layers and extremely thin Al_2O_3 of about 1 nm is used for the tunnel insulating film. Since each memory cell can be composed of one transistor and one magnetic tunneling resistor (1T1R type), it can be made in high density, and has excellent writing speed and long-term reliability (Fig. 1).

In a Phase Change Random-Access Memory (PCRAM), a ternary chalcogenide film made of Ge-Sb-Te is formed, utilizing its unique characteristics of two phases depending on the application of electric pulse field, of either high resistance amorphous phase or low resistance crystalline phase. The formation of chalcogenide material has been established in DVD technology, and it is excellent in high density implementation since it is 1T1R type cell.

Resistive Random Access Memory (ReRAM or RRAM) utilizes the change in electrical resistance by the voltage application to the metal oxide films such as PCMO ($Pr_{0.7}Ca_{0.3}MnO_3$), nickel oxide, chromium-added strontium titanate. A memory cell is formed by connecting a resistance film in series with a MOSFET (Fig. 2). Data is written with cell selection with a word line, and the electric resistance change by applying voltage between the write line and the bit line. As with other 1T1R type, it is excellent in high density.

Ferroelectric Random-Access Memory (FeRAM or FRAM) has 1T1C type cell using a ferroelectric material as a capacitor insulating film, and 1T type using it as a gate insulating film of read/write transistor. As the ferroelectric material, Pb(Zr, Ti)O_3 (PZT), $SrBi_2Ta_2O_9$ (SBT), (Bi, La)$4Ti_3O_{12}$(BLT) or the like are used. In the 1T1C type, the configuration of the memory cell is the same as that of DRAM, and the transistor and the capacitor are connected in series. The read current is changed according to the polarization direction of the written ferroelectric substance. In the 1T type, the threshold voltage of the transistor changes depending on the direction of polarization, which changes the read

current (Fig. 3). It operates with low power consumption, and it has already been put to practical use in fields such as smart cards.

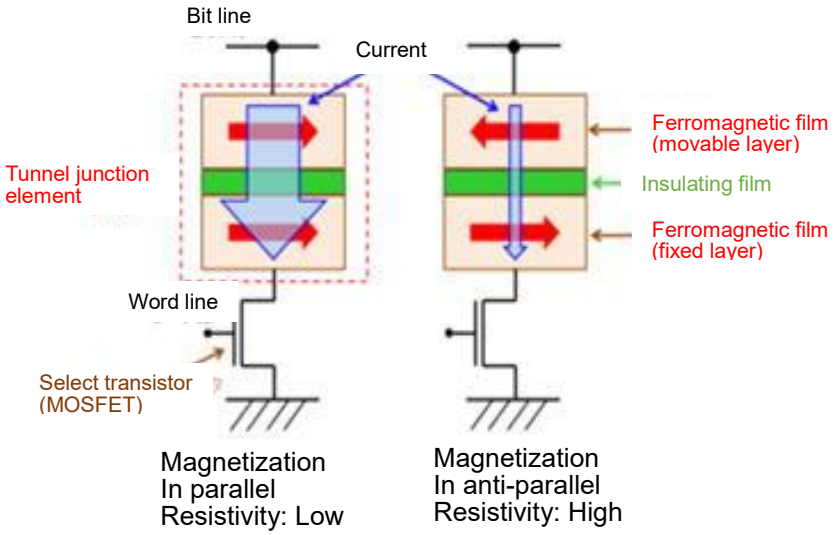

Fig.1: Operation Principle of MRAM

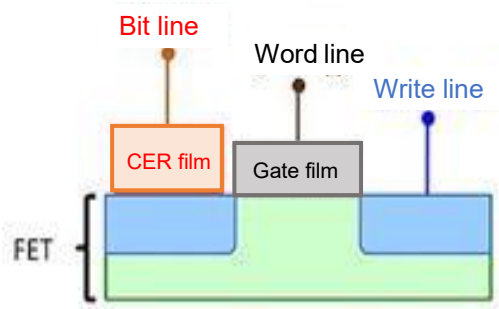

Fig. 2: Structure of ReRAM

Red lines are Ferro-electric Capacitors

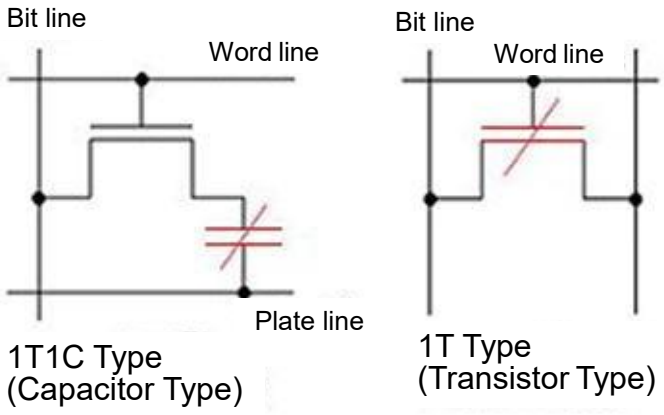

Fig.3: Schematics of FeRAM cell