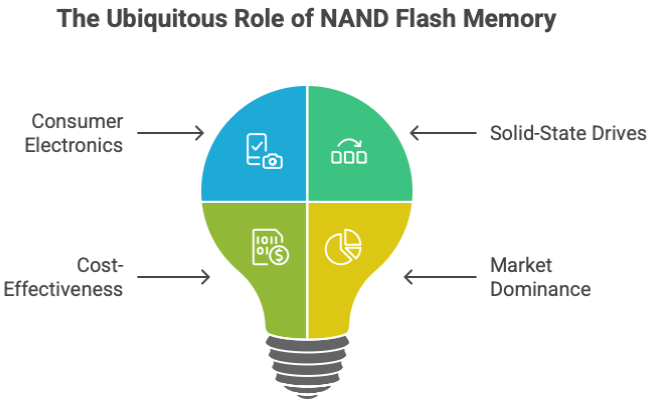
3 D NAND Memory

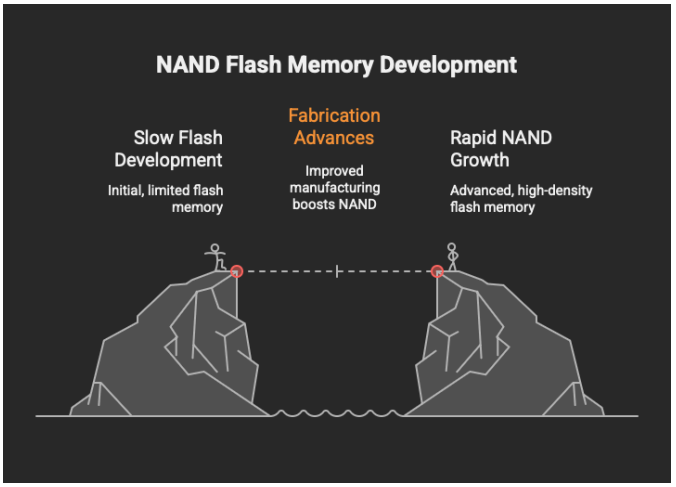
Currently, NAND flash memory is widely used in the modern electronic devices [1]-[3] and it holds about 90% of the non-volatile memory market. In order to fulfil its memory requirements, most of the consumer electronic devices are severely dependent on the flash memory. Over the years, the applications of NAND flash memory has been increasing and it has become an essential part of the social life. This is because NAND flash memory is cheap and cost-effective non-volatile memory. As shown in Figure 1, NAND flash is universal in their application in cellular phones, digital cameras, media players, flash drives etc.. The solid-state drives (SSDs) which have replaced the hard disk drives (HDD) due to their better performance and lesser power consumption, is the most important application of the NAND flash memory.



Overview of NAND Flash Memory

Flash memory is the non-volatile memory (NVM) that stores information even in the absence of power [5]. The first category of NVM consists of read-only-memory (ROM). While ROMs are very economical, they are lesser flexible, because the data cannot be modified by the handlers. The initial floating-gate-transistor (FGT) was introduced by Kahng and Sze [6] in 1967. Later on, Frohman-Bentchkowsky [7] invented a poly-silicon FGT in 1970 in which the injected hot electrons into the FG during program are removed using ultraviolet (UV) photoemission during erase. The basic flash memory architectures include NAND and NOR flash memory architectures as shown in Figure 1.3. In case of NAND architecture cells are connected in series while parallel connection of different cells is kept in case of NOR flash memory. Although, the NOR flash is faster and lesser access time is required but due to series connection NAND flash memory has higher bit density. This is attributed to lesser complicated circuitry of the NAND architecture as compared to the NOR flash architecture.

The first commercial flash memory chip (which was a NOR-type flash) was manufactured by Intel in 1988 [8]-[9]. However, the first NAND-type flash memory chip, was developed by Toshiba in 1987 [10]. The development of the flash memory was slower in the beginning, however, due to the advances in the fabrication processes has tremendously increased the development of NAND flash memory.



Read-Write Operations

Primarily, there are two important operations in a FGT which are as follows:

Read Operation

The state of the FGT is determined from its threshold voltage (V_T). From the MOSFET theory [33], it is known that a sheet of charge in the gate dielectric induces V_T shift of the MOSFET. Therefore, ΔV_T = change in V_T = $-Q / C_{FC}$, where Q is the charge induced into the FG, C_{FC} is the capacitance associated with CG and FG. ΔV_T is of the FGT which is obtained from the drain current (I_D) versus control gate voltage (V_{GS}) characteristics (I_D-V_{GS} characteristics), as shown in the Figure 2.5.

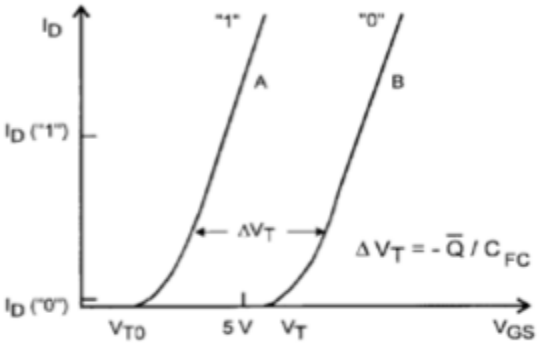


Figure 2.5 I_D–V_{GS} characteristics of FGT in the programmed state (Curve A) and erased state (curve B) [34].

Write Operation

The floating gate device is programmed by applying a positive voltage at the control gate [33]-[34]. The energy band diagram corresponding to the programmed state is shown in Figure 2.3 (b). The band banding enables the inversion layer electrons to tunnel from substrate into the floating gate and the device is said to be in the programmed state. The programmed device is erased by applying a negative voltage at the control gate. The stored electrons in the floating gate during the programmed state are tunneled back to the substrate and the device is said to be in the erased state.