Material Aspects in Emerging Nonvolatile Memories

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Driven by an increasing demand for mobile devices, the market for nonvolatile memories is rapidly growing [1]. Today all nonvolatile memories are based on charge storage and are fabricated by materials available in CMOS processes. These devices have some general shortcomings like slow programming (from microseconds up to milliseconds), limited endurance (typically $10^5 – 10^6$ write/erase cycles) as well as the need for high voltages (10-20V) during programming and erase. These shortcomings imply some severe restrictions on the system design side. A memory that could work like a random access memory (similar to DRAM or SRAM) and would be nonvolatile, would therefore greatly simplify system design, since one universal memory could be used, where two or three memories are required today. To achieve this goal, new materials that enable new switching mechanisms have to be introduced into the CMOS process flow. For many years a number of approaches based on switching in inorganic materials are widely examined. The most prominent ones are ferroelectric memories, magnetoresistive memories and phase change memories. Ferroelectric Memories use the two stable polarization values at zero bias to store a bit [2]. A variety of different approaches for magnetoresistive memories exist [3]. For high density applications magnetic tunnel junctions are the only approach to offer the appropriate features with respect to available signal and cell resistance. Finally, phase change memories are based on the reversible phase transformations of a chalcogenide material between a high resistive amorphous and a low resistive crystalline state [4]. Recently another concept based on an electrochemical silver deposition in a miniaturized electrochemical cell has been developed [5]. Besides the integration of inorganic materials, also organic materials are discussed for future memory devices. Organic memories use the bulk properties of organic materials which can be either resistance switching or ferroelectric switching. Organic memories could open the path to a class of memories that have densities between current semiconductor memories and hard disk drives by stacking several memory layers on top of each other. Finally, effects in single molecules or carbon nanotubes can be used to create molecular memory devices [6]. In each of these advanced memory concepts one of the keys will be to solve the issues with integrating the new switching materials into the CMOS process and still maintain the switching properties as well as the CMOS device properties. Fig. 1 gives a schematic picture of the issues involved. These are connected with the switching material itself, the interface between CMOS circuit and switching material, effects of the processing of the switching material on the properties of the CMOS process as well as CMOS processing effects on the properties of the switching materials. In this Presentation the above mentioned concepts will be reviewed with special focus on the key material issues. A concrete example of each of the issues shown in fig. 1 will be given using results from the development of a ferroelectric memory.

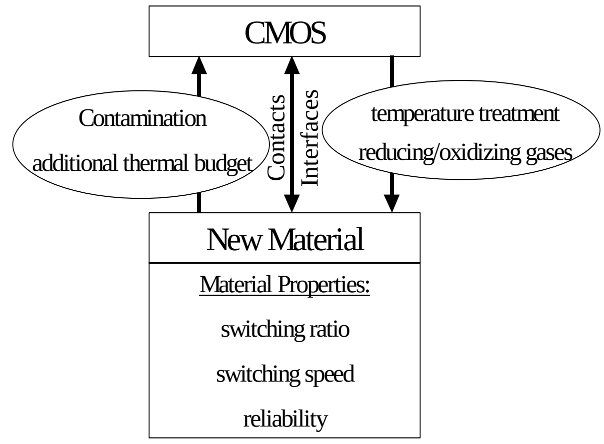

Fig. 1 Development topics associated with the integration of new switching materials into a CMOS process

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