VERSATILE

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Vertically Stacked Memory Cells based on Heterojunctions of Hybrid Organic/Inorganic Materials

The project explores the crossbar architecture as an alternative integration strategy for Non-Volatile Memory technology.
The goal is to find a process, integrating novel memory concepts such as resistive switching elements, compatible with current CMOS technology and suitable for ultra-high density data storage devices.

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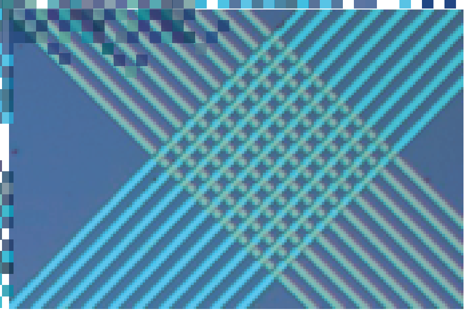

Budget - 2,950,820 €
Funding - 1,858,820 €
Start date - 1st February 2006
Duration - 3 years

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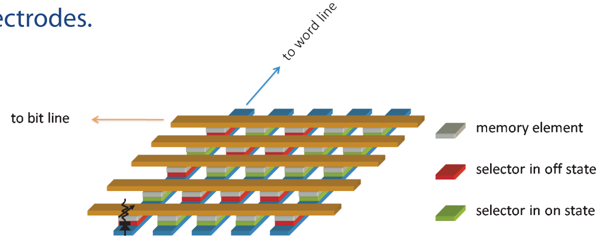
Sixt Framework Programme - Priority 2
Information Society Technologies
Specific Targeted Research Project

Objectives

Several alternative NVM concepts are currently being explored to satisfy the need for higher storage capacity and system performance, lower power consumption, smaller form factor, lower system costs and long data-retention capability. However, a limited activity is devoted to investigating their integration and scalability.

The VERSATILE project addresses a possible integration strategy for novel memory concepts that can be arranged in two terminal devices: the crossbar architecture, where the selector and the bit storage element are vertically stacked one on top of the other and embedded between two metal electrodes.

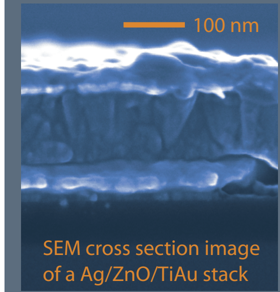


The main objectives of the project are:

- to develop rectifying junctions based either on II-VI, organic or hybrid organic/inorganic semiconductors, to be used as selectors in crossbar memories;
- to demonstrate the feasibility of the crossbar architecture by fabricating a 10kB memory prototype;
- to demonstrate the scalability of the rectifying junctions down to the 32 nm technology node.

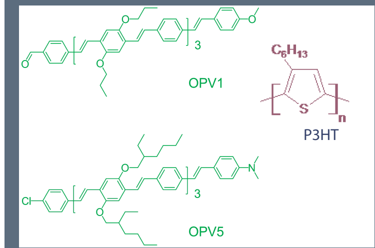
Moreover, compatibility of the developed materials and processes with current CMOS technology is constantly monitored.

Materials



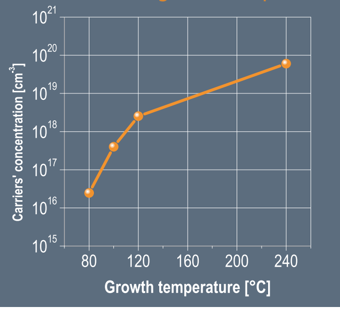
SEM cross section image of a Ag/ZnO/TiAu stack

To overcome the temperature limitation required by the integration at the BEOL level, the project focused on non-conventional materials in current CMOS technology, such as ZnO grown by atomic layer deposition at low temperature[1,2], poly 3-hexylthiophene (P3HT)[3] and phenylene vinylene oligomers (OPVs)[4].



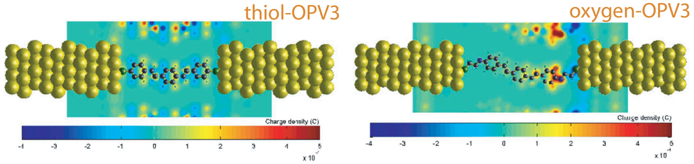
some of the investigated organic semicondcutors

carrier concentration in ZnO as a function of growth temperature

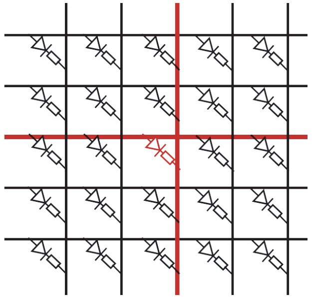


Models

Conduction properties of molecules can be tailored by an appropriate choice of molecule structure and of its ending groups. *Quasi ab-initio* calculation of the electronic states of the molecule plus metal contacts allows investigating transport properties of OPVs as a function of their termination.[5]



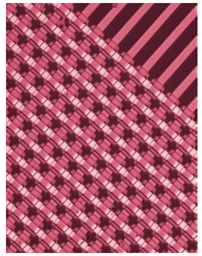
potential profile at 0-2 V for an OPV3 molecule with different ending groups

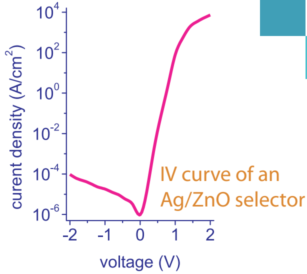


Finite-element drift-diffusion simulations are used to predict and interpret selector chracteristics.

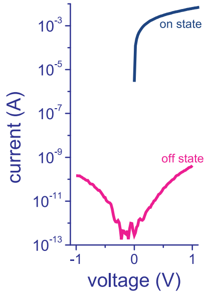
Crossbar arrays behavior is modeled by SPICE, where experimental IV curves are included to evaluate high-density integration

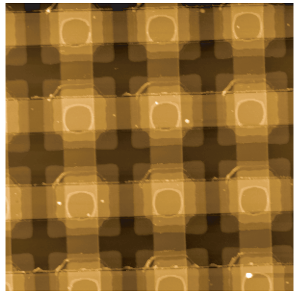
Devices


a10kB crossbar array of Ag/ZnO Schottky junctions



Ag/ZnO Schottky diodes revealed suitable characteristics for selectors[6], featuring a forward current as high as 10^4 A/cm^2 and an I_{on}/I_{off} ratio over 10^7.





AFM image of a10kB crossbar memory cell array: the Ag/ZnO selector is coupled with a resistive switching element based on NiO

IV characteristics of a memory cell in on and off state driven through the Ag/ZnO selector

10kB crossbar memory cell arrays comprising Ag/ZnO Schottky junctions and resistive switching memory elements based on NiO, developed within the project EMMA, were fabricated with a crosspoint area of 5x5 μm^2

Outlook

During the third year of the project, the focus will be on assessing the scalability of the device. E-beam lithography and nanoimprinting will be used for fabricating ultrascaled junctions with crosspoint area below 40x40nm^2.

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2 N. Huby, S.Ferrari, E. Guziewicz et al., Appl. Phys. Lett. 92, 023502 (2008)
3 E. Katsia, G. Tallarida, B. Kutrzeba-Kotowska et al., Org. Electron 9 1044 (2008)
4 E. Katsia, G. Tallarida, S. Ferrari et al., Microelectron. Eng. (2008) doi:10.1016/j.mee.2008.09.019
5 S. Schuster, G. Scarpa, L. Latessa et al., Phys. Stat. Sol. (c) 5 , 390 (2008)
6 N. Huby, G. Tallarida, B. Kutrzeba-Kotowska et al., Microelectron. Eng. (2008) doi:10.1016/j.mee.2008.07.016

(a complete list of publications is available at the website)