Disks made of silicon, the semiconductor that forms the base of memory chips

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SEMICONDUCTORS

Memory of the future

A ceramics center will develop raw materials for a new chip factory in São Carlos

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A type of memory device that stores information even when disconnected from a power source, used in smart cards, bus tickets, mobile phones, digital TV and financial transactions will be produced in a new factory whose construction will begin in 2009 in São Carlos, in inner-state São Paulo. The city houses the Multidisciplinary Center for the Development of Ceramic Materials (CMDMC), which is one of FAPESP's Research, Innovation and Dissemination Centers (CEPID). The center also gets aid from the São Paulo State University (UNESP) in Araraquara and the Federal University of São Carlos (UFSCAR). This was a key factor in the decision to locate the ferroelectric semiconductor factory in the city. The ceramic materials center, which is a partner in the project, has already awarded 25 PhDs and 17 Master's degrees in ferroelectric materials since 2000, when it was founded. Many of these professionals and students will be able to work in the Brazilian factory.

At first, the ferroelectric random access memory (FeRAM), a type of non-volatile memory, will be produced using technology developed by Symetrix, an American company founded 18 years ago by Carlos Paz de Araújo, a Brazilian professor of electrical engineering at the University of Colorado. The center will also participate actively in developing new ferroelectric memories and memories made out of other materials. "We will focus research on new ferroelectric memories because we know that it can be applied, but we will not sideline basic research", says physicist José Arana Varela, a professor at the Araraquara Institute of Chemistry and Dean of Research at UNESP, who is also responsible for the CEPID's innovation division.

The ceramics center has developed thin ferroelectric film, made of thin layers of semiconducting material, via a new method that is relatively simple and cheap. It is a strong candidate for

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Ferroelectric memory chips can be read from a distance of up to six meters.

use in the memory chips that will be produced in the São Carlos factory. "We have managed to obtain new materials with storage capacity 250 times greater than that of conventional memory", says Elson Longo, a chemist and general manager of the CMDMC. These materials are made out of an organic solution derived from citric acids, found in fruit such as oranges and lemons, mixed with barium, lead and titanium. "The compound is heated in a simple oven at about 300º C to remove some organic elements, such as carbon", explains Varela. Next, the material is crystallized in a domestic microwave oven, which produces a thin film of lead and barium titanate. "Initially we will use the American company's process. In the future, we might work with materials other than those which we have already developed, to make thinner film", says Varela. The thinner the film, the greater the integration of the semiconductor system and the lower the costs. Some of the advantages of using thin ferroelectric film in preparing electronic devices, as compared to the magnetic ceramics used for memory, are that they are smaller, lighter, have high read and write speeds, and require low voltages to operate.

Ferroelectric materials enable the development of electronic memory that does not require a constant supply of energy to work. "The information storage capacity has to do with the way the atoms are arranged", says Longo. Each memory cell is made up of one access transistor connected to a ferroelectric capacitor, a device that stores energy in an electric field. The transistor works like a switch, allowing the control circuit to read or write binary code, 0s and 1s, which is stored in the capacitors. The basic principle is the same as that of magnetic semiconductors used in standard credit cards and bus tickets. "The difference is that the magnetic cards need to be close to a reader to transmit the information, while the ferroelectric cards can be read at a distance of up to six meters", explains Longo. The reading is done by radiofrequency. The chip, which is about two millimeters squared in size, is not visible; it is embedded in the cards or mobile phones, for example, and has a system to protect it from hackers.

In Japan, where the technology developed by Araújo and his team was licensed to Panasonic, it is used in subway and train cards and driving licenses. You can also pay for your shopping with your mobile phone, without credit or debit cards. In Brazil, since the building of the factory was announced, several companies have expressed interest in the technology. They want to replace magnetic cards with ferroelectric ones in several applications. "One big Brazilian bank, which doesn't want to import the technology for security reasons, came to us for the cards", says Varela, who will not name the bank because negotiation is still under way. For the automotive industry, for instance, Symetrix has patented the technology for a crash avoidance system. "With this memory you can install a safety system in the car with infrared sensors which work like night-vision cameras to detect the presence of people, animals or stationary cars 100 to 200m ahead of the vehicle", he explains.

Integrated control – In supermarkets, the use of ferroelectric memory instead of barcodes will allow integrated product control. Information such as the expiration date, manufacturer's name, price, stock and amount purchased could be stored in a device the size of a pinhead. "It's not just a barcode – it's intelligent memory", says Longo. "Each label with an embedded chip will cost less than R$ 0,01", points out Varela. The consumer will be able to see how much he spent by passing three to four meters away from a panel. If he decides to make the purchase, the card in his pocket will be debited or credited before he walks out the door. "While a magnetic card (like credit and debit cards) lasts four to five years, the ferroelectric one can be magnetically read or written up to one trillion times, which means it could last about two thousand years", explains Varela. One reason why magnetic cards do not last as long is that they have to be in physical contact with the reader to be used.

The researchers connected to the group that founded CMDMC began studying ferroelectric devices in 1992. Their research led to the publication of 112 articles in Brazilian and foreign academic journals. "We began our research roughly at the same time as Carlos Araújo at the University of Colorado", says Longo. "We've been working essentially with the same compounds since then, but he patented the knowledge produced by his team and set up a company." Araújo, a professor of electrical engineering, founded Symetrix with resources from Small Business Innovation Research (SBIR), an American program for supporting small innovative businesses that inspired FAPESP to start the Innovative Research in Small and Very Small Companies Program (PIPE). Today Symetrix has over 200 international patents.

The partnership with the Brazilian researchers began during a convention on ferroelectric semiconductors in Portugal in 2006. At the time, Araújo

THE PROJECT

Ferroelectric memory

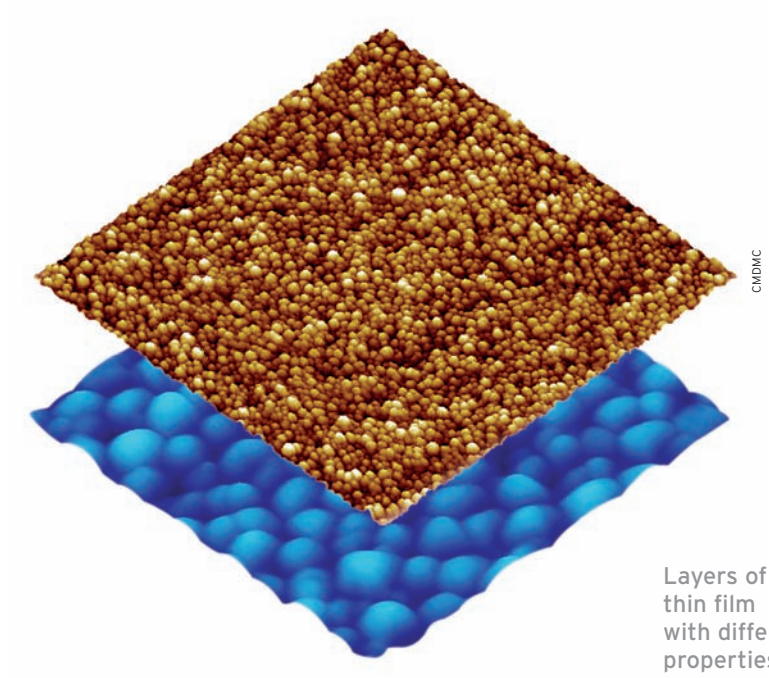
TYPE
Research, Innovation and Dissemination Centers (CEPID)

COORDINATOR
Elson Longo – CMDMC - Multidisciplinary Center for the Development of Ceramic Materials

INVESTMENT
R$ 1,200,000.00 for all of the CMDMC (FAPESP)

told Varela that he would like to come to Brazil to discuss his experience in the field. Some time later the researchers from the ceramics center organized a symposium in Natal, in the state of Rio Grande do Norte. Araújo was born and lived in the city until he was 17, before moving to the USA in the late 1960s after having gone on an overseas-exchange program. "It was during the meeting in Portugal that the idea for a ferroelectric semiconductor factory in Brazil came up", says Longo. Initially the states of Pernambuco and Rio de Janeiro were considered for the location, alongside São Paulo. The city of São Carlos was picked thanks to the know-how that Longo and Varela's group had acquired in years of research in the field. Symetrix, which has patents in Japan, South Korea, Europe and the USA, set up a partnership in Brazil with Emcalso-Damha, a Brazilian heavy construction and real estate development conglomerate that has been active in a variety of market segments for over 40 years. "The international partnership allows us to produce not only for the domestic market, but also for export", says Longo. Araújo's company has three divisions: Symetrix Devices, which is responsible for developing the systems and memory, Symetrix Systems, which takes care of intelligent cards and labels, and Symetrix Development, which is responsible for research, development, innovation and technology licensing.

German project – Every year Brazil imports about US$ 100 million of chips, but none of them have ferroelectric memory. Brazil's share is roughly 2% of the global market of about US$52 billion. The partnership plans at first to satisfy all domestic demand. Symetrix's technology competes with other non-volatile types of memory, such as Flash, which is used mainly in memory cards for cameras, pen-drives, MP3 players and mobile phones. The initial investment in the factory is US$250 million. Construction will begin in 2009 and should be completed by 2011. The partners are currently structuring the business plan. "We have already decided on the size of the factory, and so a German firm has been hired to take care of the project", says Varela.



CMDMC

Layers of thin film with different properties are created chemically

Manufacturing ferroelectric chips requires an ultra-clean environment and professionals who are capable of doing the deposition of thin film. "We have qualified personnel who know how to do the chemical deposition and the thermal treatment that are necessary for chip production", says Varela.

The thin film can be made via either physical or chemical deposition. Symetrix's patented technology, which is licensed for Japan and will be used in São Carlos, uses chemical deposition, which is cheaper because it can be applied to large volumes. "The chemical solution is deposited drop by drop on disks of silicon, a semiconductor that forms the base of the memory chip", explains Varela. "The size of the film depends on the viscosity of the drop." Several different types of film, with insulating, conducting and ferroelectric properties are deposited over the silicon disks, known as wafers. "For each different application, we use a customized architecture", says Longo. The communication between the components of the chip is instantaneous. "The more conductive the material, the faster the response", he explains. ■

› Scientific articles

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