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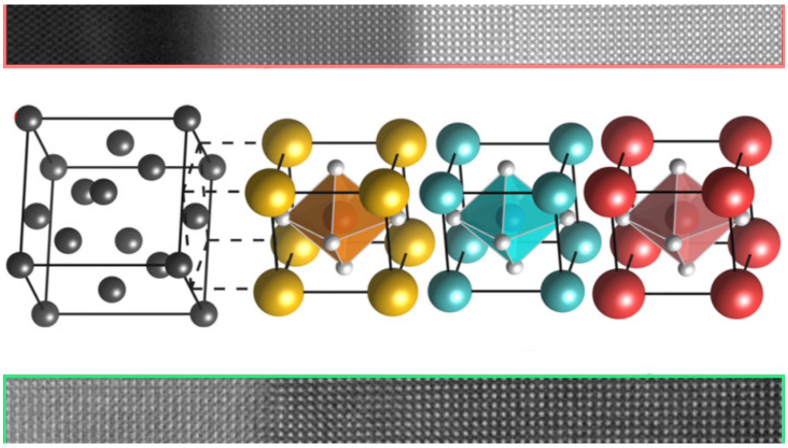
BARCELONA RECERCA I INNOVACIÓ

26/10/2017

Ferroelectric oxides on silicon wafers for new memories



Some of the memories currently used in electronic devices are based on ferroelectric insulating materials that permit non-volatile storing of information. However, they contain toxic oxides, such as lead-compounds. Researchers from the ICMAB-CSIC have replaced these lead-compounds by non-toxic oxides, achieving the epitaxial integration on silicon wafers and they have confirmed experimentally their ferroelectricity, so that they can be used as permanent memories.

Microelectronics is not only based on semiconducting materials. Insulating oxides are also important; as an example, they are main elements in field effect transistors used in RAM memories. In an insulating oxide, positive and negative ions move slightly when an electric field is applied. The oxide is polarized, and this polarization is reversed when the applied electric field is reversed. It permits defining two states of information, 0 and 1, but removing the applied field ions return to their original positions and the information is lost.

However, some insulating materials are ferroelectrics, presenting spontaneous polarization in absence of an applied external field and switchable by applying a high enough field. The stability of the polarization permits storing non-volatile information, and indeed ferroelectric memories are already in the market, although they are still used in few applications. To increase their relevance it is necessary to enhance the properties and also replace the used ferroelectric oxides, generally lead-compounds, for non-toxic ones.

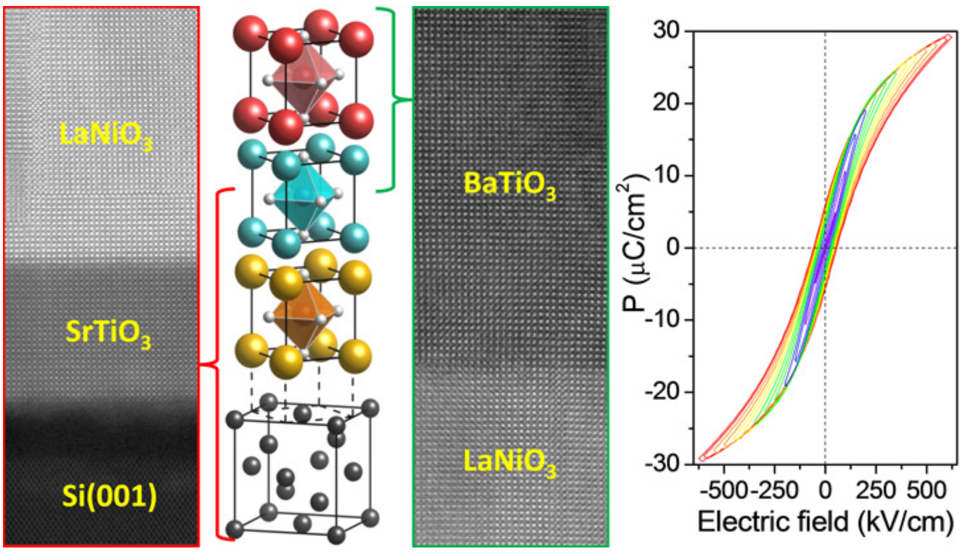


Figure adapted from M. Scigaj, C.H. Chao, J. Gázquez, I. Fina, R. Moalla, G. Saint-Girons, M.F. Chisholm, G. Herranz, J. Fontcuberta,R. Bachelet, and F. Sánchez, High ferroelectric polarization in c-oriented BaTiO3 epitaxial thin films on SrTiO3/Si(001), Applied Physics Letters 109, 122903 (2016).

Barium titanate, $BaTiO_3$, is an excellent candidate. But its good ferroelectric properties are degraded when the material is integrated with silicon. Our research group has recently achieved significant progress in this area. In particular, by using a complex epitaxial heterostructure as buffer layer between the ferroelectric and Si(001), structural properties close to those of a single crystal and ferroelectric polarization high enough for memory devices was achieved. In this work, we have used a simpler buffer layer heterostructure using $SrTiO_3$ as the main layer.

The $BaTiO_3/LaNiO_3/SrTiO_3$/Si(001) heterostructure is sketched in the Figure, as well as transmission electron microscopy images that show the epitaxial growth of all layers. The Figure includes polarization loops, confirming that the $BaTiO_3$ film is ferroelectric with a remnant polarization of around 6 $\mu C/cm^2$. The integration of $BaTiO_3$ on $SrTiO_3$/Si(001) has been a main objective of the scientific community in the past years, and our work constitutes the first experimental demonstration of ferroelectricity by direct electrical measurements.

We receive financial support from the Spanish (MAT2017-85232-R, MAT2014-56063-C2-1-R and SEV-2015-0496) and Catalan (2014 SGR 734) Governments.

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References

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http://dx.doi.org/10.1063/1.4962836

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