New ferroelectric material in the future application

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Nowadays, the electronic devices are widely used and applied in various applications such as cell phones, personal computer, laptops and so on. The building unit of the electronic devices are transistors and the most common one is the Metal-oxide-semiconductor field effect transistor (MOSFET) which comprises a capacitor placed between two contact called source and drain. The source contact and drain contact are contacted by metal to connect to the power supply.

In the past, the dielectric of the MOSFET is silicon dioxide, which has low dielectric constant, about 3.9. With the development of the electronic technology, the applied voltage on MOSFET has been scaled down and reduced in each generation of electronic circuits with increasing efficiency and lower power consumption. However, this become tough when scaling down to subnanometer range. The thickness of the dielectric is limited. Traditionally, the subthreshold swing of the scaled MOSFET in room temperature is about 60 millivolts per decade (a decade corresponds to a 10 times increase of the current). Thus, there is a strong effort to fabricate new device which can have steeper turn-off speed than traditional MOSFET, the so called steep-slope device for the purpose for various application in memory technology, new field effect transistor, and sensors.

One application is the so-called negative capacitance field effect transistor (NCFET) which uses negative capacitance as the dielectric. NCFETs are based on the inclusion of ferroelectric material as the dielectric (high dielectric constant, around 10 to 30 or even higher) instead of the traditional silicon dioxide. The ferroelectric material was first studied and researched by by Valasek in early 1920s. The basic feature of the ferroelectric material is the polarization against electric field curve. The polarization changes as an enclosed curve with respect to the electric field. Ferroelectric materials have two polarizations value (called remnant polarization) when the electric field is removed (zero value), and the positive polarization value can be "1" or "up" state while the negative polarization value can be "0" or "down" state, this can be used in memory application.

The new ferroelectric material, hafnium zirconium dioxide, $Hf_{0.5}Zr_{0.5}O_2$, has been specially researched and attractive because it is simple to be fabricated by the mature Atomic Layer Deposition (ALD) technique and cost effective. This ferroelectric material is prefered compared to the traditional lead-based ferroelectric material because of the environmental issues. Using lead-based metal is prevented and forbidden in many countries. This high dielectric constant ferroelectric material shows promising features. For instance, the thickness of the insulator layer can be made very thin, around 10 nanometer or less, good thermal stability, compatible with the traditional silicon technology. And this material which I am currently doing research now can be applied in the future memory application called FeRAM, ferroelectric field-effect transistor, sensors, and energy-related applications.