Nanoscale study of ferroelectric HZO

The advancement of technology is often taken for granted. Our devices become smaller and smaller as well as faster and faster, but this is not something that happens on its own. Behind every advancement, like the new mobile phone you bought, lies countless hours of hard work and heavy investments. Research is always done into new materials in the search of new, interesting, properties. One such property is ferroelectricity, the less famous sibling to ferromagnetism which is how your fridge magnets actually stick to your fridge. You are probably aware of how you can turn a paper clip magnetic by exposing it to an external magnetic field in the form of a magnet, the paper clip ”remembers” its history even after it is no longer in contact with the magnet. Ferroelectricity works in the same way with electricity, it ”remembers” the electric field it was exposed to even after it is no longer applied. This means that even if a ferroelectric component is not provided with electricity, it ”remembers” that it was: so called ”Non-volatile memory”. Through applying the external electric field in the opposite direction, the direction of the ferroelectric field also switches direction, and we have an opposite state. As computers work with binary ”0s” and ”1s”, the ability to have a material that can remember if it is a ”0” or a ”1” even after an electric field is no longer applied is of great importance.

One such ferroelectric material is a thin film of HfO_2 and ZrO_2 (HZO) which, ever since its ferroelectric properties were discovered around 10 years ago, has been heavily studied. When hafnium oxide and zirconium oxide are combined under certain conditions, the resulting compound is ferroelectric. In this compound there can exist several different crystal structures of the atoms, and in one of these the atoms reorient in a special shape such that we get a positive charge that is separated from a negative charge which results in an electric field. While this effect averages out over the entire thin film, applying an external field aligns the negative and positive charges in the same direction over the whole sample such that when the electric field is switched off, the effect will no longer average out. This is the same thing that happens to your paperclip with magnetism. The process described above is how ferroelectric HZO is created. The ferroelectric properties are therefore highly dependent on the structure of the HZO. To study the structure, synchrotron facilities like MAX IV in Lund, Sweden are ideal. In such facilities, an X-ray beam is directed at the sample and depending on the crystal structure of the sample, the X-rays are then reflected in different directions. Measuring the reflection pattern using a detector, the structural properties of the material can be studied. In this paper the NanoMAX beamline at MAX IV was used to study the structural properties of HZO. Knowing that the desired property is the special ferroelectric crystal structure, the reflection off this structure is analyzed in order to get a measure on how prevalent it is in the sample. Different properties from different regions of the sample are investigated from this, as well as material properties. Since the HZO thin film is produced such that it is sandwiched between two TiN electrodes, which impact the creation of the ferroelectric shape, these electrodes will also be studied from the reflection pattern.

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