It has been demonstrated that ferroelectric insulators exhibit negative capacitance, which could lead to the operation of FETs at lower voltages. However, while the ferroelectric capacitor reduces the total amount of power needed to operate the FET, the power used in the FET operation is necessary to switch off the ferroelectric insulating layer. One approach to removing the need for this extra voltage is to use an antiferroelectric insulating layer. To begin to better understand antiferroelectrics for this potential application, lead zirconate (PZO), an antiferroelectric, was grown on different oxide substrates with conductive strontium ruthenate (SRO) as a bottom electrode and examined via X-Ray Diffraction (XRD). We found that the PZO-SRO grows well on STO, DSO, GSO, and that the c lattice parameter of the PZO layer decreases as substrate lattice parameter increases.

**Background**

Ferroelectric materials have a spontaneous polarization that can be changed by an applied electric field.

Ferroelectric insulators have exhibited negative capacitance. In a FET, this acts like a voltage amplifier for our gate voltage, lowering the subthreshold swing.

An Antiferroelectric material has a spontaneous electrical polarization, but the neighboring polarization directions within the crystal are antiparallel. Antiferroelectric materials can transform into a metastable ferroelectric when energy is applied.

One benefit for using antiferroelectrics for our device over ferroelectrics is that ferroelectrics need energy to switch into the off state, while antiferroelectrics do not.

**Our Experiment**

We studied lead zirconate (PZO), which transitions from an antiferroelectric to a ferroelectric when strain is applied. It has been reported that PZO grown on STO exhibits ferroelectric behavior when the PZO thickness is 22 nm.

We grew PZO on a layer of strontium ruthenate, a conductive material, and four different substrates with different lattice parameters in order to see the effects of epitaxial strain on the PZO and used X Ray Diffraction to characterize the film.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Lattice Parameter (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strontium Titanate (SrTiO₃)</td>
<td>3.905</td>
</tr>
<tr>
<td>Dysprosium Scandate (DyScO₃)</td>
<td>3.94</td>
</tr>
<tr>
<td>Gadolinium Scandate (GdScO₃)</td>
<td>3.97</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>4.2111</td>
</tr>
</tbody>
</table>

*Pseudocubic lattice parameter

Each sample was grown using Pulsed Laser Deposition (PLD) and characterized using XRD using a 15-55 degree omega scan.

Pulsed Laser Deposition Growth Conditions:
- Substrates were heated to 700°C to grow the SRO and then lowered to 550°C to grow the PZO.
- The laser was set to 125 mJ at a frequency of 10 Hz.
- The target was ablated for 4 minutes in the 100 mTorr oxygen atmosphere.

**Results**

We see our ‘c’ lattice parameter decreasing as the substrate lattice parameter increases. We also measured the thickness of our samples using Kiesseg fringes.

**Conclusions**

- A new conductive layer must be found to grow on MgO so we can test the PZO’s electrical properties on MgO.
- We must grow thinner films to isolate the ferroelectric phase of PZO.
- More characterization work must be done in order to see fully understand PZO.

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**References**


