Pyroelectric Gas Sensing

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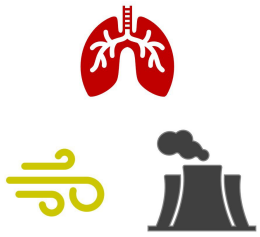
Nanotechnologies

Need

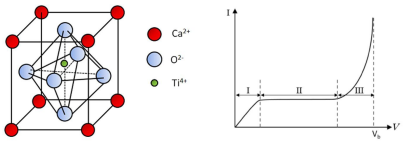
According to the World Health Organization, air pollution kills ~7 million people each year. Furthermore, there are strong links between air pollution and poor mental health outcomes including depression, schizophrenia, and bipolar disorder. Improving air quality requires monitoring the chemical compounds driving the negative effects. Selectivity (the ability to distinguish different gasses), sensitivity (the ability to detect gasses at very low concentrations), size, and cost are key for a gas sensor's success. High performing gas sensors are important for more than just fighting air pollution. They are needed in healthcare for exhaled breath analysis-based diagnostics having the potential to detect diseases, cancers, and covid-19; the chemical industry for process monitoring and gas leaks; and defense for the detection of explosives, biohazards, and other hazards.



[1]van den Broek, et al., *Materials Horizons*, 2021
[2]Jendrny, et al., *BMC Infect. Dis.* 2020
[3]Moser and McCulloch, *J. Vet. Behav.*, 2010

Pyroelectricity and Gas Ionization Sensing

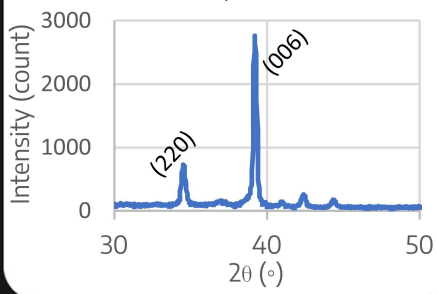
A promising approach for creating effective gas sensors is to harness the unique ionization characteristics of a gas. A gas's breakdown voltage can fingerprint it, enabling its detection and identification. The breakdown voltage is the point at which an insulator transforms from an insulator to a conductor, resulting in a massive increase in current. To generate the voltage, pyroelectric materials (PEMs) can be used. PEMs are a non-centrosymmetric material that develop a voltage when subjected to temperature change because the positive and negative centers of charge in the unit cell are not aligned. To develop a chip-scale device, we fabricated thin films of lithium tantalate (LiTaO3), which was chosen for user safety and its relatively large pyroelectric coefficient.



[4]Sohi and Kahrizi, Journal of Materials Science: Materials in Electronics, 2019
[5]Lang, *Sourcebook of pyroelectricity,* 1974
[6]Datta, *COMSOL Blog, 2014*

Fabrication of Thin Film PEM

Pyroelectricity requires uniform orientation in the material so the different directions do not cancel out. To ensure this, the structure of the substrate must match that of the LiTaO3. Thus, Platinum with a (111) orientation was chosen. Titanium was deposited beneath the platinum to ensure it adhered to the bottommost layer of silicon. Platinum and titanium were deposited using electron gun deposition, while RF magnetron sputtering was used for LiTaO3.



Results

The quality of the LiTaO3 thin film was determined by the depostion time and pressure of the sputtering system. Results showed that as depostion power and time increased, the thickness increased, but the quality decreased. The challenge is to acquire a large thickness while remaining c-oriented. The above figure shows the results for a 150W, 1 hour depostion. The (006) peak responsible for pyroelectricity is roughly fives times the height of the next largest peak, indicating the thin film to be roughly 80% c-oriented. Future work could include testing the thin film's gas sensing ability and improving the thin film fabrication process.

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