Determination of Elastic Modulus of IrO_2 Thin Films for PiezoMEMS Applications

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Ferroelectric thin films are vital components for a number of applications such as non-volatile memory, RF devices, and various other microelectromechanical systems (MEMS) devices utilizing their piezoelectric properties. The performance of thin film PZT-based MEMS is effected by the processing conditions, composition, device design, and electrode materials. Iridium oxide (IrO_2) top electrodes have been identified as a substitute for platinum (Pt) on current PiezoMEMS devices due to its thermal stability, reliability performance, ability to prevent hydrogen diffusion, and the ability to allow oxygen vacancy migration across the electrode interface [1].
One challenge associated with changing the top electrode material is the accuracy of devices modeling as the mechanical properties of IrO_2 thin films are currently unknown. One of the properties that is of upmost importance is the Young's Modulus (E) of thin film IrO_2. Currently, the only data for E_{IrO2} is a first-principles calculation based on density functional theory [2] but this may not be applicable because the deposition conditions during sputtering change based on the device application. Experimental verification is needed to increase the fidelity of piezoelectric actuator models where IrO_2 is the top electrode.

Two independent analysis techniques are used to obtain the Young's Modulus. Nanoindentation uses the force-displacement relationship on IrO_2, where a 1 μm film thickness is used negate any contributions of the substrate. A modulus of 193.81 GPa was measured, compared to 290 GPa from DFT. In the second technique, the resonant frequency of released IrO_2 cantilevers can also be used to calculate E from,

$$\omega = (1.875)^2 \sqrt{\frac{EI}{mL^4}}$$

Released cantilever structures are being designed and fabricated to resonate at <9kHz, using the Young's modulus obtained from nanoindentation. These two techniques will be compared with the DFT calculations and the implications of the error in the modulus measurement will be presented in terms of a simple PZT cantilever actuator data. In the future, a better understanding of the modulus will improve DFT and finite element modeling, and hence the optimization, of more sophisticated actuator geometries.

[1] G.R. Fox, et al. "Properties of reactively sputtered IrO_x for PZT electrode applications", *Integrated FE* 31, 47-56 (2000).
[2] Li, Yanling, and Zhi Zeng. "Elastic properties of transition metal dioxides: XO_2 (X= Ru, Rh, Os, and Ir)." *International Journal of Modern Physics C* 19.08 : 1269-1275 (2008).