Electronic Supplementary Information for

Ultra-thin Atom Layer Deposited Alumina Film Enables Precise Lifetime Control of Fully Biodegradable Electronic Devices

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1. Brief introduction to the mass loading effect

For mass loading-based resonant sensors, the relationship between the resonant frequency shift, *Δf,* and the mass change, *Δm*, is expressed by Sauerbrey equation as follows,[1]

$$\Delta f = \left(-2.3 + 10^6 \times \frac{f_0^2}{A} \right) \Delta m \qquad (S1)$$

where *A* is the active surface area, f_0 is the original resonant frequency of the SAW device. It indicates that the frequency shift, *Δf*, is mainly determined by *Δm* for fixed *A* and f_0. In the case of humidity responses, the mass change is determined by the condensation of water vapor on the active area on the surface of delay-line type SAW device. Equation S1 indicates that more condensation of water vapor will result in more significant frequency shift.

2. XRD spectrum of alumina film

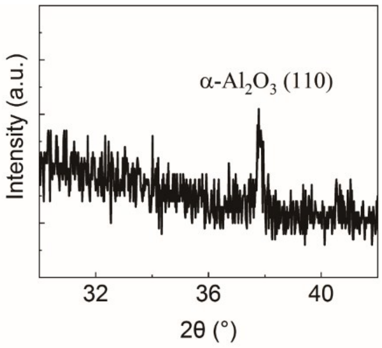

Figure S1. An XRD spectrum of the alumina film deposited by ALD, which shows the (110) crystal orientation of α-Al_2O_3.

Alumina has more than ten types of isomorphous crystals, and most common types are α-Al_2O_3, β-Al_2O_3 and γ-Al_2O_3. Figure S1 shows an XRD pattern of the alumina film deposited by ALD method, the dominant peak at 37.78° indicates (110) crystal orientation of α-Al_2O_3, which is the most suitable type of Al_2O_3 material for this work as they have the smallest lattice mismatch with ZnO film at the interface.[2]

3. Properties of ZnO thin films

High quality ZnO thin film is essential for fabricating high-performance ZnO-based Surface Acoustic Wave (SAW) devices. Figure S2a shows an atomic force microscope (AFM) image of the surface of ZnO film with a scanning area of 2×2 µm^2, the root mean square roughness is about 5.2 nm. The sputtering deposited ZnO film is columnar structure along the c-axis, and the AFM image confirms that the top-view surface morphology of ZnO film is a cell-unit like shape. Figure S2b shows an X-ray diffraction (XRD) pattern of the ZnO film with a dominant peak at ~34°, the peak confirms the (002) crystalline orientation of ZnO, which is critical for ZnO film to obtain high piezoelectric effect. The full-width at half-maximum (FWHM) is 0.184°, and an average grain size was calculated to be ~45 nm using the Scherrer Equation. [3]

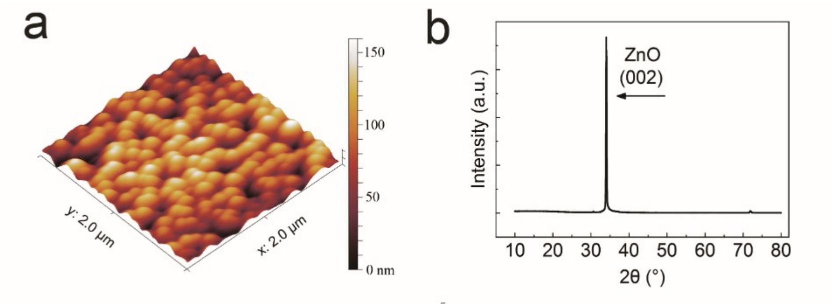

Figure S2. (a) An AFM image of the surface of ZnO film with a scanning area of 2×2 µm^2. (b) An XRD spectrum of the ZnO film, showing a good c-axis orientation;

References

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