The absorption properties of ZrO_2 nanoparticles in the THz and sub-THz frequency ranges

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§ 1. PXRD patterns

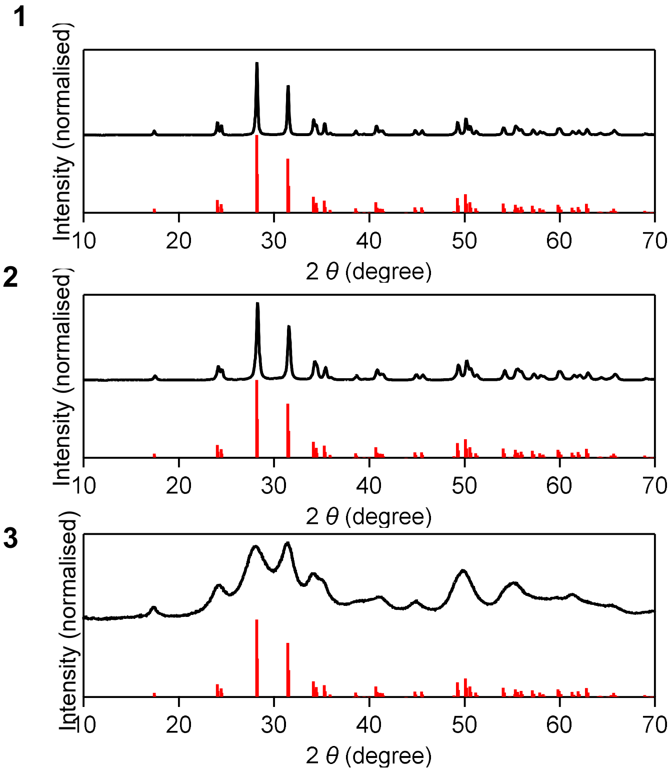

Figure S1. Observed PXRD patterns (black line) for **1**, **2** and **3** in comparison to a standard CIF file for *m*-ZrO_2 (red line).

§ 2. Particle size distribution

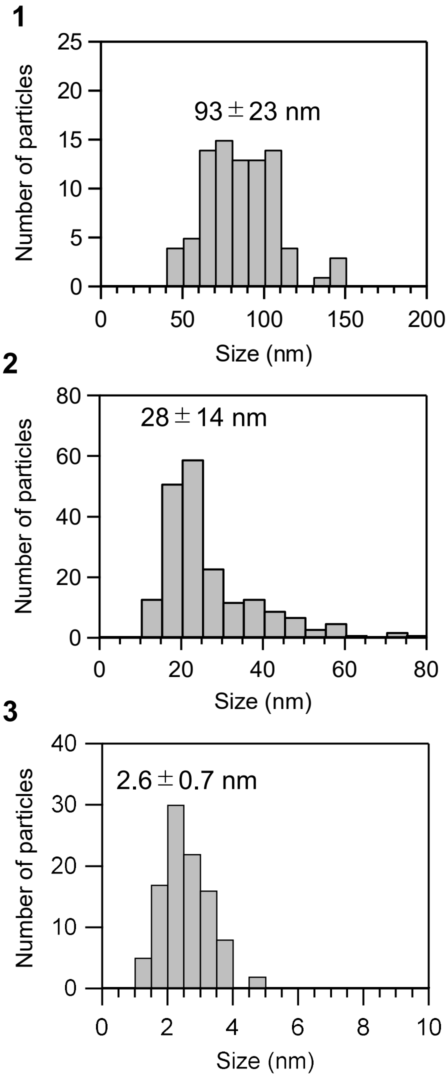

Figure S2. Particle size distribution for **1**, **2** and **3** obtained from the TEM images.

§ 3. Raman spectra assignment

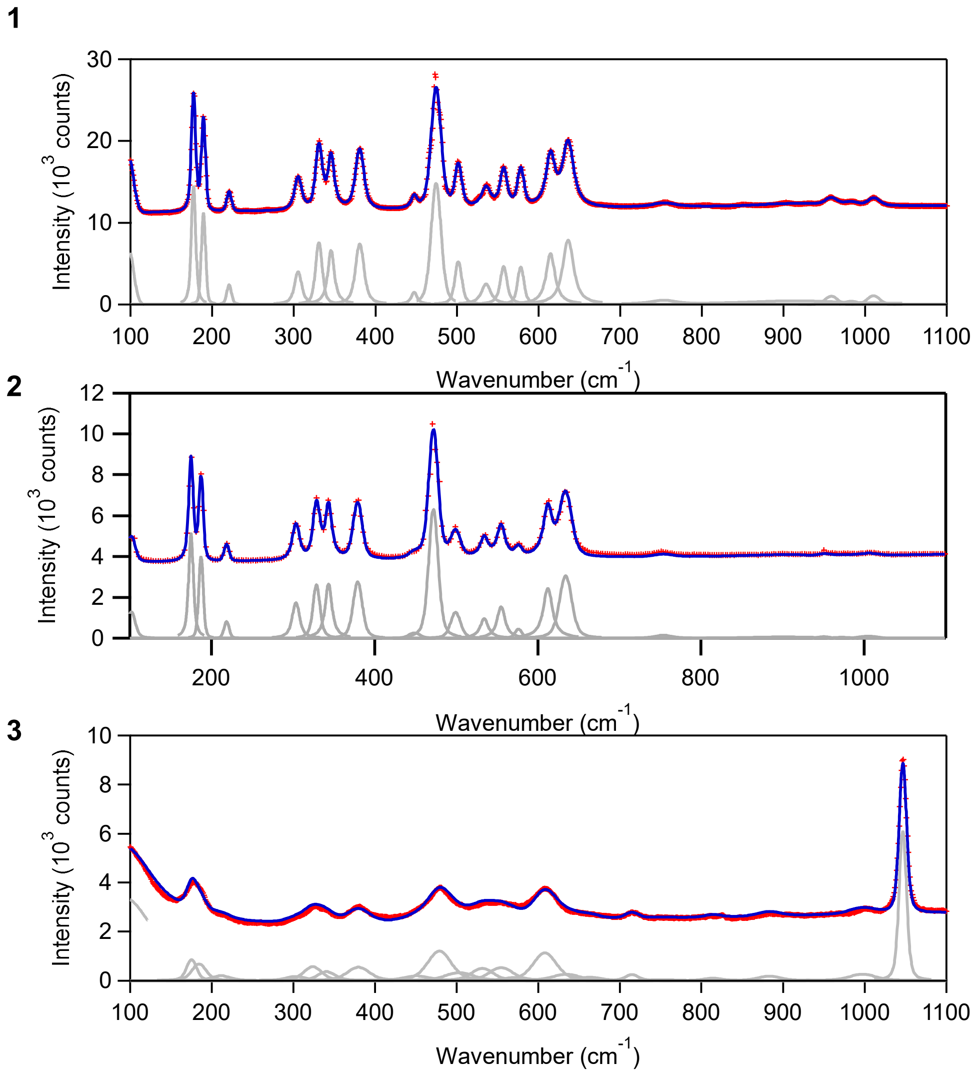

Figure S3. Raman spectra fitting for **1**, **2** and **3**. The red dots, blue, and grey lines indicate the observed pattern, the calculated pattern, and individual peaks, respectively.

§ 4. THz-TDS measurements

Millimeter wave absorption measurements.

The millimetre wave absorption properties were assessed using a terahertz time domain spectroscopy (THz-TDS) system, Advantest TAS7400. The THz light was generated using a 1550-nm laser and a GaAs photoconductive antenna, then condensed using a silicon lens and paraboloidal mirrors. The THz light was irradiated onto 13 mm*φ* pelletised samples in transmission and reflectance modes, and the signal was detected using a GaAs photoconductive antenna. The THz wave signal was obtained in the time domain and converted to absorption spectra by Fourier transformation.

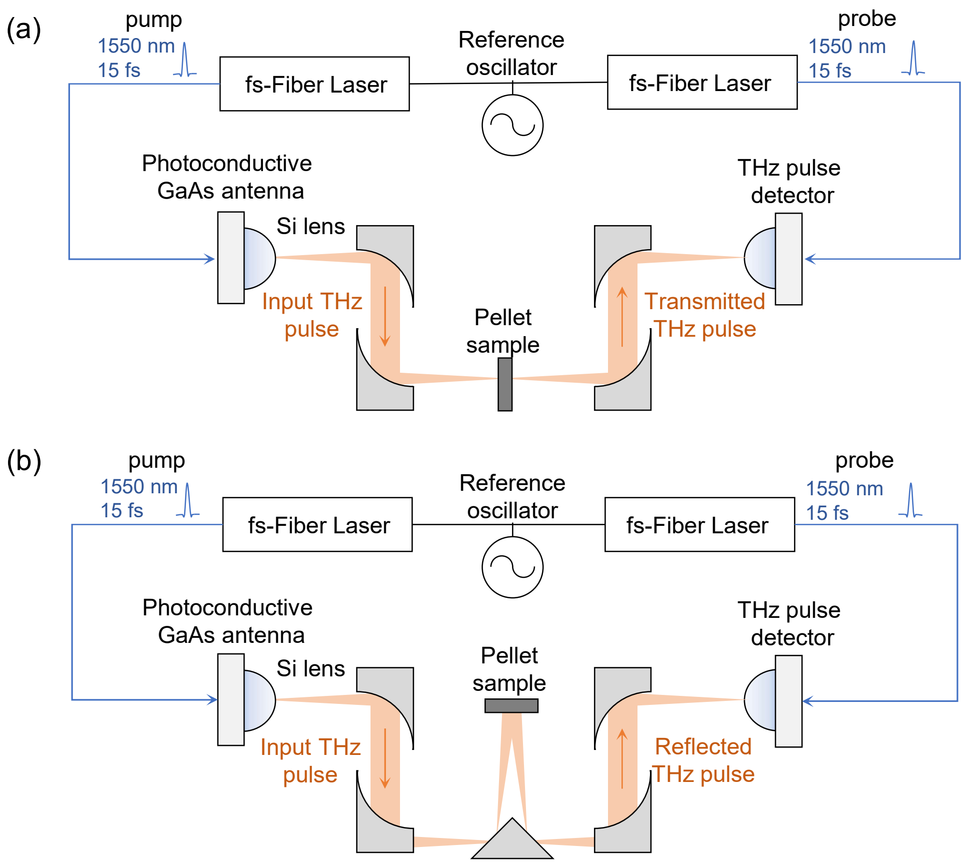

Figure S4. Schematic of the THz-TDS measurement system in (a) transmission mode and (b) reflection mode.

Determination of permittivity and dielectric loss.

In THz-TDS, determining the real (ε') and imaginary (ε'') parts of the dielectric constant involves the following steps: (1) The time-domain waveforms of the THz pulse that has passed through the sample, as well as the reference pulse, are converted into complex amplitudes (amplitude and phase) in the frequency domain by a Fourier transformation. (2) The frequency-dependent transmission coefficient $T(f)$ is calculated from the ratio of the amplitude of the pulse that has passed through the sample to the amplitude of the reference pulse. (3) Frequency-dependent phase change $\phi(f)$ is obtained by comparing the phase of the pulse that has passed through the sample to that of the reference pulse. (4) From the $T(f)$ and $\phi(f)$, the sample's complex refractive index ($n + ik$) is calculated. (5) Permittivity (ε') and dielectric loss (ε'') are obtained from the following equation: $\varepsilon' = n^2 - k^2$, $\varepsilon'' = 2nk$.