# A tunable zero nanometer gap platform on wafer scale for electromagnetic wave control

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Modern nanotechnologies such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM) heavily rely on our ability to control and maintain the gap width between two objects, often with a sub-nanometer precision. These mature quantum technologies have their applications largely limited to imaging or to single molecular manipulations because of the small device footprints of the point-like, 1 $nm^2$ variable gap architectures. We refer to the AFM and STM technologies and the scanning probe microscopies (SPM) in general '0-dimensional gaptronics'. For photonic applications encompassing the microwave and terahertz regime, we need to vastly increase the effective area of gap control, to truly a macroscopic scale (Fig. 1). The waferlength gaps are tunable from zero to 1000 nm, with the 'zero nanometer' essentially being frequency dependent. Quantum plasmonic actions over the uniform length of nanotrenches traversing tunneling, quantized conductance and semi-classical regimes produce an extinction better than 10,000 repeatable over 10,000 times in real time for terahertz and microwave electromagnetic incidents. Our results have far-reaching implications in bridging the gap between the quantum world to the macroscopic one and we anticipate wide ranging applications in radiation and molecular sensing, quantum conductances measurements, electrochemistry and photocatalysis.

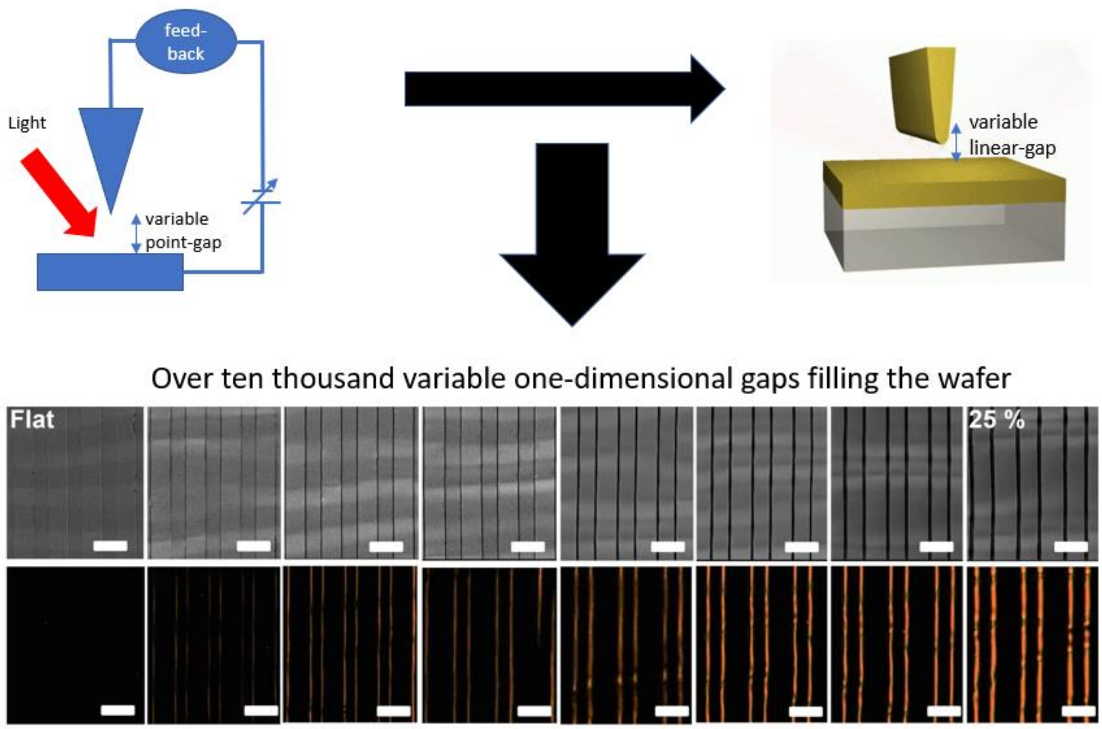


**Fig. 1** Inspiration behind the waferscale tunable zerogap platform. Conventional STM, AFM, and SNOM technologies have a single device footprint of a dimension ~$nm^2$. While these single, variable point-gap technologies provide images of unprecedented beauty and lead to many discoveries, large-area quantum platform is required for industrial applications. One-dimensional, curtain-like variable gap would enlarge the device footprint but is largely impractical. Thereby, on flexible substrate such as PDMS, wafer-length, zero-to-1000 nm tunable gaps are realized with many potential applications. Scale bars are 10 μm. SEM and optical microscopic images of the gaps in action are presented at the bottom.

## References

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