Self-focusing Nanomechanical Sensors for High-throughput Detection of Single Viruses and Nanoparticles

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Nanoelectromechanical systems-based mass spectrometry (NEMS-MS) is a powerful and emerging tool for the characterization and detection of nanoparticles and viruses that have a mass larger than 10 MDa. In NEMS-MS the particle delivery to the sensitive region of the NEMS device is facilitated by electrospray ionization. The analytes that are landing in the sensitive region of the device create frequency shifts in the resonance frequencies which enables us to back-calculate the mass of each landing particle. However, the NEMS-MS technique suffers from low throughput due to the minuscule size of the NEMS devices and hence limits the applications. In this work, we increased the throughput of the NEMS devices by integrating a polymeric ion lens that focuses the particles electrostatically to the NEMS resonator. This increase in the throughput and the integration of the polymeric ion lens allowed us to operate the NEMS-MS system entirely under atmospheric conditions for the first time. After the integration, we successfully detected the mass of gold and polystyrene nanoparticles with an increase in the capture efficiency compared to the state-of-the-art. Also, after benchmarking the system with gold and polystyrene nanoparticles, we detected the mass of single SARS-CoV-2 viruses. The increase in the capture efficiency facilitated by the polymeric ion lens demonstrates that NEMS-MS operated in atmospheric conditions is a powerful tool for the characterization and detection of engineered nanoparticles and biological samples [1].

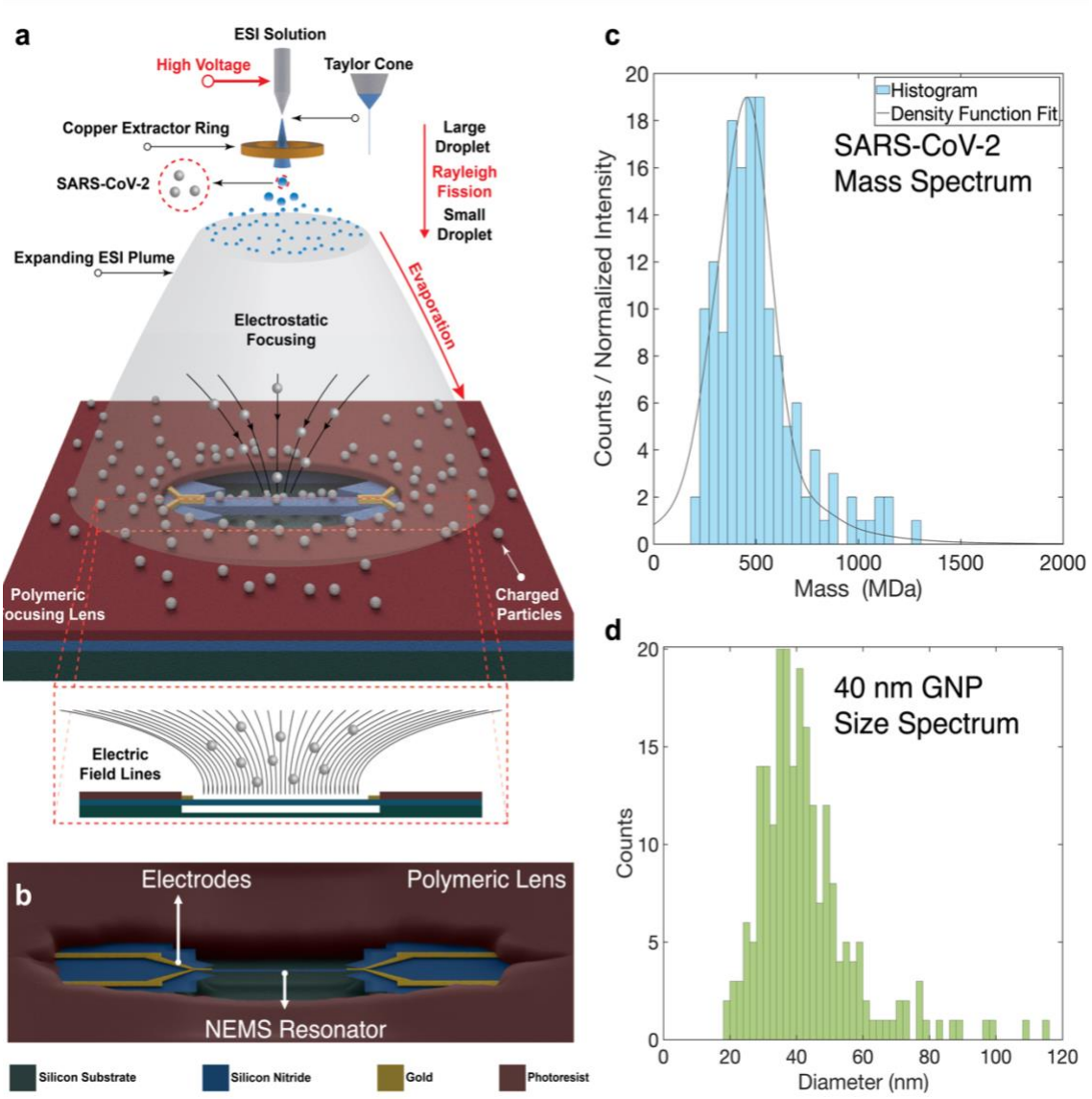

Figure 1: Atmospheric Pressure NEMS Mass Spectrometry: (a) Illustration of the setup consisting of an Electrospray Ionization (ESI) needle to generate nanoparticles and viruses in the gas phase, a copper extraction ring for coarse focusing, and a chip that combines both a polymeric lens for self-focusing of ions, and a NEMS sensor, (b) NEMS with polymeric lens, (c) Mass spectrum of SARS-CoV-2 virions (d) Size spectrum of 40 nm Gold Nanoparticles, obtained. In each case, the NEMS analysis time was less than 20 minutes.

References

[1] R. T. Erdogan *et al.*, ACS Nano **16**, 3821 (2022).