Real-time detection of airborne dust particles using highly sensitive paddle type silicon cantilevers

Bonghyun Park[1], Jiseok Hong[2] and Seung-Beck Lee[1,2,3*]

[1]Department of Nanoscale Semiconductor Engineering, Hanyang University
[2]Department of Information Display Engineering, Hanyang University
[3]Division of Electronics and Computer Engineering, Hanyang University
Seoul 133-791, Korea
*email: sbl22@hanyang.ac.kr

Increasing air pollution caused by airborne dust particles, with diameters less than a few hundred nanometers, which bypasses conventional filtering systems, has become one of the main threats to human health and the environment [1]. Therefore, to actively monitor the levels of deep submicron particle contamination in the air, a sensor which can detect the density of airborne submicron particles in real-time is required since conventional sensors detect only the mass-concentration per unit area or the size distribution above a few microns [2].

Here, we present the fabrication and operation of silicon based paddle-type cantilever sensors for real-time monitoring of mass and density distribution of airborne deep-submicron dust particles by using electrostatic attraction. Electrostatic fields applied to the large paddle at the end of a cantilever oscillating at resonance, collects the airborne dust particles resulting in a lag in phase between the driving PZT and the paddle-type cantilever. A phase shift of 0.1^o correlates to the collection of 0.12 pg of dust particles. We used a silicon wafer with 500 nm Si_3N_4 deposited on both sides. Optical lithography and RIE was performed to pattern the device outline and chemical etching through the back-side etch window freed the paddle-type cantilever (Fig.1.). The shift in phase was measured by a lock-in-amplifier through the laser interferometer which detects the cantilever motion. When voltage was applied to the paddle, a shift in phase was detected, which increased with time indicating steady collection of dust particles (Fig.2). Increase in collector voltage results in the collection of higher mass, therefore larger size, dust particles. This also depends on relative humidity RH. The saturated phase change increased from 0.4^o at 30 %RH to 0.6^o at 50 %RH showing higher RH enhances dust particle adhesion. Fig.3. shows the collected airborne submicron dust particles ranging in size from about 50 ~ 800 nm after measurement. By applying negative voltage beyond a critical value, it was possible to remove the collected particles from the paddle (Fig.4). We will further present results on dust particle density dependent sensing characteristics and particle mass detection.

[1] Yoram J. Kaufman et al., Science, 313 (2006) p.655~658
[2] Syvitski James P. M., *Principles, methods, and application of particle size analysis* (Cambridge University Press, 1991)

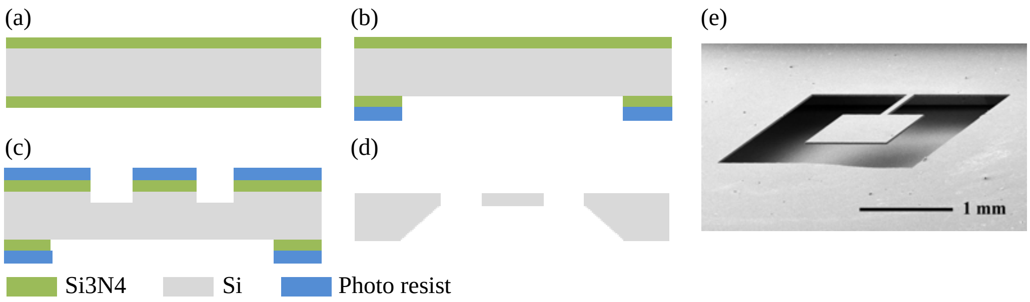

Fig.1. Schematic diagram of the fabrication process; a) A LPCVD Si_3N_4(500 nm) coated silicon wafer, b) the Si_3N_4 RIE for a back-side window, c) the Si_3N_4 and silicon RIE for cantilever definition, d) the cantilever releasing process, e) the SEM image of the paddle-type cantilever

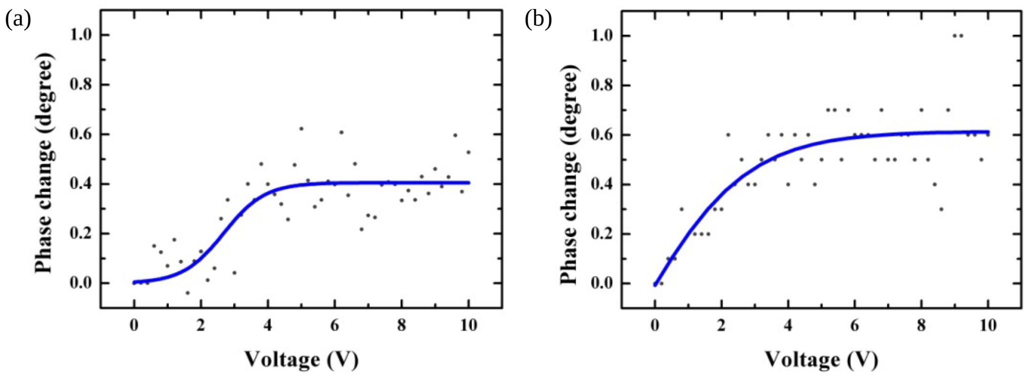

Fig.2. Oscillating phase change due to dust particle adhesion on the paddle surface with voltage sweep from 0 to 10 V a) at 30 %RH, b) at 50 %RH.

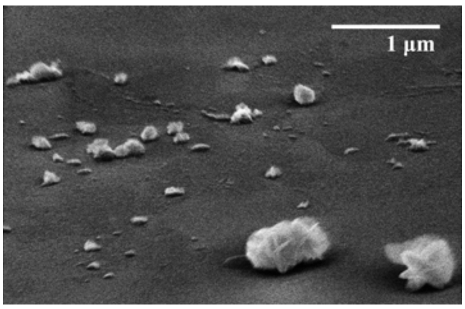

Fig.3. SEM image of the submicron dust particles collected on the paddle-type cantilever using electrostatic attraction.

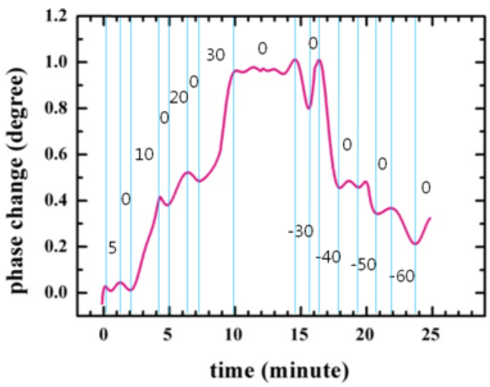

Fig.4. Collection and removal of dust particles depending on applied field polarity. The numbers indicate applied paddle voltage.