Silicon and Silicon Carbide MEMS Sensors and Actuators

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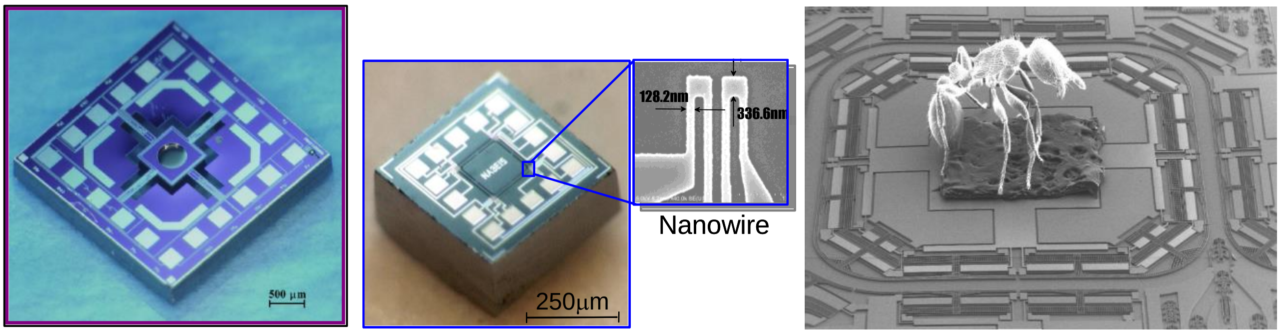
This work presents our innovative micro physical, gas sensors and actuators developed based on MEMS (Micro-Electromechanical Systems) technology. The presentation starts with introduction of MEMS R&D and future forecast, and then it goes into details of designs, fabrications and characterizations of Si and SiC MEMS devices.

Introduction: MEMS technology relates to research and development of micro/nano electro-mechanically integrated sensors and actuators fabricated based on microelectronic technology with high accuracy and throughput. MEMS sensors and actuators possess many advantages, such as miniaturization, multifunctional integration, high performance, mass production, low cost. Therefore, MEMS sensors have been widely used in consumer and industrial applications, such as automotive, biomedical, robotics, smart home/city, defense, etc. The first idea of MEMS was proposed by the 1965-Nobel laureate Richard Feynman in 1959. However, MEMS were not widely known until the late 1960s and early 1970s when silicon's sensing properties, microfabrication techniques, and some mechanical sensors were successfully demonstrated. MEMS technology has experienced huge investments in infrastructure, improvements in design and fabrication, and successful commercialization. Typical examples of successful MEMS devices include pressure sensors, accelerometers, gyroscopes, flow sensors, magnetic sensors, gas sensors, microphones, resonators, RF MEMS, ink-jet printer heads, digital micro mirrors, and optical switches. MEMS technology has attracted great attention globally to develop new applications and new industry. It is forecasted that the market for MEMS sensors will grow from US$42 billion in 2017 to US$100 billion in 2023 [1].

Methods: Piezoresistive and thermoresistive effects are used as the sensing principles for our Si and SiC MEMS physical sensors, while the electrostatic effect is utilized for our Si MEMS actuators. The devices were fabricated based on the Si micro/nanomachining technology, which includes thin-films deposition, photolithography, electron beam lithography, wet and plasma etching steps. Thousands of micro sensors and actuators were fabricated in the same fabrication process with high accuracy and throughput. Compared to Si MEMS, SiC MEMS sensors can work more reliably in harsh conditions, e.g. high temperature, high chemical corrosive environments, thanks to its unique properties, such as larger bandgap, higher thermal stability, higher breakdown voltage, higher Young's modulus than silicon.

Results: Figures 1 shows some photos of our micro/nanomachining sensors and actuators. All devices were charaterised and their perforamnces were excellent.



(a) (b) (c)

Figure 1: (a) A Si MEMS 6-DOF force sensor chip [2], (b) Ultra-small 3-DOF accelerometer (overall dimensions are 0.5×0.5×0.4mm^3), and (c) SEM image of a micro transportation system working based on the electrostatic effect. The system can transport micro containers. The length, width and thickness of each container are 450μm, 250μm and 30μm, respectively. (An ant is sitting on top of the system is for scaling illustration) [3].

References:

[1] "Status of the MEMS Industry 2018", 2018, Yole Développement.
[2] Dzung V. D, S. Sugiyama et al (2003), Sensors and Materials, **15**, **3**, pp. 113-135
[3] Dzung V. D et al (2010), Adv. Nat. Sci: Nanosci. Nanotechnol. 1 013001 (10pp)