World Academy of Science, Engineering and Technology
International Journal of Nuclear and Quantum Engineering
Vol:11, No:04, 2017

Quantum Conductance Based Mechanical Sensors Fabricated with Closely Spaced Metallic Nanoparticle Arrays

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Abstract : Mechanical sensors have undergone a continuous evolution and have become an important part of many industries, ranging from manufacturing to process, chemicals, machinery, health-care, environmental monitoring, automotive, avionics, and household appliances. Concurrently, the microelectronics and microfabrication technology have provided us with the means of producing mechanical microsensors characterized by high sensitivity, small size, integrated electronics, on board calibration, and low cost. Here we report a new kind of mechanical sensors based on the quantum transport process of electrons in the closely spaced nanoparticle films covering a flexible polymer sheet. The nanoparticle films were fabricated by gas phase depositing of preformed metal nanoparticles with a controlled coverage on the electrodes. To amplify the conductance of the nanoparticle array, we fabricated silver interdigital electrodes on polyethylene terephthalate(PET) by mask evaporation deposition. The gaps of the electrodes ranged from 3 to 30μm. Metal nanoparticles were generated from a magnetron plasma gas aggregation cluster source and deposited on the interdigital electrodes. Closely spaced nanoparticle arrays with different coverage could be gained through real-time monitoring the conductance. In the film coulomb blockade and quantum, tunneling/hopping dominate the electronic conduction mechanism. The basic principle of the mechanical sensors relies on the mechanical deformation of the fabricated devices which are translated into electrical signals. Several kinds of sensing devices have been explored. As a strain sensor, the device showed a high sensitivity as well as a very wide dynamic range. A gauge factor as large as 100 or more was demonstrated, which can be at least one order of magnitude higher than that of the conventional metal foil gauges or even better than that of the semiconductor-based gauges with a workable maximum applied strain beyond 3%. And the strain sensors have a workable maximum applied strain larger than 3%. They provide the potential to be a new generation of strain sensors with performance superior to that of the currently existing strain sensors including metallic strain gauges and semiconductor strain gauges. When integrated into a pressure gauge, the devices demonstrated the ability to measure tiny pressure change as small as 20Pa near the atmospheric pressure. Quantitative vibration measurements were realized on a free-standing cantilever structure fabricated with closely-spaced nanoparticle array sensing element. What is more, the mechanical sensor elements can be easily scaled down, which is feasible for MEMS and NEMS applications.

Keywords : gas phase deposition, mechanical sensors, metallic nanoparticle arrays, quantum conductance
Conference Title : ICQMNT 2017 : International Conference on Quantum, Micro and Nano Technologies
Conference Location : Kyoto, Japan
Conference Dates : April 27-28, 2017