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Design and characterization of an inertial microswitch with synchronous follow-up flexible compliant electrodes capable of extending contact duration

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ABSTRACT

An inertial microswitch with synchronous follow-up compliant electrodes for extending the contact duration is proposed in this paper. A flexible movable electrode and a stationary electrode in the double-stair and spring-shape structures are used for not only extending contact duration but also reducing the impact bounces. The simulated contact time can reach 350 μs under 500 g applied acceleration, which indicates there is a better contact effect than that reported elsewhere. The fabricated inertial microswitch based on surface micromachining technology was characterized by the dropping hammer system. No contact bouncing behavior can be observed under the acceleration amplitude ~466 g and the test contact duration can reach 390 μs, longer than the microwitch with only one flexible electrode. The testing comparison of the microswitches with and without constraint structure indicates that the contact-bouncing behavior is easier to happen if without constraint structure, which indicates that the designed constraint structure can restrain the vibration of the proof mass in *z*-off-axis sensitive direction and effectively improve the stability of the device. The test results have an agreement with the simulated ones.

1. Introduction

In recent years, micro-electro-mechanical systems (MEMS) inertial microswitches based on surface micromachining technology have been used widely in a variety of applications such as toys, automotive electronics and remote monitoring (RMON) [1–3]. There is a significant impact of the MEMS inertial microswitches on the power reduction, mass production, better performance and miniaturization of the inertial microswitch compared with the conventional mechanical inertial microswitches [4,5].

The working principle of the MEMS inertial microswitch is that the movable electrode moves rapidly toward the stationary electrode when the inertial microswitch is accelerated up to the threshold level in the sensing direction, putting out a pulse signal and forming an external electric path. In the traditional designs, both the two electrodes are usually rigid due to the high mechanical elasticity modulus of electrode material of nickel. Thus, it would result in an extremely short contact time and an inevitable bouncing behavior. Consequently, this transient contact time is a great obstacle for the subsequent signal processing when the microswitch is employed in an integrated circuit [6–8]. What is worse, the bounces from the contact between the electrodes can lead to the low reliability due to the frequent rigid collision between the two electrodes. Therefore, great efforts have been contributed to reducing the disadvantageous effects of the two rigid electrodes. Tonnesen et al. reported an inertial microswitch where the cantilever beam located in the middle of the proof mass was regarded as the movable electrode in order to enhance the contact effect [9]. Matsunaga et al. utilized the squeeze film effect to design a microswitch in order to enhance the contact effect [10]. Guo et al. reported a silicon-based switch with robust latching and cylindrical contacts to decrease the rebound [11]. However, it is not convenient for the latching switch for the pre-test because the subsequent release is very difficult once the latching has been carried out. Recently, Yang and Kim et al. introduced vertically

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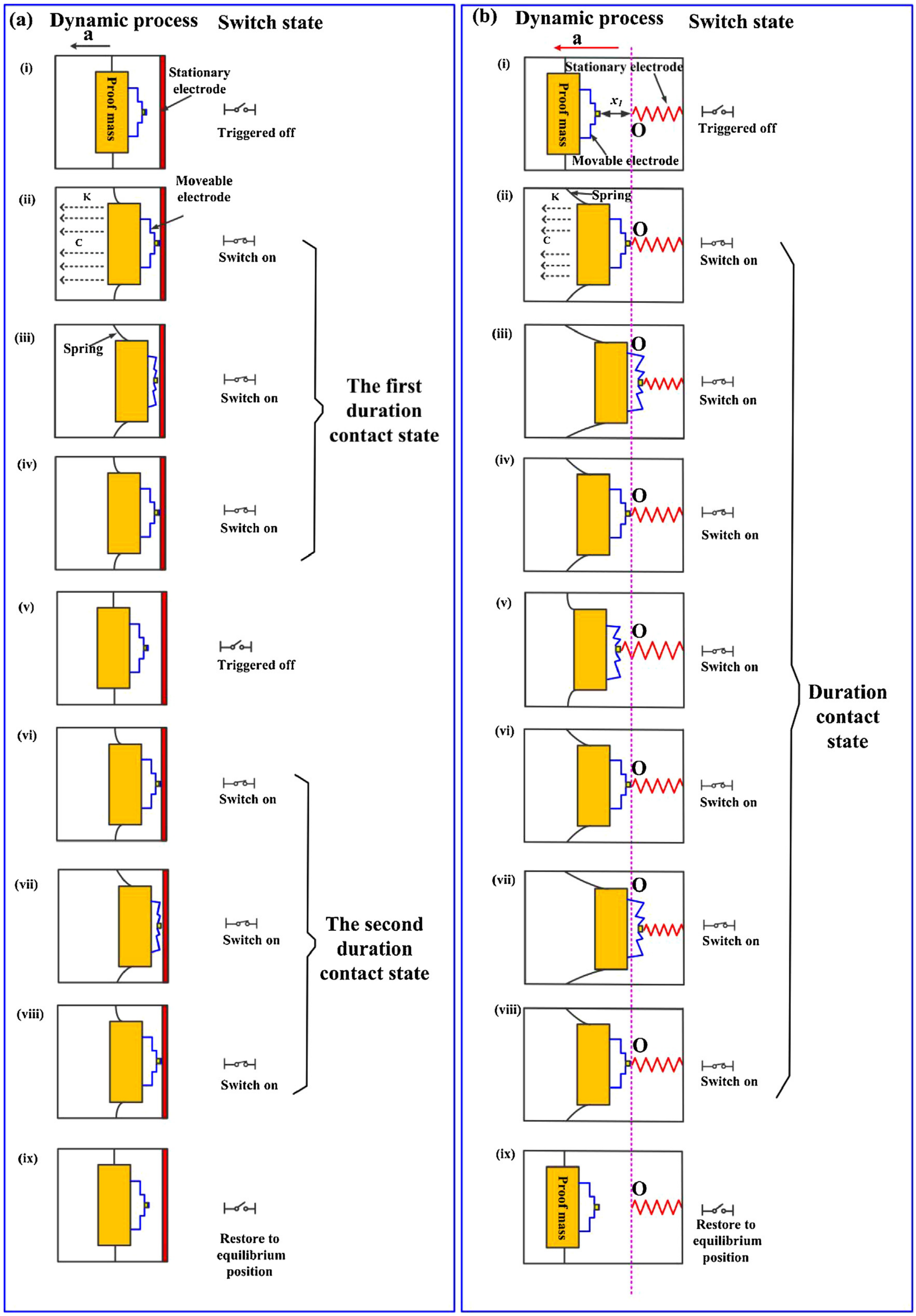

Fig. 1. Dynamic contact process comparison between (a) the inertial microswitch with one elastic movable electrode and (b) the inertial microswitch with synchronous follow-up compliant electrodes.

aligned carbon nanotube-bundles into the two electrodes in the microswitch to extend its contact time [12,13]. However, the fabrication process was redundant and difficult. Jia et al. reported an acceleration switch to prolong the contact duration using electrostatic force combined with the dynamic shocking force [14]. In our previous works [15,16], a vertically driven inertial microswitch was designed for improved contact effect because an inner spring was placed in the middle of the proof mass as the movable electrode.