Investigation of Diamagnetic Levitation for Dynamic MEMS Devices

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Abstract

The mechanical performance and lifetime of dynamic MEMS (micro electro mechanical systems) devices such as micropumps, micromotors, and micropositioners heavily rely on the bearing mechanism that enables motion per applied actuation. To improve the performance and lifetime metrics, various different bearings have been developed and reported in the literature including (i) contact bearings (sliding contacts, ball bearings) and (ii) non-contact bearings (air bearings, magneto-pneumatic bearings, and magnetic bearings taking advantage of eddy currents). While the non-contact bearings are superior to contact bearings in terms of device performance, friction, and wear, they also present major disadvantages including power consumption and the need for external equipment. In this work, the applicability of diamagnetic levitation featuring the advantage of both bearing mechanisms is investigated for dynamic MEMS devices, where the moving component of the device is levitated through a repulsive interaction between a magnetic field and a diamagnetic material. A flux-generating multi-turn coil (as the source of magnetic field) and a pyrolytic graphite disc (as the diamagnetic material, χ = -4e-4) were modeled on COMSOL software under AC/DC module. Multiple simulations have been carried out to explore the effect of graphite radius, air gap, and core permeability on the magnetic repulsion force in various geometries. It has been demonstrated that a 10 µm-thick graphite disc having a radius of 300 µm can be levitated by using a similar-sized 15-turn helical coil carrying 1 A current on a nickel core. In addition, it has also been shown that the ratio of diamagnetic force to the graphite weight increases as the radius, and hence, the device size decreases. This clearly proves that diamagnetic levitation can be applied to micron-sized and even smaller NEMS (nano electro mechanical systems) devices. Furthermore, the current-carrying coil can be replaced by engineered permanent magnets so that the levitation can be performed with no electrical power input and external equipment. This will extend the mechanical performance, speed, efficiency, lifetime, and portability of dynamic MEMS devices, and will further facilitate the use of these devices in real-life applications.

Keywords: Diamagnetic, levitation, MEMS, magnetic bearings