17

Micro Magnetic Bearings

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17.1 Introduction to micro magnetic actuators and their down-scaling

A micro magnetic actuator is any device based on magnetic effects to achieve mechanical actuation. The meaning of the word “micro” depends very much on context. Let us call such an actuator “micro” when the magnetic part of the actuator proper, i.e. without electronics, is confined to sizes typically measured in micrometers and up to a maximum of about one or two centimeter in overall size. This includes mm and sub-mm actuators and MEMs devices (definition see below) based on magnetic effects. Larger actuators are treated in other chapters. After an introduction to downscaling of magnetic actuators, this chapter will concentrate on micro magnetic bearings. There are, up to now, only very few examples of realizations: all are purely experimental systems, but there is a number of potential applications to be explored once the basic issues will have been resolved.

17.1.1 MEMS

“MEMs” stands for “Micro Electro Mechanical Systems” and designates essentially devices fabricated by technologies developed for microelectronics, and ICs. Technologies such as photolithography, chemical or ionic etching, sputtering, vapor deposition, screen printing, LIGA etc. all typically are MEMS technologies. Materials include silicon, other metals and semiconductors, oxides and nitrides, polymers, glasses, ceramics etc. A MEMS device combines some electronics with a mechanical component, i.e. certain parts should be in mechanical motion, as opposed to purely electronic devices. Examples are integrated miniaturized accelerometers (as used e.g. for the deployment of airbags in cars), integrated pressure transducers or micro pumps used in microfluidic devices for chemical analysis of very small quantities of reactants or for localized drug delivery.
17.1.2 Some potential application fields of micro magnetic bearings

- gyroscopes
- rotating mirrors
- beam choppers
- spinning vacuum gauges
- micromachining
- micro turbines

17.1.3 Often underestimated: The potential of micro magnetic actuators vs. electrostatic actuators

It is commonplace to state that electrostatic actuators are greatly favored over magnetic actuators when it comes to microsystems. The argument essentially states that electrostatic forces scale down with the square of length because they are proportional to surface. Magnetic forces are assumed to scale down with the third power of length as they are, so it is claimed, proportional to volume. Therefore, there is a crossover to be expected. This crossover is generally situated in the mm order of magnitude. It is not evident to define the models and the hypotheses involved in a computation of this supposed “crossover point”. The argument is supported by the fact that there are no large mechanical actuators based on electrostatic forces. MEMS devices on the other hand, rely to a great majority on electrostatic effects, a few on piezo effects and indeed very few only on magnetic effects. Does this alone support the argument against micro magnetic actuators? A careful analysis reveals that the commonplace argument banning magnetic actuators from the micro world does not stand so strongly. It will be shown in the following sections that magnetic actuators in general, and in many cases even electromagnetic actuators promise superior performance as compared to electrostatic actuators.

There are several reasons why this is not yet generally recognized:

1. The fabrication of electrostatic actuators is relatively straightforward in the context of production technologies for microcircuits and, by extension, for MEMS. A large workforce of engineers and scientists is familiar with these technologies and their expensive equipment. Ferromagnetic materials do not fit into this production technology and are exotic to many processes. Microelectronics production equipment is very sensitive to unusual materials, it is easily “polluted” and this reinforces the tendency to favor processes with the usual material. This point has strongly played in favor of electrostatic actuators for MEMS, which can be easily produced in silicon.

2. The comparison is often carried out for the interaction of capacitor plates versus current carrying leads. As we will see, this is the least favorable configuration for magnetic actuators, the use of ferromagnetic material or permanent magnets greatly improves the efficiency of magnetic actuators.