Abstract:
Large length-to-diameter aspect ratio silicon-based gas journal microbearings have been fabricated to study their wear and impact characteristics. The bearing system is characterized by a rotor, which is manually assembled to a hub. The rotors are driven by compressed air through a rectangular microchannel. A coefficient of restitution value is determined for silicon-on-silicon hub-on-rotor impact using a simulation model and measured rotor speeds, and the value is found to be similar to previously published results obtained with polysilicon materials over a range of hub-to-rotor radial clearances typically found in practice.

Summary of Research:
To date, relatively little is understood about the wear behavior of large length-to-diameter (L/D) aspect ratio journal microbearings. In the past, researchers worked primarily on surface micromachined polysilicon electric-driven rotating machinery. The design space available for employing this fabrication methodology resulted in bearings with L/D ratios on the order of approximately 0.05. This ultra low aspect ratio was due to the limitations of the surface micromachining planar fabrication technology.

Recently, wear characteristics of larger aspect ratio (~ 0.6) plain cylindrical journal bearings fabricated using x-ray lithography, nickel (Ni) electroplating, and tungsten alloy coatings were reported [1]. Results indicated that coated microbearings have lower wear rates than uncoated bearings. Recently, we reported on, apparently, the first published study, which investigated the wear behavior for large-aspect ratio silicon-based microbearings fabricated using deep reactive ion etching (DRIE) [2]. It was found that wear progression is substantially dependent on bearing geometry for bearing configurations with similar hub-to-rotor radial clearance values. The observed wear morphology in conformal and non-conformal bearing configurations could not be attributed to an adhesion wear model, but was instead strongly suggestive of impact wear.

As a continuation of this work, we have developed a new test apparatus characterized by a rotor-hub system driven by compressed gas through a single rectangular channel, as shown in Figure 1. The rotor bearing length and diameter are approximately 190 µm and 400 µm, respectively, resulting in an L/D ratio of approximately 0.5. Thrust bearing pads are etched into the hub base in order to promote gas lubrication and reduce rotor-hub base contact. In order to mitigate inter-wafer fabrication process uniformity concerns, all rotors are fabricated on the same type of (1 0 0) single crystal, single side polished wafer substrate. Likewise, all hubs are fabricated on a separate individual wafer configured as shown in Figure 2. This hub configuration enables rotor-hub testing without the need for hub wafer dicing.
A dynamic impact model of the bearing system based on classical impulse-momentum relations has been formulated to assess the effect of rotor-hub radial clearance on rotor speed. The model assumes a constant dynamic coefficient of friction of 0.3 representative of silicon surfaces [3], constant radial load, and an adjustable coefficient of restitution value. The radial load was computed from a computational fluid dynamics model of the channel in a manner similar to that described in our previous work [2].

Each simulation is run with an assumed coefficient of restitution value, and the value is adjusted until the average computed rotor speed is equal to the corresponding measured rotor speed. A preliminary set of simulated results gives a coefficient of restitution value of 0.5 for radial clearances ranging from 3.5 to 9.2 µm. This value agrees reasonably well with a coefficient of restitution of 0.56 obtained for polysilicon on polysilicon microstructures [4].

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