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TRIBOLOGICAL BEHAVIOR OF MICRON-SCALE POLYCRYSTALLINE SILICON STRUCTURAL FILMS IN AMBIENT AIR

D.H. Alsem[1,2], R. van der Hulst[3], E.A. Stach[4], M.T. Dugger[5], J.Th.M. de Hosson[3] and R.O. Ritchie[1,6]

1 Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
2 National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
3 Department of Applied Physics, University of Groningen, Groningen, The Netherlands
4 School of Materials Engineering, Purdue University, West Lafayette, IN, USA.
5 Materials Science and Engineering Center, Sandia National Laboratories, Albuquerque, NM, USA
6 Department of Materials Science and Engineering, University of California, Berkeley, CA, USA

Because tribological properties are critical factors in the reliability of silicon microelectromechanical systems (MEMS) it has become important to understand the physics of the mechanical processes associated with wear and friction in polysilicon. To address this issue, dynamic friction, wear volumes and wear morphology have been studied for MEMS sidewall friction and wear devices (fabricated in the Sandia SUMMiT V^{TM} process), which were run in ambient air at μN normal loads and at different relative humidity (%RH). For about half of the devices, with increasing number of wear cycles the friction coefficients showed a peak at three times the initial value, with failure after 10^5 cycles. The other half of the devices displayed similar behavior, but after peaking reached a steady-state friction coefficient regime showing no failure after millions of cycles. In this steady-state regime increasing the %RH resulted in a linear increase in the dynamic coefficient of friction. Additionally, the average nano-scale wear coefficient sharply increased in the first ~10^5 cycles up to about 10^{-4} and then decayed by an order of magnitude over the course of several million cycles. Under these conditions, abrasive wear is the governing mechanism, and early failures are being attributed to differences in the local surface morphology (and wear debris) between the sliding surfaces. During these wear processes the re-oxidation of worn polysilicon surfaces only affects the friction coefficient after periods of inactivity (>30 min). Such results are considered in terms of a mechanistic understanding of the process of micron-scale wear in polysilicon.