Investigating the Robustness of MEM Relay Beams

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Abstract

Integrated circuits (IC) now in use are not electrically efficient—such inefficiency is a barrier to further technological advancement. Micro-electromechanical (MEM) relays have the potential to replace common transistors in IC. IC with MEM relays would be more electrically efficient than current IC. What follows is a report concerning the robustness of 4-terminal (4T) MEM relay beams.

Introduction

- Integrated circuits (IC) use inefficient electrical switches, hindering further innovation
- Off-state current leakage is a main reason for IC power inefficiency
- 4T MEM relays have been shown to be promising switches for energy efficient electronics [1]
- Because of the mechanical nature of MEM relays, when in the off-state there is no current flow physically possible (see Fig 2 below)
- The mechanical nature of MEM relays also means mechanical fatigue and failure
- The robustness of MEM relays needs to be tested to help further their development [2]
- Results concerning the robustness of MEM relay beams are reported here

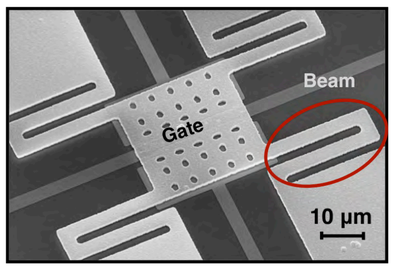
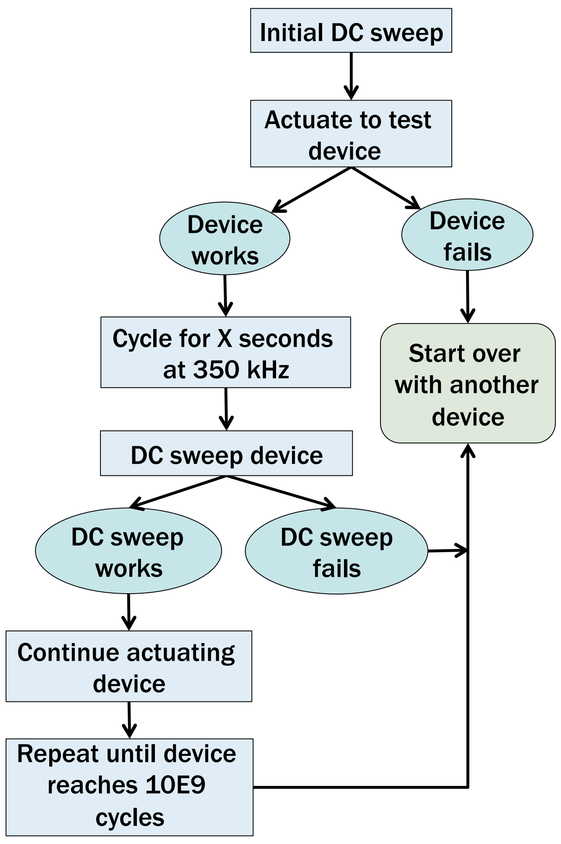


Fig. 1 Picture of 4-T MEM relay tested. Gate structure is ~30 µm

Methods

Procedure for testing 4T MEM relays



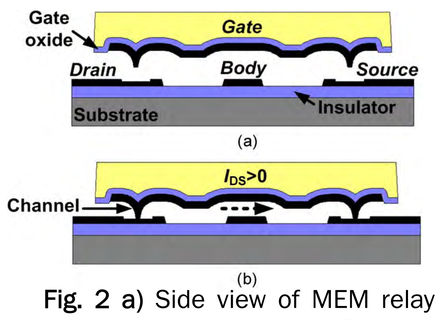


Fig. 2 a) Side view of MEM relay in off-state, b) side view of MEM relay in on-state. Current flows from *D* to *S*.

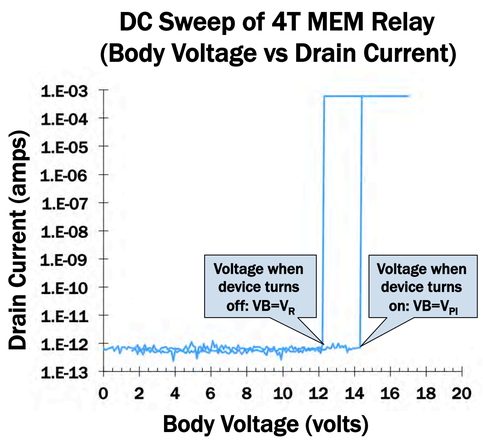
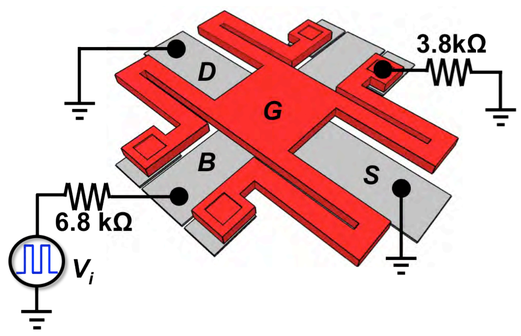


Fig. 3 An incremental increase in voltage, applied to the body terminal, is how pull-in and release voltage were determined (V_{PI} and V_R.)

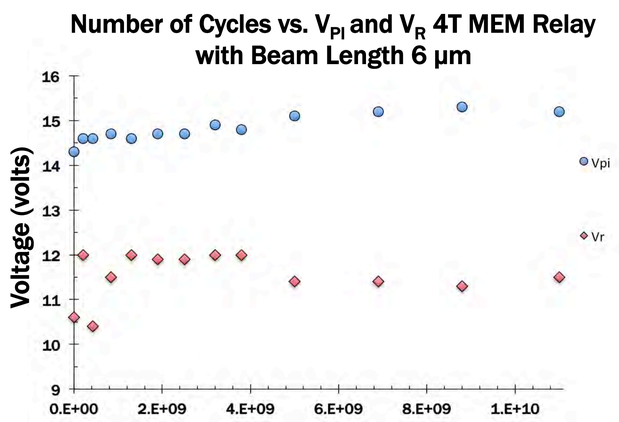
Setup used to cycle 4T MEM relays



Test conditions:

- **Actuation voltage**: V_{PI}+3V
- **Input frequency**: 350 kHz
- **Ambient pressure**: ~3E-6 torr
- **Temperature**: fixed at 300K
- Relays tested with various beam lengths
- Cold switch, e.g. V_D=V_S=0V

Results



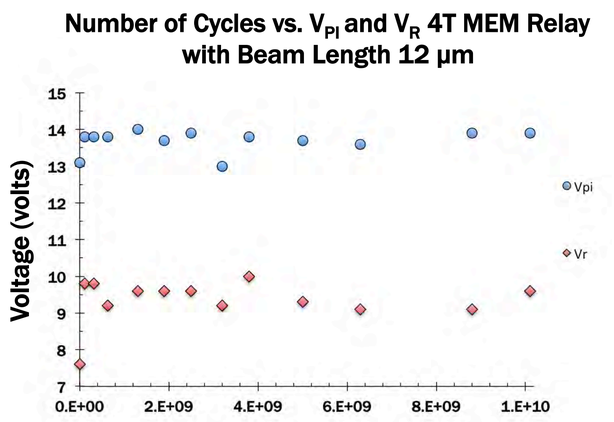


Fig. 4 The change in V_{PI} and V_R over time is shown above. Note how the MEM relay on the left seems to have a slightly more consistent V_{PI} and V_R than the relay on the right. The MEM relay on the left has a beam length of 6 µm, while the beam length of the devices on the right is 12 µm. Beam length is the only variable between the two MEM relays, leading us to conclude beam length is a contributing factor to the differences in V_{PI} and V_R between the two MEM relays. Since the MEM relay on the left has a more consistent V_{PI} and V_R, we believe a shorter beam length may be advantageous.

Expected Results

- MEM relay beam would soften, V_{PI} and V_R would decrease in magnitude over relay's lifecycle.
- Some beams would break over time due to fatigue.
- A longer beam length would make the device more reliable.

Actual Results

- No discernable relationship of V_{PI} and V_R and number of cycles was able to be determined.
- No beams seemed to have been broken during testing. Close examination of beams was not able to be conducted.
- With the data collect, a shorter beam length seems to be more reliable. More testing is need to substantiate this claim.

Future Directions

- Further testing of MEM relay beam robustness is needed to verify the results presented and help answer the question of what length beam is most reliable.
- Testing of beams on other MEM relay designs.
- Testing of beams under different conditions, e.g. varied temperature.
- Visual investigation of MEM relay beams after actuation cycles could provide valuable insight into the long term wear and fatigue experienced by MEM relay beams.
- Continued testing of MEM relay beams will help in the designing of better MEM relays in the future.

References:

[1] R. Nathanael, V. Pott, H. Kam, J. Jeon, and T-J. King Liu, "4-terminal relay technology for complementary logic," in *IEDM Tech. Dig*, 2009, pp. 223–226.

[2] I. Stanimirović and Z. Stanimirović, "MEMS Reliability," in *Int. Conf. on Microelectronics*, Niš, Serbia, 2012, pp. 173- 175.

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