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Design and Fabrication of a Gold Electroplated Electromagnetic and Electrostatic Hybrid MEMS Relay

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MEMS-based microrelays attract attentions recently because of the advantages they offered such as significantly smaller size, less weigh and power consumption, as well as the lower cost. Electrostatic replays consume minimal power, exhibit larger contact forces. On the other hand, electromagnetic relays are capable of achieving large deflections from the Off-to-On state, thus, providing enhanced contact-to-contact isolation at high signal frequencies.[1,2] We report on a gold electroplated hybrid microrelay that synergistically integrates the advantages offered by each of the two actuation mechanisms.

The microreply design achieved signal by out-of-plane moving a contact cross-bar fabricated on a diaphragm fixed at both ends to short the isolated input and out put contact lines. This device transition from the "OFF" to "ON" and then to "OFF" state is accomplished using electrostatic and electromagnetic co-actuation mechanisms. Figure 1 illustrates a cross-sectional view of the microrelay in the open position.

The microrelay is fabricated using surface micromachining technique, and all structures are built by through photoresist masks electroplated gold using a cyanide bath. Electroplated copper is used as the sacrificial material that is easy to be removed. Electroplating technique is used extensively in the fabrication process, which is suitable for thick film (>1 µm) deposition and profoundly lower the fabrication cost. The main process flow is presented in Figure 2.

Step A. A blank <100> P-type silicon wafer is RIC (reactive ion clean) cleaned.

Step B. LPCVD (low pressures chemical vapor deposition) 0.1µm silicon nitride as an insulating layer. An electroplated gold layer maybe added as a ground plane to improve the system insulation.

Step C. Sputter plating seed layers of Ti/Au and electroplate Au to form the lower electrode and contact lines. Remove the plating seed layers by Ion Mill etching.

Step D. Sputter plating seed layers of Ti/Cu and electroplate Cu 12-15 µm thicker than the lower electrode as a sacrificial layer; planerize the Cu layer by chemical mechanical polishing.

Step E. Wet etch holes in the Cu sacrificial layer to form the plating modes for contact cross-bars.

Step F. Gold plate the contact cross-bars through the modes formed in the step E; planerize the contact cross-bars by CMP (chemical mechanical polishing).

Step G. RF sputter an insulating silicon nitride layer and Cr/Au plating seed layers for movable electrode; fabricate the movable electrode and springs by gold electroplating.

Step H. Wet etch plating seed layers and RIE (reactive ion etching) the silicon nitride layer; remove the Cu sacrificial layer in the ammonium persulfate aqueous solution.

The devices are released after this step. After integrating two pieces of magnet into the separated dice, the device is ready to be packaged and tested. An SEM image of a released device is shown in Figure 3.

Testing results show that 95% of the devices can be actuated and approximately 50% of them can pass signal. The average contact resistance is about 170 mOhm. The average electrostatic breakdown voltage is around 170 V and the system isolation is -70 dB at 20 MHz when a gold ground plane was added.

Reference:
1. H. Hosaka, H. Kuwano and K. Yanagisawa, *Sensors and Actuators A*, 40 (1994), pp. 41-47.
2. R. Wood et al., *Mechatronics*, 8 (1998), pp.535-547.

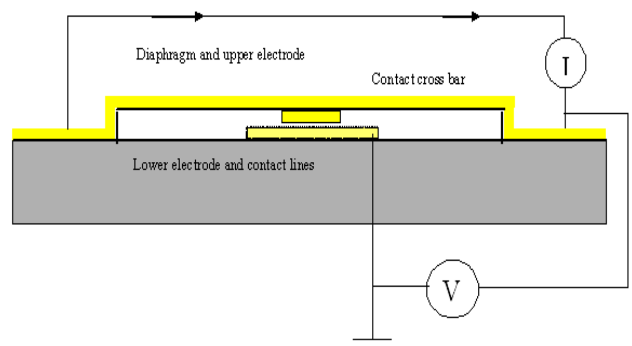

Figure 1. A cross-sectional device view

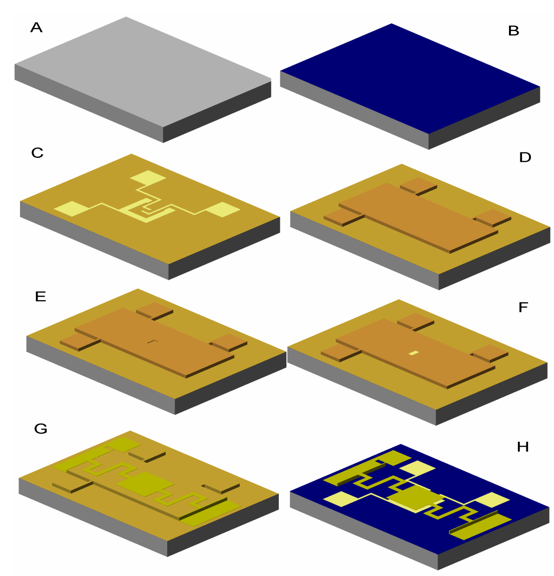

Figure 2. Microrelay fabrication process flow

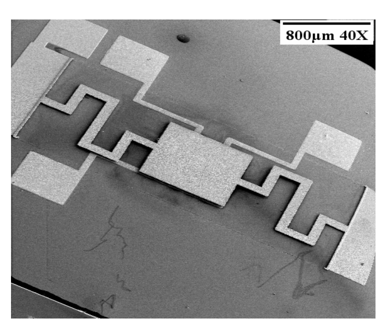

Figure 3. An SEM image of a released microrelay device