MEMS - Micro Electrical Mechanical Systems

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MEMS

Micro Electro Mechanical Systems
Switches

In this case, RF (high frequency) switches with an average length of 200 microns, width of 50 microns, and height of 6 microns.
What are MEMS made of?

- The switch itself is made of gold.
- The dielectric layer is made of silicon nitride.
- The substrate used is LCP (liquid crystal polymer). This was used because it is extremely cheap and very pliable.
MEMS Substrate Requirements

- Smooth surface roughness
  - Roughness < MEMS height
- Flat
  - For good lithography
- Chemical resistance
  - For fabrication
- Temperature compliance
  - For fabrication and operation
- Uniform electrical properties
  - Uniform permittivity for high frequency devices
- CHEAP!
What is LCP?

Chemically:

- 2-Naphthalenecarboxylic Acid, 6-(Acetyloxy)-Polymer with 4-(Acetyloxy) Benzoic Acid
- 1,4-benzenedicarboxylic acid (terephthalic acid), 4-hydroxybenzoic acid, and 4,4`-dihyroxypipheny
What is LCP?

- A thermoplastic polymer made of aligned molecule chains with crystal-like spatial regularity.
- When flowing in liquid crystal state, rigid segments of the molecules align next to one another in the direction of shear flow.
- This structure persists even after cooling below the melting point.
- Roughly 18 microns thick.
What is LCP?

- Commercially available from 25um-3mm thick
- Available bare, single, or double copper cladded
- Cladding is 15-18um thick
- Has been researched since 1980s; used in high frequency applications since 1990s
The picture shows a switch in the up position.

Red Area: Gold
Green Area: Dielectric layer (usually silicon nitride) used to prevent metal-to-metal stiction, to decrease mechanical wear and tear, and to prevent DC contact.
How it works?

If you apply a DC voltage so that both ends of the switch are charged differently you create an electrostatic force. This force causes an attraction between the two areas.
Switch on.

The attractive force causes the switch to close. This allows the RF power to flow through the switch but the dielectric layer does not allow the electricity to flow through.

When the voltage is turned off the switch open back up. Without the dielectric layer the DC current would flow through the switch causing it to stick closed permanently. It would be a one time switch.
Advantages

- Advantages of using MEMS switches over solid state switches (i.e. PIN diodes, JFET):
  - Can be designed for any frequency (Other only good up to a few GHz)
  - Can be fabricated on wafer (Other require soldering)
  - Much less power loss
  - Excellent RF isolation
Disadvantages

- Relatively new technology (10 years old versus 50 years old)
- More complicated
- Packaging is large and expensive
- Slow switch time (microseconds instead of nanoseconds)
- Reliability (best switches reported only good for 100B cycles)
Problems

- The probes used for the input of the DC voltage have a low resistance for the RF power. The RF power flows into the probes not where you want it.
- This causes the data collected from the switch to be wrong.
- To solve the problem switches without dielectric layers were created.
Why do this?

- Without the dielectric layer the switch will come on and not be able to open back up.
- Normally this would be bad but because the DC probes are creating a problem this would allow for them to be removed so that measurements could be taken accurately.
- Unfortunately this did not work as effectively as hoped.
- Next new switches were made and tested using normal scenarios.
- The dielectric layer becomes charged over time and begins to hold the switch down even when the DC power is off. Using the property allows for the results to be taken after the layer has become charged.
My contributions

- I helped complete performance evaluations of MEMS switches.
- I helped to set up the equipment and run simulations.
- Unfortunately because of the clean room restrictions I was unable to help in fabrication.
- My current mentor, Nickolas is working on the MEMS switches in phase shifters.
Simulation

http://www.uk.comsol.com/showroom/animations/
Storage

All of the research material is stored in the container which is filled with Nitrogen.
Setting up the equipment.
Here is the switch that I tested.
What are MEMS switches for?

**Coplanar Wave Guide Pads**: Used to apply the input RF signal and to collect the output RF signal.

**Radial Stubs**: Used to apply DC voltage for MEMS switch actuation. Also prevents RF power from leaking into the DC voltage source.

**MEMS Switches**: When no DC voltage is applied to the Radial Stubs, the switches remain in the OFF state. When a DC voltage is applied, the switches actuate or turn ON.
How does a phase shifter work?

- **Signal Path**: The RF signal will either propagate through the top path or bottom path, depending on which set of MEMS switches are actuated (turned ON). Since the top path is longer than the bottom path, the signal takes longer to propagate through the top path than the bottom path. Therefore, a phase shift is implemented.

- **Example**: For a 1 GHz signal (period, \( T \), 1ns), it takes 125ps for the signal to propagate through the bottom path (shown in red) and 250ps for the signal to propagate through the top path (shown in blue). Therefore, we can calculate the phase difference as:

So this would be a 45 degree phase shifter.
Where and how will it be used?

- The overall goal is to create a weather device that will be placed in space.
- The goal of this project is to develop dual-frequency (14/35 GHz), dual-polarization radar and radiometers to monitor precipitation patterns to improve our scientific understanding of the Earth’s environmental system and investigate its response to natural and man-made changes. The common requirement in such systems is the need for low-cost, low-mass, deployable antennas with large surface area that can be rolled-up or folded for launch and then deployed in space. To overcome the drawbacks of current solutions (parabolic reflectors, reflectarrays) for such applications, a liquid crystal polymer based microstrip antenna array is proposed and its feasibility for integration of different microwave components to realize scannable arrays is investigated.
MEMS Switch Zoomed Out
SEM Photo of single supported MEMS Switch
SEM Photo of double supported MEMS Switch
Two MEMS switches in parallel at a T-junction
Special Thanks

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