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Electrostatic Liquid-Metal Capacitive Shunt MEMS Switch

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1. Motivation

Major challenges of conventional RF MEMS switches:

1. High current density limits power handling

2. Roughness limits reliability and performance

250-nm thick Au virgin contact

After 10³ cycles at 200 μ N contact force

Plastic deformation

After 10⁶ cycles at 200 μ N contact force

Material transfer
N. McGruer, MEMS 2006

Proposed solution:

1. Lower current density

2. Limited damage and better conformity

Overall objective:

Using liquid to achieve:

- higher power handling
- better reliability
- potential for combined switching & cooling

2. Design Idea

4. Complete Device

3. Droplet Movement

Challenge:

Overcome surface tension (hysteresis force)

F : external force
F_s : hysteresis force
γ_{lv} : surface tension
R : droplet radius

$$F_s = 2\gamma_{lv} R \sin\left(\frac{\theta_{adv} + \theta_{rec}}{2}\right) (\cos\theta_{rec} - \cos\theta_{adv})$$

Solution:

Surface treatment with a thin Teflon layer (reduces hysteresis force)

5. RF Performance

Insertion loss:

<0.05 dB at 2-20 GHz (deembedded CPW)

Mainly caused by the CPW itself

Isolation:

>20 dB at 20 GHz

3000-Å SiO₂ layer shows 4 pF shunt capacitance