Tunable Inductors and Transformers Utilizing Electro-Thermal Vibromotors

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Design of tunable solenoid microinductors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic path length along the core</td>
<td>9310 μm</td>
</tr>
<tr>
<td>Magnetic path length in the armature</td>
<td>490 μm</td>
</tr>
<tr>
<td>Air gap between core and armature</td>
<td>20 μm</td>
</tr>
<tr>
<td>Maximum displacement of the armature</td>
<td>500 μm</td>
</tr>
<tr>
<td>Cross-sectional area of the core</td>
<td>1800 μm²</td>
</tr>
<tr>
<td>Cross-sectional area of the armature</td>
<td>1800 μm²</td>
</tr>
<tr>
<td>Number of coil turns</td>
<td>74</td>
</tr>
<tr>
<td>Designed minimum inductance</td>
<td>24.69 nH</td>
</tr>
<tr>
<td>Designed tuning ratio</td>
<td>15.57:1</td>
</tr>
</tbody>
</table>
Design of electro-thermal vibromotor

- Electro-thermal actuators are 400μm long and 8μm thick, which can be driven by 1 volt for 2μm deflection.
- Travel distance of the slider is 300μm.
- Dimples are made under the vibromotor to prevent sticking to the substrate.
- Flange guides are built to prevent the out-of-plane motion of the slider.
- 10μmx10μm release holes are patterned on the armature.

Fabrication of tunable inductors and transformers (I)

- Electroplated Copper – Inductor Coil
- Electroplated Permalloy – Magnetic Core, Vibromotor
- Polyimide – Insulator
- Aluminum – Sacrificial layer
- Photore sist – Electroplating mould

(a) Lower coil → Anchor of electro-thermal actuator
(b) Insulator → Dimple holes
(c) PR mould → Permalloy core → Slider → Electro-thermal actuator → Slider
Fabrication of tunable inductors and transformers (II)

Fabricated Devices

Tunable solenoid microinductor

Tunable solenoid microtransformer

Permalloy core and copper coil

Armature

Flange guide

Impact element and slider
Testing results of tunable inductor

- Maximum tuning ratio is 18:1 at 10kHz.
- Self-resonant frequency is approximately 7.5MHz.

δ is defined as the displacement of the armature divided by its limit. δ=0 is the origin of the displacement of the armature. δ=1 means the armature’s closest position to the magnetic core.

Summary

- Tunable inductors have been designed, fabricated, and characterized.
- Dynamics of vibromotors have been modeled. Fabricated vibromotors are under characterization.
- Fabricated tunable transformers are being characterized.
- Potential applications of fabricated devices are performance optimization and functionality enhancement to RF circuitry, magnetic microsensors, and micromagnetic power devices, such as dc/dc converters.

Future work

Using different materials or tuning schemes for higher frequency applications.