A split-resonator integrated-post vibratory microgyroscope may be fabricated using micro electrical mechanical systems (MEMS) fabrication techniques. The microgyroscope may include two gyroscope sections bonded together, each gyroscope section including resonator petals, electrodes, and an integrated half post. The half posts are aligned and bonded to act as a single post.

15 Claims, 6 Drawing Sheets
A vibratory microgyroscope may include an upper gyroscope section bonded to a lower gyroscope section. Each gyroscope section may include resonator petals, electrodes, and an integrated half post. The half posts are aligned and bonded to act as a single post.

The gyroscopes may have symmetrical designs, each include three resonator petals alternating with three electrode sections. The electrodes sections may include drive and sense electrodes for driving and sensing rocking modes, respectively. Each gyroscopic section may include a hub connected to an outer ring by spring members. The hub may support the resonator petals and the integrated half post.

The vibratory microgyroscopes may be microelectromechanical systems (MEMS) devices fabricated from silicon-on-insulator (SOI) wafers using semiconductor processing techniques.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a perspective sectional view of a vibratory microgyroscope.
Typical microgyroscopes require a post (metal or silicon) to be inserted and bonded individually. With the split resonator design, an individual post insertion step is not required, which may facilitate mass-production of the microgyroscopes. The two integrated half posts align to serve as a single post. Both halves of the post are supported by the resonator springs across the midline of the respective gyroscope section, and thus no separate supports are necessary.

The upper and lower gyroscope sections may be fabricated from silicon-on-insulator (SOI) wafers, e.g., with a 500 micron bulk silicon substrate and a 10 micron silicon oxide membrane, as shown in FIGS. 4A and 4B. The cloverleaf design of the petals may be etched into the top silicon layer of the SOI wafer using precision etching techniques, as shown in FIGS. 5A and 5B. In similar SOI cloverleaf microgyro designs, etching equipment from Surface Technology Systems plc (STS) of Newport, UK has been used for the precision etching.

Electrodes may then be deposited and patterned on the insulator membrane in the electrode sections, as shown in FIGS. 6A and 6B. The electrode sections may be, e.g., thin film Cr/Au electrodes deposited by thermal evaporation of chromium and gold. Thin film metal layers may also be deposited at feed-through sites and eutectic bonding sites during the thermal evaporation process. The bulk silicon substrate may then be etched to form a frame including the electrode sections and the half post for that section, as shown in FIGS. 7A and 7B. Portions of the oxide membrane may then be etched to free the resonator petals, as shown in FIGS. 8A and 8B.

The gyroscope may be assembled by eutectic-bonding the upper and lower gyroscope sections at the eutectic bonding sites and wire-bonding the feed-throughs to the electrodes, as shown in FIG. 9.

As described above, the split design of the split-resonator integrated-post MEMS gyroscope may facilitate mass-production of the microgyroscope. Since an individual post insertion step is unnecessary, the processing steps and time may be independent of the number of devices being produced. Consequently, an entire wafer full of devices may be processed simultaneously.

In alternative embodiments, the resonator section may include different numbers and arrangements of petals and electrodes. The electrode sections may include more than one electrode. Different electrodes on each or different electrode sections may be used for driving and sensing rocking modes.

A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. An apparatus comprising:
   an upper gyroscope section including
   a resonator section including a plurality of resonator petals and a half post section, and
   a base section including a plurality of electrode sections, each electrode section including one or more electrodes; and
   a lower gyroscope section, the lower gyroscope section including
   a resonator section including a plurality of resonator petals and an integrated half post section, the half post section being aligned with the half post section in the upper gyroscope section, and
   a base section including a plurality of electrode sections, each electrode section including one or more electrodes.

2. The apparatus of claim 1, wherein each resonator petal in the upper gyroscope section is aligned with an electrode section in the lower gyroscope section, and
   wherein each resonator petal in the lower gyroscope section is aligned with an electrode section in the upper gyroscope section.

3. The apparatus of claim 2, wherein the aligned resonator petals and electrode sections are separated by a distance approximately equal to the thickness of a resonator section.

4. The apparatus of claim 1, wherein the upper gyroscope section is bonded to the lower gyroscope section.

5. The apparatus of claim 1, wherein the apparatus comprises a micro electrical mechanical systems (MEMS) device.

6. The apparatus of claim 1, wherein each of the upper and lower gyroscope sections include three resonator petals and three electrode sections.

7. The apparatus of claim 1, wherein the upper and lower gyroscope sections include drive electrodes and sense electrodes.

8. The apparatus of claim 1, wherein each resonator section includes:
   an outer ring;
   a hub supporting the integrated half post and the resonator petals; and
   a plurality of spring members connecting the hub to the outer ring.

9. A method comprising:
   etching a pattern defining alternating resonator petals and electrode sections into a top silicon layer of a first silicon-on-insulator wafer section;
   etching a pattern defining alternating resonator petals and electrode sections into a top silicon layer of a second silicon-on-insulator wafer section;
   forming electrodes on the electrode sections of the first and second wafer sections;
   etching a bulk silicon section of the first wafer section to form a frame and an integrated half post;
   etching a bulk silicon section of the second wafer section to form a frame and an integrated half post;
   bonding the first and second wafer sections such that the half posts are aligned and bonded to form a split-post microgyroscope.

10. The method of claim 9, further comprising:
   etching the insulator in the first wafer section to release the resonator petals; and
   etching the insulator in the second wafer section to release the resonator petals.

11. A vibratory microgyroscope comprising:
   an upper gyroscope section including
   a resonator section including an outer ring,
   a hub connected to the outer ring by spring members,
   a plurality of resonator petals connected to the hub, and
   an integrated half post connected to the hub,
   a base section including a plurality of electrode sections, each electrode section including at least one of a drive electrode and a sense electrode; and
   a lower gyroscope section including
   a resonator section including an outer ring,
   a hub connected to the outer ring by spring members,
   a plurality of resonator petals connected to the hub, and
   an integrated half post connected to the hub,
a base section including a plurality of electrode sections, each electrode section including at least one of a drive electrode and a sense electrode, wherein the lower gyroscope section is bonded to the upper gyroscope section such that the integrated half posts are aligned.

12. The microgyroscope of claim 11, wherein each resonator petal in the upper gyroscope section is aligned with an electrode section in the lower gyroscope section, and wherein each resonator petal in the lower gyroscope section is aligned with an electrode section in the upper gyroscope section.

13. The microgyroscope of claim 12, wherein the aligned resonator petals and electrode sections are separated by a distance approximately equal to a thickness of a resonator section.

14. The microgyroscope of claim 11, wherein the microgyroscope comprises a micro electrical mechanical systems (MEMS) device.

15. The microgyroscope of claim 11, wherein each of the upper and lower gyroscope sections include three resonator petals and three electrode sections.