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PL-2 (Plenary)

MEMS as Key Components for Systems

Masayoshi Esashi

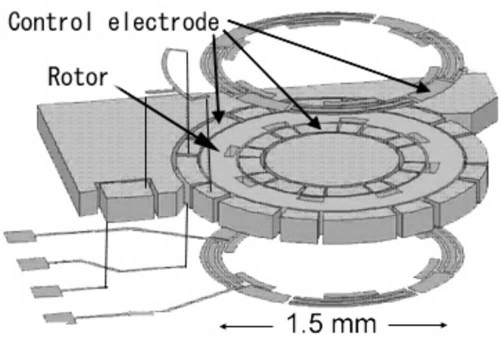
Department of Nanomechanics, Tohoku University
Sendai, 980-8579, Japan
Phone : +81-22-795-6934, Fax : +81-22-795-6935, E-mail : esashi@cc.mech.tohoku.ac.jp

1. Introduction

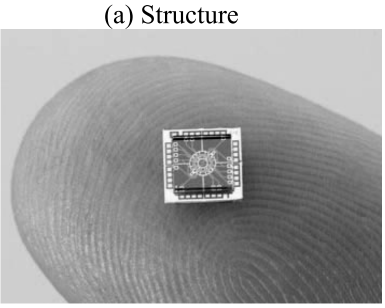
Micromachining is an extended IC fabrication based on deep etching, anodic bonding and other advanced process technologies. This is used to produce MEMS (Micro Electro Mechanical Systems) featuring multi-functions, small size and low cost. MEMS are used as value added key components in systems. Examples of application oriented MEMS developed with attention to packaging and circuit integration will be described below.

2. Electrostatically Levitated Rotational Gyroscope

Silicon rotational gyroscope has been developed for the purpose of motion control and navigation [1]. The principle and the photograph are shown in Fig.1. A 1.5 mm diameter silicon ring which is electrostatically levitated by digital control using capacitive position sensing and electrostatic actuation is rotated at 75,000 rpm. The rotation is based on the principle of a variable capacitance motor. A 5μm radial gap between the ring rotor and stator electrodes is formed using deep RIE (Reactive Ion Etching) of a silicon wafer. The silicon is anodically bonded on both sides to glasses which have electrodes. The chip is packaged in a vacuum cavity to prevent a viscous dumping. This inertia measurement system can measure two axes rotation and three axes acceleration simultaneously with high precision (sensitivity 0.01 deg/s and 0.2mG respectively).



(a) Structure

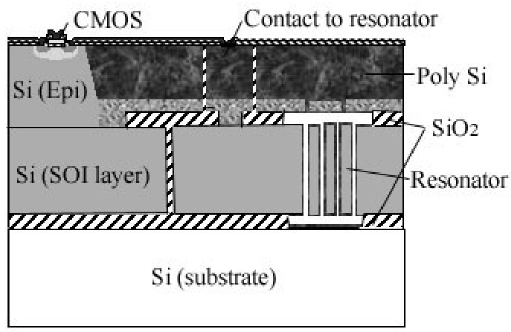


(b) Photograph

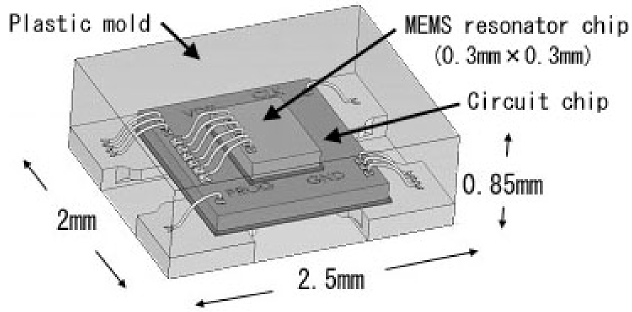
Fig.1 Electrostatically levitated rotational gyroscope

3. MEMS Resonator

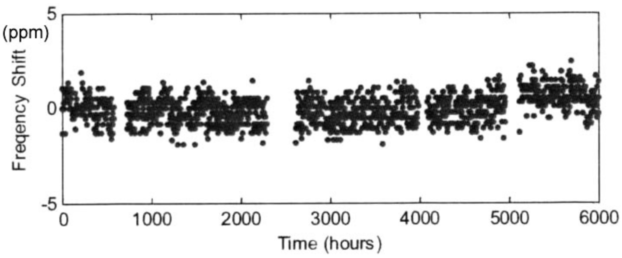
MEMS resonator which is encapsulated in a vacuum chamber inside a wafer has been developed for frequency reference. This achieves smaller size and lower cost than conventional quartz crystal oscillators [2]. The structure is shown in Fig.2(a). The circuit can be integrated with the MEMS resonator but at present circuit chip is stacked with the resonator chip for temperature compensation and PLL and molded into standard plastic packages as shown in Fig.2(b). An example of long term drift measured is shown in Fig.2(c). The long term drift is less than 3ppm because of the negligible adsorption on the resonator.



(a) Structure integrating CMOS for next generation



(b) Plastic mold resonator chip stacked on a circuit chip



(c) Long term drift measured at 30℃ under temperature cycles from -50℃ to 80℃

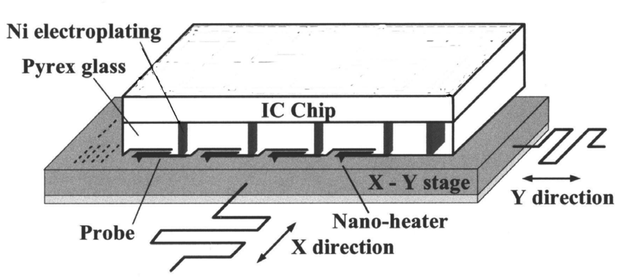
Fig.2 MEMS resonator for frequency references

4. Arrayed MEMS

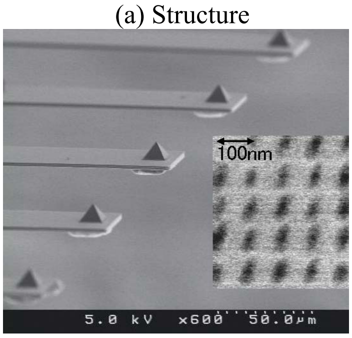
Multi-probe Data Storage

Parallel data recording and reading can be made using a multiprobe data storage system shown in Fig.3(a). Thermal multiprobe data storage systems have been developed [3], however the speed is not fast enough because of the limited thermal response time. To solve this problem electrical recording to a ferroelectric recording media ($LiTaO_3$) using a diamond multiprobe system was developed (Fig.3(b))[4].

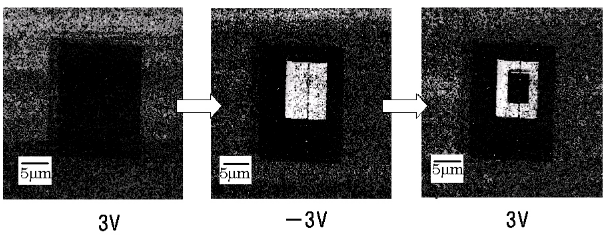
Electrical recording using the microprobe array on a 7nm thick conductive polymer (doped polyaniline) film has been also studied for the multiprobe data storage (Fig.3(c)) [5].



(a) Structure



(b) Diamond tip probe array for ferroelectric recording and recorded data bits on 60nm thick single crystal $LiTaO_3$



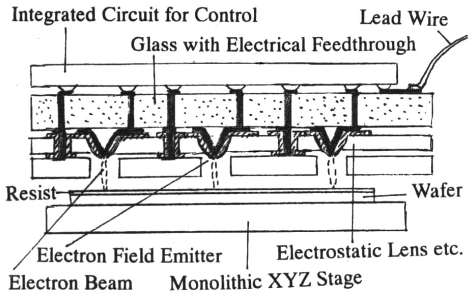
(c) Conductance image of the recorded pattern on a conductive polymer film (white part: conductive) recorded at different substrate voltages

Fig.3 Multi-probe data storage

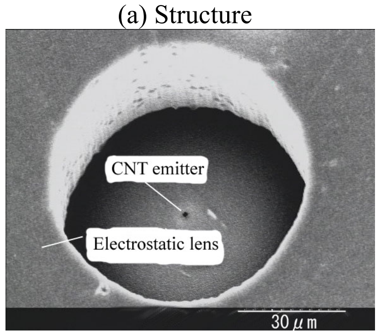
Multi-column Electron Beam Lithography

Electron field emitter array with electrostatic focusing lens has been developed for the purpose of high throughput multi-column electron beam lithography system [6]. The principle and the photograph of the emitter are shown in Fig.4(a)(b) respectively. CNT(Carbon Nano Tube) has been applied to the electron field emitter. The CNT was grown selectively at an apex of catalytic nickel by negatively biasing the substrate in a hot-filament CVD system. Low threshold voltage for electron field emission and small emitter size for fine focusing was achieved owing to the essential feature of the CNT. Hydrogen coverage on the CNT enhanced the field emission and reduced the emission current noise [6].

As shown in Fig.3(a) and Fig.4(a) electrical interconnection from the probe array and the emitter to the control IC chip and stages which has move in X-Y direction to cover the area determined by the pitch are needed. High density electrical feedthrough in glass was developed for this purpose [7]. A monolithic stage which have 6 degrees of motion freedom ($X,Y,Z,\theta,\varphi,\psi$) was fabricated on a PZT (lead zirconium titanate) ceramic plate [8]



(a) Structure



(b) Photograph

Fig.4 Multi-column Electron Beam Lithography

5. Conclusions

Packaging and electrical interconnection are needed for high reliability and arrayed MEMS respectively. Materials such as conductive polymer and carbon nanotube could be used effectively for MEMS.

References

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