MICROFABRICATED DEVICES FOR HIGH PRECISION SENSING AND RF-APPLICATIONS

MICROSYSTEMS AND ATOM OPTICS GROUP

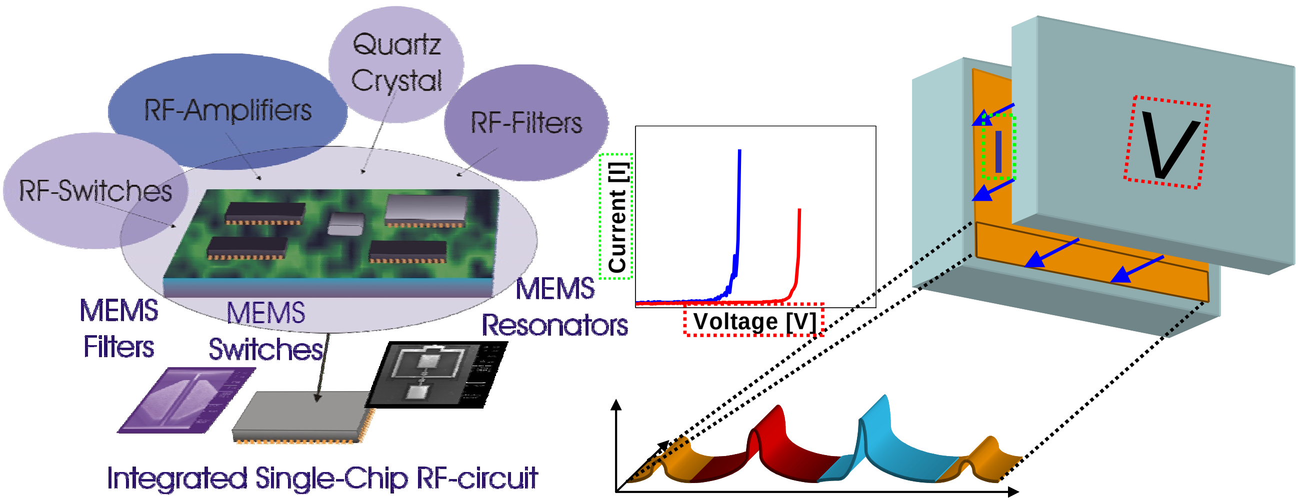
OPTICS AND MOLECULAR MATERIALS LABORATORY

High mechanical quality (Q-factor) of the resonance is desired in many high precision sensing applications. High-Q oscillators can be utilized e.g. in realizing sensors for weak forces, acceleration, pressure etc. More applications can be found in detection of gravitational waves and radiation pressure [2,3], in atomic force microscopes and even in sophisticated experiments for observing quantum effects.

Another approach in the utilization of resonant microfabricated structures is in the field of RF-applications. The research concentrates on the design, fabrication and characterization of micromechanical devices that can be used as building-blocks for novel radio-architectures. These blocks include for example mixers, filters and oscillators (Fig. 1 a). The fundamental idea is to apply the fabrication methods developed in the semiconductor IC-industry in the fabrication of mechanical microsized components. [9].

Recent results

We have constructed a very sensitive optomechanical sensor to detect the vibration of a high-Q mechanical oscillator [4]. An HR-coated silicon oscillator is employed as a planar rear mirror in an actively stabilized Fabry-Perot interferometer. At present the minimum detectable displacement in the oscillator position is ca. 10 fm which corresponds to the force of 5 fN acting on the oscillator at its resonance frequency.

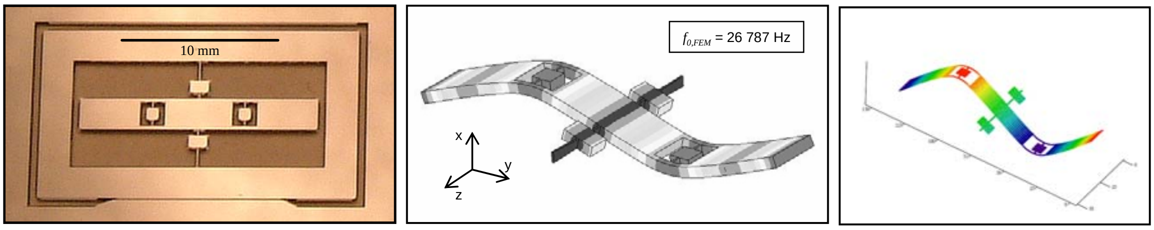


a) b)

Fig. 1 : a) Artist's view of a radio-on-a-chip concept. b) Recent research has concentrated also on the fundamental stability issues, namely the charge transport phenomena taking place before the electro-static breakdown in microscopic capacitive coupling gaps with rough electrode surfaces [6].

In addition, we have designed, fabricated and characterized a high-Q oscillator structure vibrating effectively in a non-tilting out-of-plane mode [1] (Fig 2.). This allows measurement schemes that require strictly parallel surfaces to very small distances, e.g. when studying Casimir force of two conducting plates. Due to the non-tilting vibrational behaviour, oscillators are especially suitable as moving mirrors in interferometric systems.

The development in the field of sensing has also produced an ultra-sensitive photoacoustic gas-sensor. Our contribution to the success of this sensor has been in improving the sensitivity of the sensor by enhancing the design and fabrication of the dynamic mechanical parts of the sensor.
The single most important result in RF-applications has been the creation of a micromechanical oscillator with custom IC-electronics. This oscillator consists of a silicon fabricated resonator chip, wire-bonded to a separate chip containing the sustaining and buffer amplifier electronics. The phase-noise of this 13 MHz oscillator was measured to be better than -120 dBc/Hz with noise-floor -144 dBc/Hz on a power consumption of 240 µW [5,7]. Also the stability issues of micromechanical devices has been under research. This includes the studies on long-term stability of resonators [8] as well as studies about the charge transfer phenomena taking place in capacitive coupling gaps [6].



a) b) c)

Fig. 2 : a) Photograph of the non-tilting out-of-plane mode high-Q oscillator. b) FEM-simulation result of the high-Q resonance mode. c) The actual measured mode pattern.

Recent publications:

1. O. Hahtela, N. Chekurov and I. Tittonen: Non-tilting out-of-plane mode high-Q mechanical silicon oscillator, J. Micromech. Microeng. **15** (2005).
2. O. Hahtela and I. Tittonen: Optical actuation of a macroscopic mechanical oscillator, Appl. Phys. B **81** (2005).
3. O. Hahtela: Optical actuation of a micromechanical oscillator, Licentiate´s Thesis, HUT 2004
4. O. Hahtela, K. Nera and I. Tittonen: Position measurement of a cavity mirror using polarization spectroscopy, J. Opt. A: Pure Appl. Opt. **6** (2004).
5. P. Rantakari, V. Kaajakari, T. Mattila, J. Kiihamäki, A. Oja, I. Tittonen and H. Seppä: Low noise, low power micromechanical oscillator, Digest of Technical Papers, Transducers ’05 (2005).
6. N. Chekurov : Pre-breakdown processes in capacitive Microsystems, M. Sc Thesis (2005)
7. P. Rantakari : Mikromekaaninen oskillaattori, Diplomityö (2005)
8. M, Koskenvuori, T. Mattila, A. Häärä, J. Kiihamäki, A. Oja, H. Seppä and I. Tittonen: Long-term stability of single-crystal silicon microresonators, Sensors and Actuators A: Physical **115** (2004).

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