Atomic Layer Deposition (ALD) Enabled RF MEMS Resonator by IC-Compatible Process

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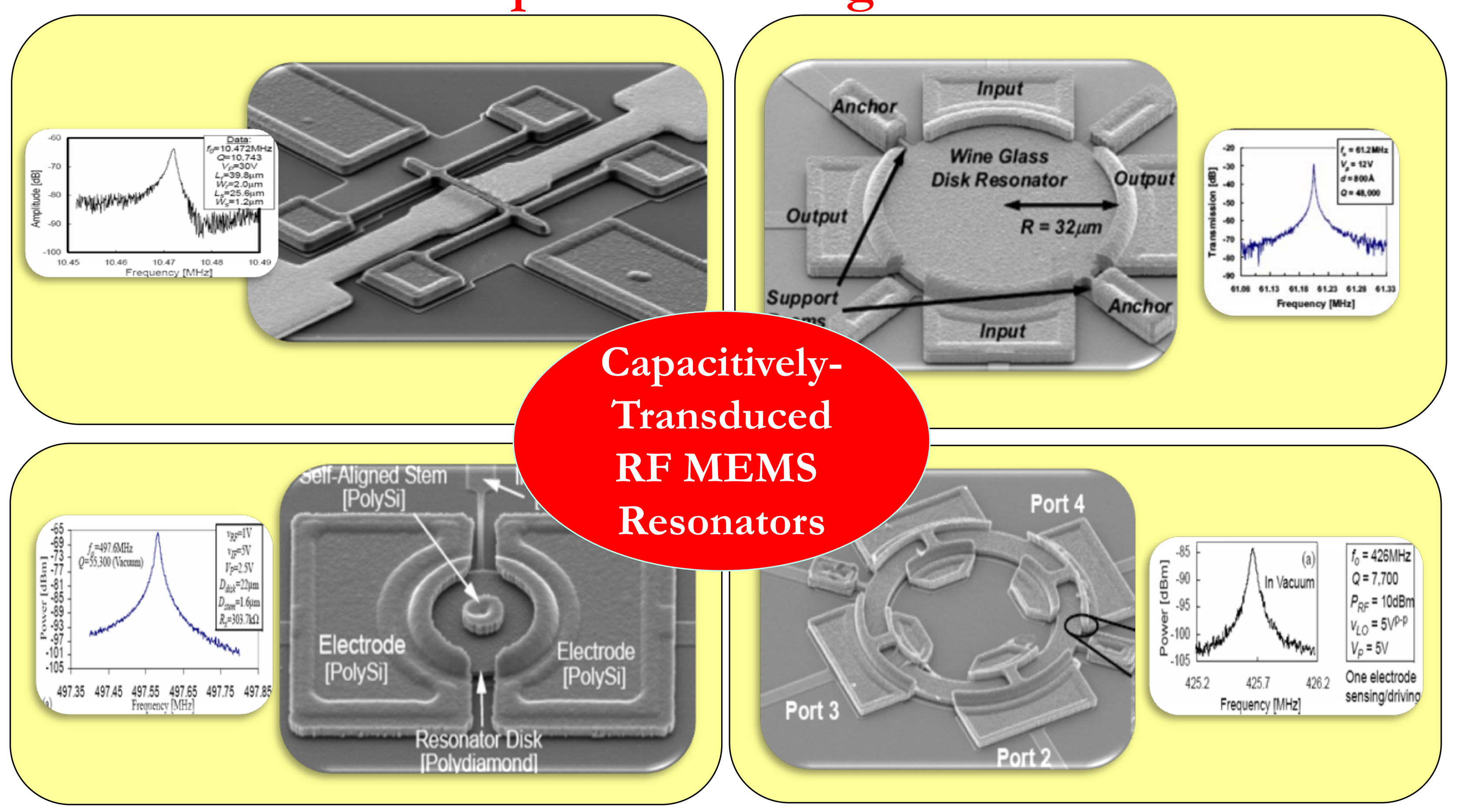
Introduction

Capacitively-transduced MEMS resonators

- ✓ Higher Q-factor (Q >160,000)
- ✓ High frequency (f > 6GHz)
- ✓ Radius controlled frequency
- ✓ Low temperature coefficient
- × High impedance
- × Low power handling



Motivation

In spite to high-Q, concerns about ***impedance matching*** and ***power handling*** of the micromechanical resonator reveal due to its orders of magnitude smaller dimensions comparing to its bulky counterparts, such as quartz crystals.

Impedance Matching

- ✓Reduced resonator-to-electrodes gap
- ✓High dielectric material
- ✓Increased overlap area

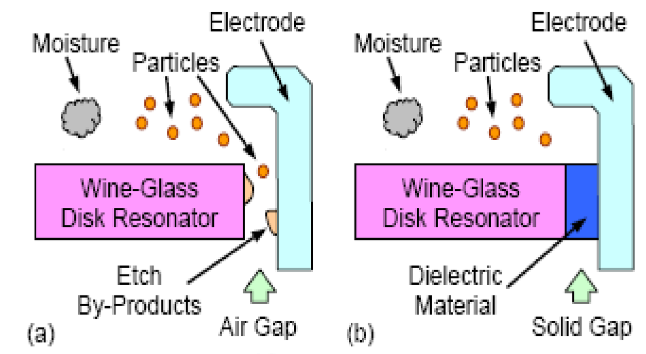
Power handling

- ✓Large arrays of identical devices

Impedance Matching Design

ALD Solid Gap vs. Air Gap

- ➤Ease of the process
- ➤Eliminate the particles
- ➤Reduce characteristic impedance

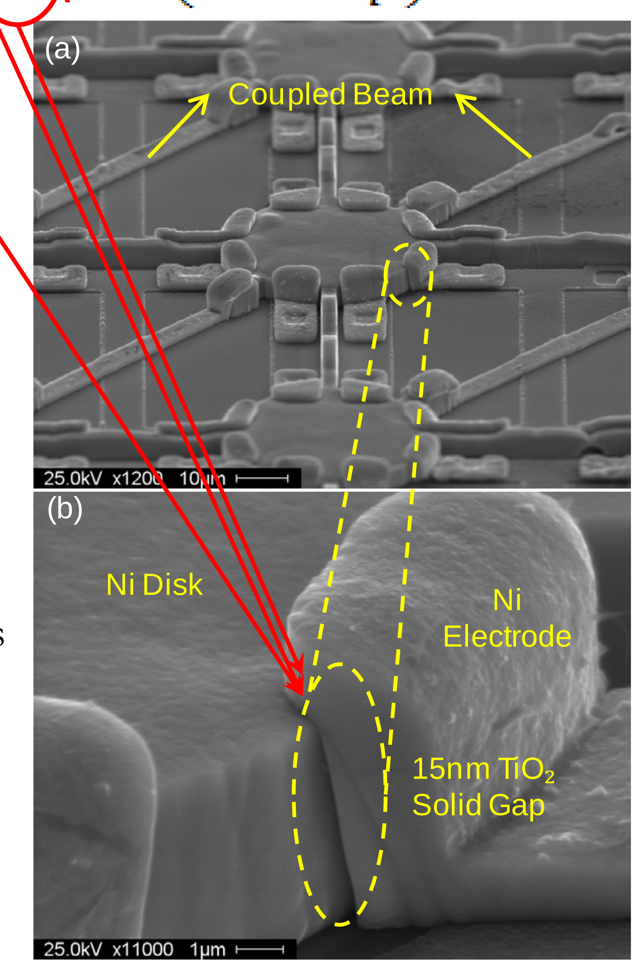


$$\downarrow R_{x(Air\ Gap)} = \frac{v_i}{i_o} \cong \frac{k_r}{\omega_o V_p^2} \cdot \frac{\downarrow d_o^4}{\uparrow \varepsilon_r^2 \varepsilon_o^2 A_o^2 \uparrow} \cdot \frac{1}{Q_{(Air\ Gap)}}$$

d_o: disk-to-electrode gap

ε_r: dielectric constant of the gap material

A_o: overlap area



Savannah 100 ALD

Cambridge Nanotech Inc.

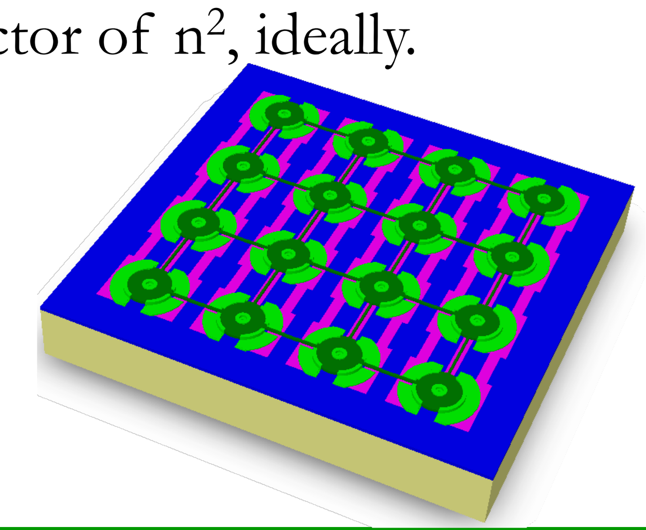
Adventages of ALD

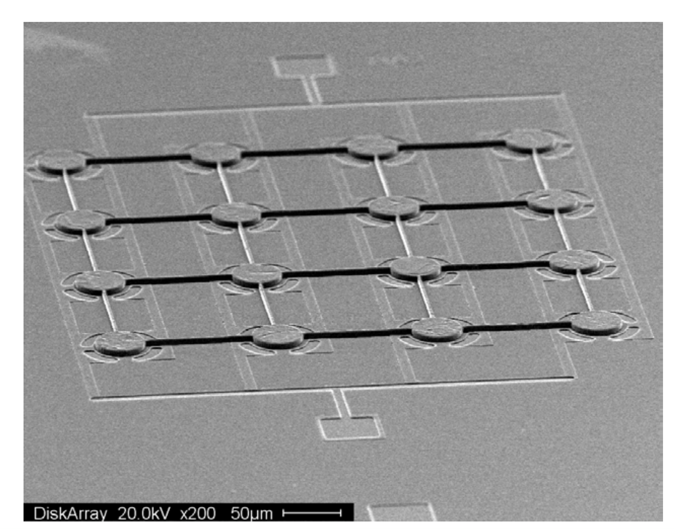
- ➤Ultra Thin (~nm)
- ➤High-k Dielectric Material
- ➤Atomically Controlled Thickness
- ➤Low Temperature (~100 °C)
- ➤Conformal and Uniform

High Power Handling Design

$$P_{0\max,n} = n \cdot \frac{\omega_0}{Q_n} k_r a^2 d_0^2 \quad \text{(n: number of resonators)}$$

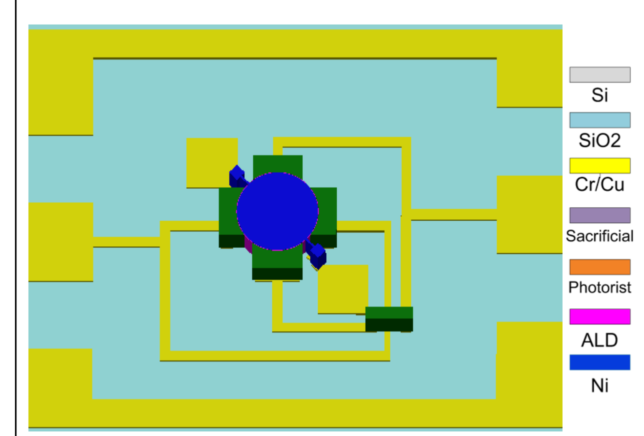
A n×n array has capability of increase the power handling by a factor of n^2, ideally.



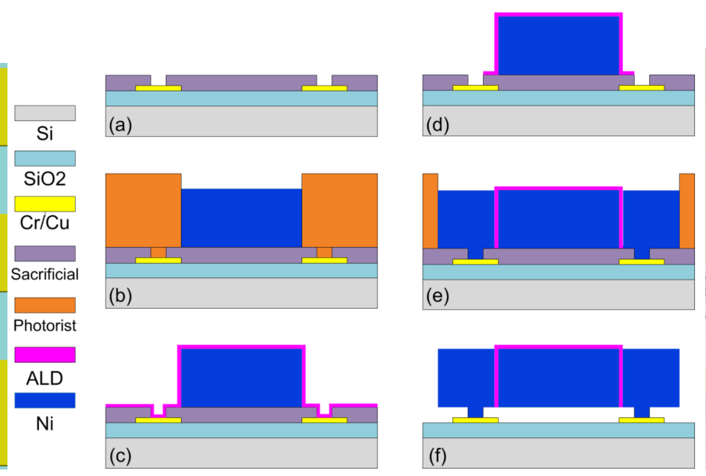


Fabrication

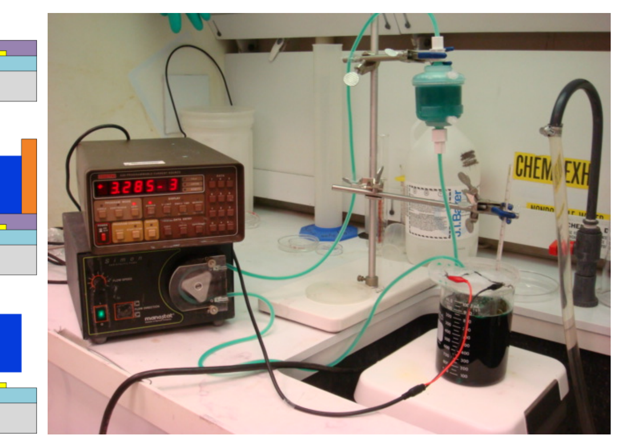
3D Schematic View



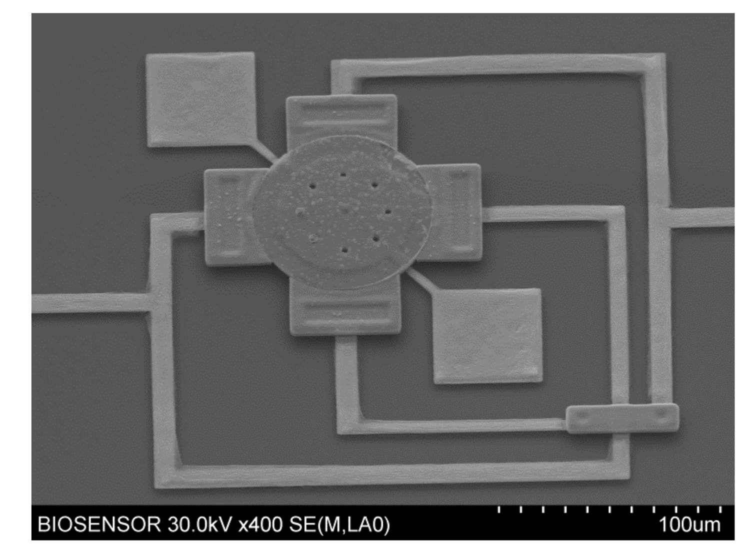
Process Flow



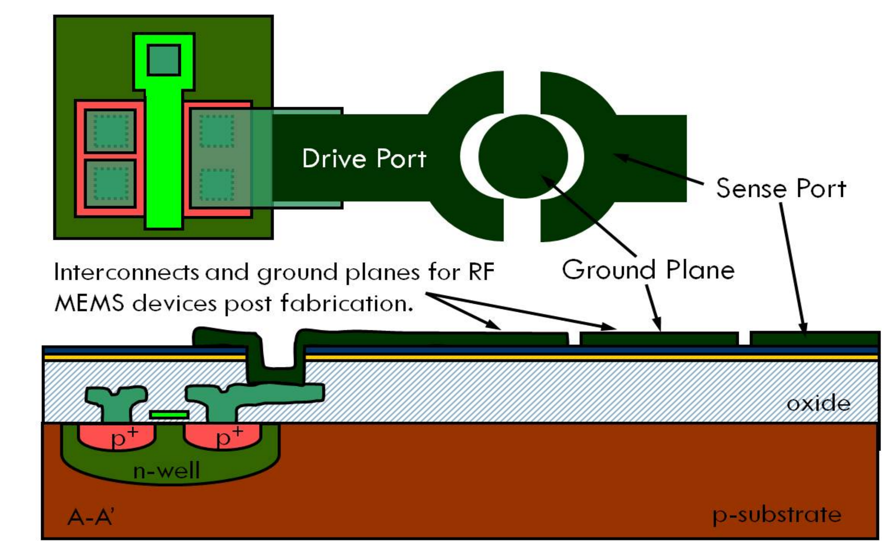
Ni Electroplating Set-up



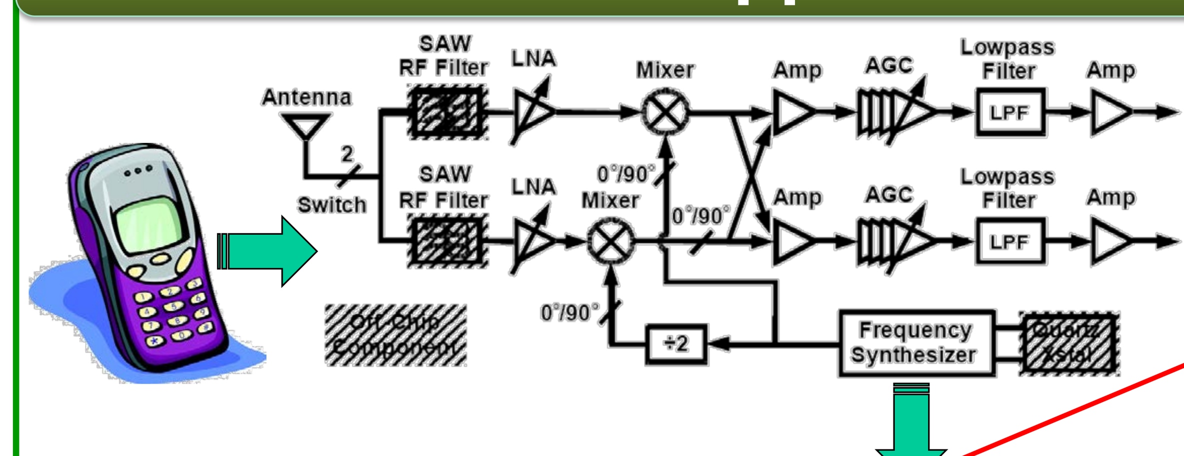
SEM Photo of a Fabricated Device

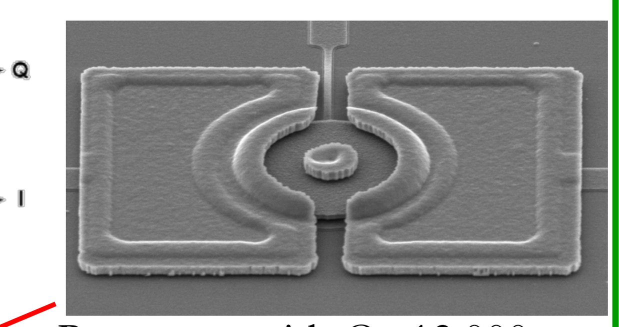


Post-CMOS of Integration

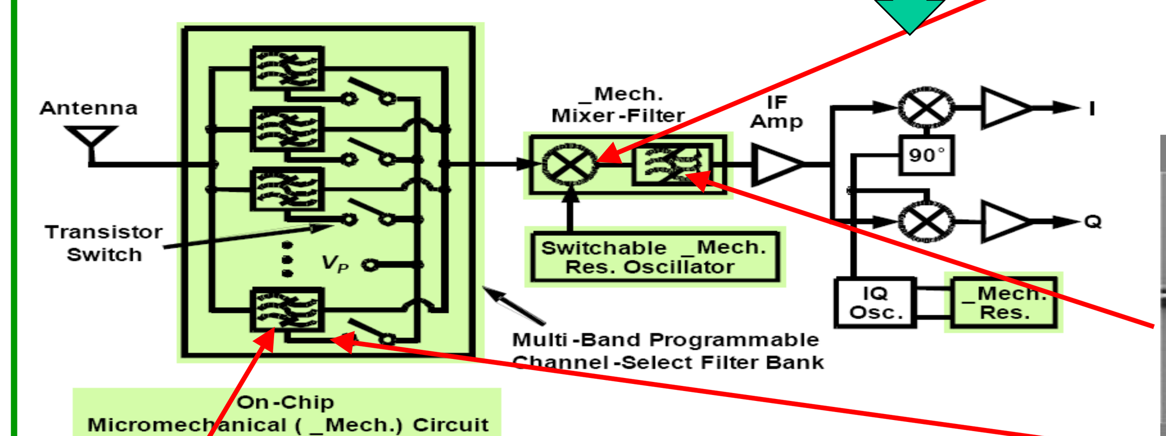


Applications

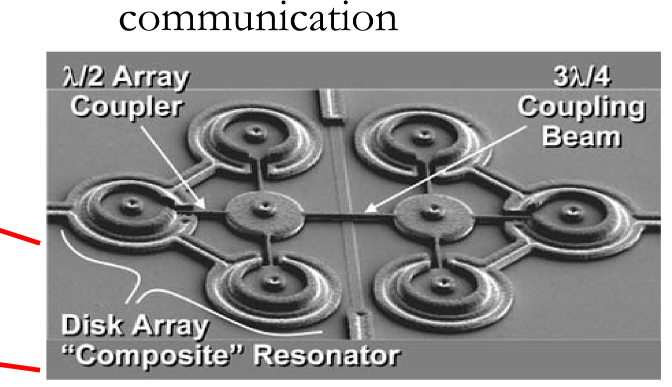




Resonator with Q≈12,000 at 1.5GHz allows ultra low phase noise for oscillator in RF communication



Switchable Channel-Selected Bandpass Filters



Two 4-disk array resonators coupled to realize a 2-resonator filter with an array-reduced impedance.