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 ($f > 6$GHz)  
- 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 Design**  
**ALD Solid Gap vs. Air Gap**  
- Ease of the process  
- Eliminate the particles  
- Reduce characteristic impedance

$$R_x(\text{Air Gap}) = \frac{v_i}{i_o} = \frac{k_f}{\omega_0 V_p^2} e^{\varepsilon_\varepsilon_r d_2 A_2} Q(\text{Air Gap})$$

- $d_2$: disk-to-electrode gap  
- $\varepsilon_r$: dielectric constant of the gap material  
- $A_2$: overlap area

**Advantages of ALD**  
- Ultra Thin (~nm)  
- High-$k$ Dielectric Material  
- Atomically Controlled Thickness  
- Low Temperature (~100 ºC)  
- Conformal and Uniform

**High Power Handling Design**  
$$P_{\text{max},A} = n \frac{\varepsilon_0}{Q_0} k_s \alpha^2 d_0^2$$  
($n$: number of resonators)  
A $n \times n$ 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

**Applications**

- Capacitively-transduced MEMS resonators  
  - Higher Q-factor ($Q > 160,000$)  
  - High frequency ($f > 6$GHz)  
  - Radius controlled frequency  
  - Low temperature coefficient  
  × High impedance  
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- Resonator with $Q=12,000$ at 1.5GHz allows ultra low phase noise for oscillator in RF communication

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