

GEOMETRICAL SCALING EFFECTS IN HIGH PERMITTIVITY CAPACITORS

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One of the advantages of high permittivity thin films such as barium strontium titanate (BST) and bismuth zinc niobate (BZN) is the ability to make small capacitors. The benefits of small device size arise from smaller circuit designs and conservation of substrate area. Unfortunately, in small area devices we have observed electrical properties that scale as a function of device geometry. In our work we have found that geometric scaling factors result in small devices having lower Q values at low frequencies (Figure 1) while larger devices have lower Q at high frequencies (Figure 2) where series resistances dominate.

A parallel conduction path over the surface of a film is one example of a process that can result in a capacitor's Q factor scaling as a function of periphery over area. Equation 1 is an expression for the resulting Q, where c_d is the film's capacitance density, A is the electrode area, g_d is the film's conductance, P is the electrode perimeter, g_p is the conductance associated with the surface conduction, and δ is the small thickness through which the conduction takes place.

$$Q = \frac{\omega c_d A}{g_d A + g_p \delta P} = \frac{\omega c_d}{A} \frac{1}{1 + \frac{g_p \delta}{g_d} \frac{P}{A}} \quad (1)$$

An example of this behavior is shown in Figure 3, where 1 MHz Q values in a BST film are shown to be a function device periphery to area ratio. The results of the data fit yield $g_d = 10^3 (\Omega\text{m}^2)^{-1}$ and a sheet resistivity of $4 \times 10^7 \Omega/\text{square}$ for the film surface.

In this work we investigate the relationship between device geometry and device capacitance density, Q, and leakage current density. The devices in this study have electrode areas ranging from $12 \times 12 \mu\text{m}^2$ to $45 \times 45 \mu\text{m}^2$. For each electrode area we have structures with $5 \mu\text{m}$, $7.5 \mu\text{m}$, $10 \mu\text{m}$, $12.5 \mu\text{m}$ and $15 \mu\text{m}$ mesa ledges.

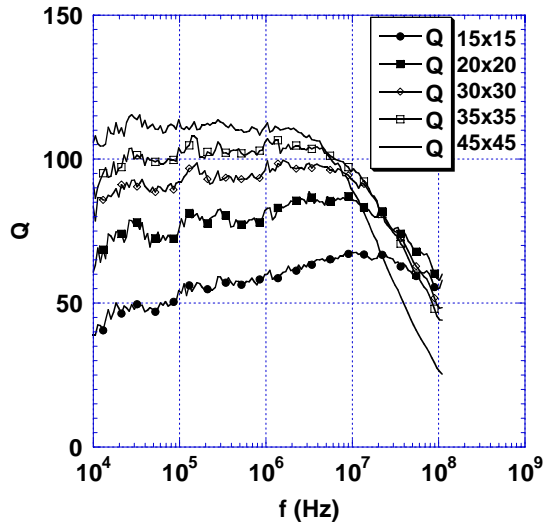


Figure 1. Q vs. frequency at low frequencies where smaller device areas have lower Q values (BST). Device areas are in μm^2 .

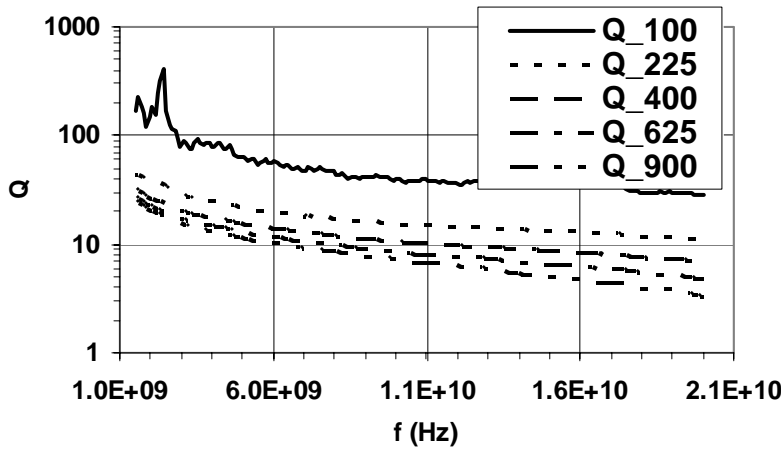


Figure 2. Q vs. frequency at high frequencies where larger devices have lower Q values (BZN). Device areas are in μm^2 .

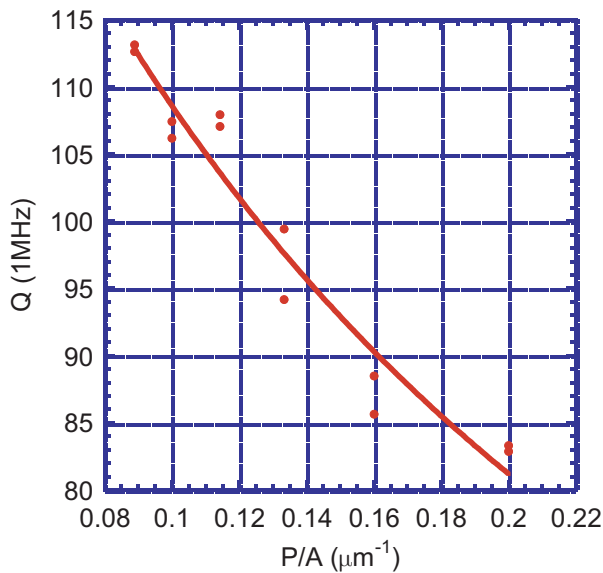


Figure 3. Q as a function of ratio of electrode perimeter to area (BST). Solid line is data fit to equation 1.