High performance MIM capacitors with nanomodulated electrode and dielectric surfaces

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The development of MIM capacitors has attracted a great deal of attention in recent years due to their use in analog, mixed signal and radiofrequency (RF) circuit applications. The need for more compact circuits has created a need for the engineering of high capacitance density capacitors since they, along with other passives, take up most of the silicon die space in such applications. High-k materials have therefore been investigated in order to meet the requirements posed by the practical applications [1]. According to ITRS (international roadmap for semiconductors), there are four main requirements for MIM capacitors: a capacitance density larger than 10fF/μm^2, a leakage current less than 10^{-8}A/cm^2, a non-linearity factor less than 100ppm/V^2 and process temperatures that do not exceed 300 to 400^{o}C, as these are back-end devices. Almost all reports in the literature fail to meet all of the above requirements.

We demonstrated that anodic alumina is an interesting choice as the dielectric material of MIM capacitors [2, 3]. Its advantages include high performance and an easy and cost effective fabrication of the capacitors at room temperature. Low leakage current, as well as high capacitance densities with good stability in terms of frequency were demonstrated.

In this work, we present a novel fabrication scheme for MIM capacitors using bulk anodic alumina as the dielectric. These capacitors have capacitance density and leakage current that both satisfy the posed requirements by ITRS. The non-linearity factor requirement, although not satisfied as in all cases in the literature of a single high-k dielectric layer, is greatly reduced without significant loss to either the value of the capacitance density or the stability of the capacitor with respect to frequency. This is achieved by nanostructuring the bottom electrode surface before the formation of the dielectric layer, using electrochemistry. This nanostructuring leads to reduced leakage current and greatly reduced non-linearity co-efficient.

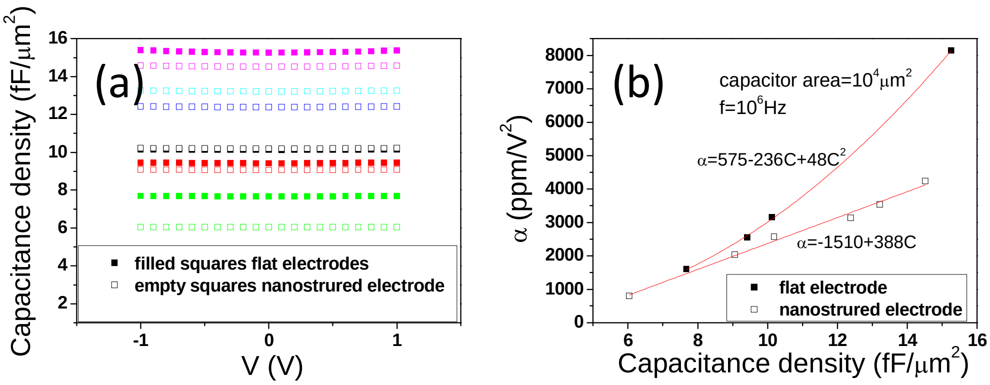

Figure 1: (a) Capacitance density vs. voltage for various MIM capacitors with flat and with nanomodulated electrode and dielectric surfaces. The different colours represent different anodic alumina thicknesses (from 12nm (green) down to 5nm (magenta)). (b) Non-linearity factor α vs. capacitance density for flat (full squares) and nanomodulated (open squares) electrode and dielectric surfaces.

References

[1] ITRS roadmap 2013 edition (http://www.itrs.net/Links/2013ITRS/Home2013.htm)

[2] Hourdakis and Nassiopoulou, IEEE Trans. on Electr. Devices **57**, 2679 (2010).

[3] Hourdakis and Nassiopoulou, Microelectron. Engineering **90**, 12 (2012).

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