

High-density capacitors for nanoFarads and GigaHertz: Digging deeper in porous Si

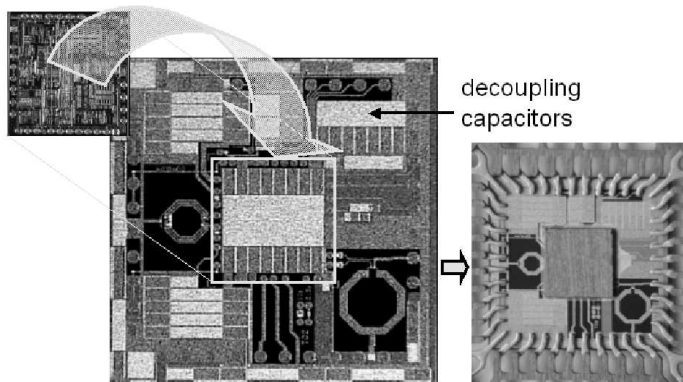
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This paper reports on high-density ($\sim 25\text{nF}/\text{mm}^2$) MOS 'trench' capacitors that were fabricated from silicon containing arrays of dry-etched macropores with $\sim 1.5\mu\text{m}$ diameter and up to $\sim 30\mu\text{m}$ depth.



Passive die with active die flipped on top, double-flipped on a leadframe.

Capacitors with $\sim 30\text{nm}$ ONO dielectric and poly-Si/Al top electrode showed $\sim 10\text{MV}/\text{cm}$ dielectric breakdown field and leakage $< 1\text{ nA}/\text{mm}^2$ @ 22V [1-2]. Dies integrated in radio frequency (RF) front-end test modules (e.g. power amplifiers) showed superior signal stability compared to identical test modules containing conventional surface mount (SMD) ceramic capacitors. This makes these capacitors very suitable for integrated decoupling purposes, e.g. supply-line decoupling in RF wireless communication (GHz-regime) and analog and mixed-signal systems.

This high-density capacitor concept is now a vital part of the first highly integrated cellular transceiver to be produced using Philips' new

silicon-based RF System-in-Package technology. This new technology utilizes back-end silicon processing to integrate passive components (particularly high-density capacitors) onto a silicon substrate that then acts as a carrier for the necessary active component dies. The active dies are direct-bonded onto the passive component silicon using flip-chip techniques [3]. This sub-assembly is then flipped back in a standard leadframe package.

[1] F. Roozeboom, R. Elfrink, T.G.S.M. Rijks, J. Verhoeven, A. Kemmeren and J. van den Meerakker, *High-Density, Low-Loss MOS Capacitors for Integrated RF Decoupling*, Int. J. Microcircuits and Electronic Packaging, **24** (3) (2001) pp. 182–196.

[2] F. Roozeboom, A. Kemmeren, J. Verhoeven, F. van den Heuvel, H. Kretschman and T. Frič, *High-Density, Low-loss MOS Decoupling Capacitors integrated in a GSM Power Amplifier*, Mat. Res. Soc. Symp. Proc. **783** (2003) pp. 157–162 [paper B6.3].

[3] http://www.semiconductors.com/news/content/file_1044.html

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