Analysis of Decoupling Capacitor for High Frequency Systems

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Abstract

In this paper a embedded decoupling capacitor design with gap structure will be discussed. A novelstructure is modeling and analization by High Frequency Structure Simulator (HFSS). Proposed capacitor have 2m×2m in rectangular shape. The film thickness of copper/dielectric film/substrate is respectively 35um/20um/35um. A dielectric layer of BaTiO3/epoxy has the relative permittivity of 25. Compare of the planar decoupling capacitor, capacitance densities of this structure in the range of 55μF/mm2 have been obtained with 50um gap while capacitance densities of planar structure 25μ F/mm2 in the same size. The frequency dependent behavior of capacitors is numerically extracted over a wide frequency bandwidth 500MHz—7GHz. The decoupling capacitor can work at high frequency band increasing the gap size.

I. Introduction

Due to market demands for increased circuit density, reduced parasitic and increase reliability, the design of in integrated passive components is receiving considerable attention. There was not dedicated to passive devices less than ten years ago. At that time, passives were just an assembly issue as far as packaging was concerned. You would purchase a manufactured resistor, capacitor, or inductor that came in its own little enclosure, and you mounted it on the printed circuit board and that was all that related to packaging. However, passives are current starting on a major change in the way they can be included in micro electronic systems.[1-2] As ICs move towards higher speed/frequency bands, it is hard to design a decoupling network for the suppression of switching noise because most commercial surface mount capacitors work below a few hundreds of MHz. The reason these capacitors operate only at low frequencies is that thee equivalent serial inductance (ESL) and resistance (ESR) are high[3-5]. Usually, ESL is about hundreds of pH to nH, which is too large to decouple noise at high frequency band.

Embedded capacitors provide a better solution for noise decoupling in power/ground network by introducing small parasitic inductance. Embedded capacitors provide a better solution for noise decoupling in power/ground network by introducing small parasitic inductance. The inductances for buried capacitors vary from several to teens of pH depending on the capacitor structure and size.

This paper will address a novel structure designs and analysis of electrical performance properties on decoupling capacitor between 500MHz and 7GHz through the High Frequency Structure Simulation (HFSS) tool.

II. Simulation Methodology

In order to generate an electromagnetic field solution, HFSS employs the finite element method. In general, the finite element method divides the full problem space into thousands of smaller regions and represents the field in each sub-region (element) with a local function.

In HFSS, the geometric model is automatically divided into a large number of tetrahedra, where a single tetrahedron is a four-sided pyramid. This collection of tetrahedra is referred to as the finite element mesh.

Ⅲ. Results and Discussions

Table 1 shows the capacitance with respect to size of the gap. High capacitance is needed for design of decoupling capacitors. In the conventional structure, capacitance is around 25pF at 1.3GHz which is resonant frequency. Capacitance with the gap of 50um is even around 55pF. Increasing the gap size, the capacitance is a little bit decreased but they have little difference.

Table 1 Capacitance of the gap size

Gap Size (㎛)	Capacatance(pF)
Conventional	25.51
50	54.22
100	31.56
150	27.03
200	23.14

The capacitor is changed to inductor from self resonant frequency due to parasitic. There is no more capacitor after the self resonant frequency. Therefore, the higher resonant frequency is needed for high frequency digital system. The self resonant frequency of the suggested gap structure is shifted from 1GHz to 4GHz in the Fig. 1. At this time, the gap size is 50um.

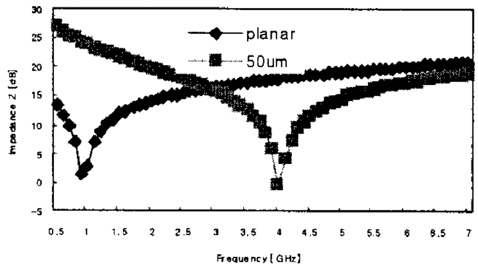

Fig. 1 Impedance on gap size change of the conventional structure and the gap structure

The impedance profile with respect to the gap size is plotted in Fig. 2. The resonant frequency is usually shift to high level with increasing the gap size. In other words, the decoupling capacitors with the proper gap size are able to operate in the high frequency band.

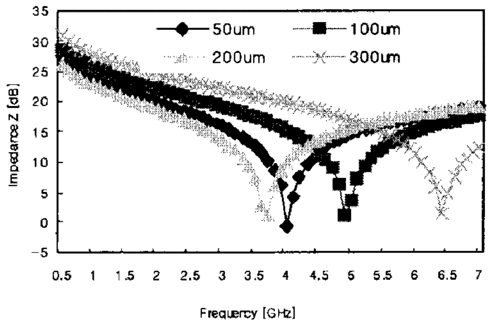

Fig. 2 Impedance profile on the gap size

Ⅳ. Conclusions

In this paper, the suggested electrode structure which is mininum the loss at the high frequency can concurrently get the higher capacitance and the low impedance. As a result, the electrode layer structure provides a high self resonant frequency while maintaining a high capacitance. The resonant frequency is not shifted to low frequency band while the dielectric constant is still high in the novel structure.

References

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