Review: Advancement of Integrated Passive Device Technology

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Abstract

In this paper, an advancement of integrated passive device (IPD) technology will be reviewed and its wide implementation will be investigated. This technology can be implemented to fabricate passive components like resistor, inductor and capacitor to design and fabricate filters, combiners, dividers, baluns, and antenna etc. This is a kind of radio frequency (RF) solution in wireless technology and its main features are excellent device performance, higher integration, and higher reliability, and higher repeatability, device packaging and low cost. IPD can be fabricated using especially thin film and photolithography processing. The substrates can be used for this are silicon, GaAs, InGaP, alumina etc. and this technical is more beneficial to internet of things (IoT) which is an emerging technology.

Keywords: IPD; integrated passive technology; passive device technology.

1. Introduction

Recently, the trend of miniaturization with good performance of devices is being popular in the radio frequency (RF) communication systems design, simulation and fabrication. IPD technology is that in which all kinds of passive components can be integrated. A few years ago, the passive components like resistor, inductor and capacitor were not integrated due to its bigger size. However, because of technology development, passive components are also able to integrate to make it very smaller and smaller using various types of technologies like qazSilicon (Si), Gallium Arsenide (GaAs), InGaP, Complementary Metal Oxide Semiconductor (CMOS) etc. in low cost. Such technologies are used in radio frequency (RF) transceiver module and RF passive circuits design. This technology cover almost all RF frequencies ranges.

There is also another technology termed as low temperature co-fired ceramics (LTCC) that utilizes a ceramic material. By this technology, passive components can be integrated in the ceramic substrate by sintering the ceramic elements in order to reduce the size. It is also termed as thick film manufacturing process technology. However, the demerits are increment of layers that makes difficulty and the rate of production is higher. As a result, poor product characteristics, inaccuracy of tolerance and so on. Therefore, by using thin film process with semiconductor technology, the integration of passive components can be improved with excellent component or device characteristics. There are some companies which use IPD technology such as Telephus, SyChip, IMEC, Di Nippon, etc. Telephus Company developed a thick copper process for passive components and SyChip used Si3N4 as a substrate. In the same way, IMEC used copper plating with Benzocyclobutene (BCB) as the dielectric layer while DiNippon developed Ti/Cr based process with anodic oxidation process of Ta2O5 [1-5].

The features of IPD are high quality factor of inductor (high Q), metal-in-metal (MIM) capacitor, thin film resistor, high resistivity wafer, high potential of device integration, low cost, fast fabrication, flexibility of design and tool and so on. Moreover, the IPD technology is more beneficial to internet of things (IoT) due to inherent capability to reduction of size. Therefore, the module or system related to the IoT can be fabricated
with more reduced size that makes device smaller and smaller. In this paper, the resister, inductor and capacitor thin film process will be describe in the section 2, and concluded in the section 3.

2. Thin film process technology

There are many IPD process technologies including GaAs technology. The Figure 1 shows the cross sectional view of the 6-inch semi-insulating GaAs wafer on which the passive components can be fabricated with different process steps. In this process, seed metal, Ti can be used on the SI-GaAs substrate as shown in Figure 1 (a) and (b). Then Si3N4 layers are deposited to solve the problem of surface defects as depicted in Figure 1 (c). And then Ti/Au layer can be plated to enhance the metal adhesion to the substrate as in Figure 1 (d). The passive components especially resistor, inductor and capacitor are explained and the overall cross-sectional view is illustrated in Figure 2 in which the process of fabricating resister, capacitor and inductor are shown [6].

![Figure 1. The cross sectional view of IPD fabrication process flow on SI-GaAs process.](image)

2.1 Resister

Sputtering process is used for thin film resistor process. Then we perform resistive material plating on the substrate (whether it can be Si or GaAs or other materials). Generally NiCr thin film is used to fabricate resistor using various processes like vacuum deposition, sputtering and thermal deposition and the metal is used of alloys or other materials. As the last process, RF characterization is performed.
2.2 Capacitor

The metal insulator metal (MIM) capacitor can be fabricated on the substrate like Si or GaAs or other materials. In the case of MIM capacitor, the parasitic resistance can be reduced to have in implementation to high frequency. In between two metal, dielectric material is used. Especially Si3S4 can be used as the dielectric in the process. To evaluate the device, RF characterization is performed.

2.3 Inductor

Similar process can be used as in resistor for inductor fabrication but in this process, the material to make high Q inductor can be designed and used. The inductor can be fabricated by electro-plating and confirm the surface roughness which can be used for reducing the device noise in high frequency. For this process, Si or GaAs or other materials as a substrate can be used that can be decided by the designer and operator.

The advantages of IPD process technology overall process are saving packing size, cost reduction, easy and only four layer processing, high repeatability, broad marketing, high frequency applications etc. The IPD technology can be used to fabricate RF filters, combiners, dividers, antenna by combining thin film resistor, high Q inductor with low parasitic elements and MIM capacitor. It can be implemented for high frequency in almost all wireless communication systems, especially in internet of things (IoT) devices which are currently emerging and popular field. Because, we need devices smaller and smaller as possible.

3. Conclusion

The investigation of IPD process was performed which is an emerging technology that integrates all kinds of passive components like resistors, capacitors and inductor. This can be accomplished by using Si or GaAs or other materials as substrate. During the process, various processing steps like sputtering, vacuum deposition, thin film deposition, metallization, and passivation etc. can be used. The IPD devices can be used for the high frequency applications in all kinds of wireless communication system including IoT, home-networking system etc. and this technology is promising technology for the future too in order to making devices / modules / systems smaller and smaller as possible.

References