Ministry of Education of the Republic of Belarus
Educational Institution Belarusian State University
Informatics and Radioelectronics

"TahyrAtayev "

Modeling of Magnetic-Anisotropic Behavior of a Nanocomposite Based on Porous Silicon for Electromagnetic Shielding

1-98 80 01«Methods and Systems of Information Protection, Information Security»

Thesis
for The Degree of Master of Science

The scientific adviser:
Prof. Dr. S.L. Prischepa

Minsk 2015

Introduction

The increasing expansion of telecommunication applications leads to the integration of complete system-on chip (SOC) associating analog and digital processing units. Such mixedsignal integrated circuits embed CMOS and bipolar transistors as well as key passive components (inductors and/or capacitors),required in many applications as amplifiers, mixers, voltagecontrolled oscillators, filters, or resonators. These passive elements occupy an increasing silicon footprint, compromising circuit scalability and cost. Moreover, passive components' performances are limited by the proximity of lossy Si substrate and surrounding metallization. Then, obviously, the characteristics of the substrate become crucial for monolithic radio frequency (RF) systems to reach high performances.

These performance limitations due to the substrate have various causes if a conventional silicon substrate is used. Indeed, capacitive effects and eddy current losses have a severe impact on the quality of integrated spiral inductors.Moreover, parasitic signal transfer through the silicon causes undesirable feedback (crosstalk) between RF circuits. Even in the case of typical resistivity values of 10–20 Ωcm, substrate couplings are still efficient. Thus, resistivities of 100 Ωcm and beyond are required. Unfortunately, this range is currently not reached by commercially available Czochralski material but only with float-zone (FZ) silicon wafers. The migration from 6 in. to 8 in. wafers appears technically feasible, but the cost of FZ wafers is currently higher than that of CZ substrates.

Better electrical characteristics can be achieved by applying glass or quartz substrates through substrate transfer techniques, but the thermal resistance of such materials is rather high and may lead to undesirable self-heating phenomena in such RF structures.Another solution consists in crosstalk reduction using guard rings, but this technique is mostly effective at frequencies below 1 GHz.[1] A midprocess option could be the incorporation of novel materials into the interconnect layers. One example is the insertion of ferromagnetic (FM) thin films into a metal solenoidal coil, thus confining the magnetic field. Bulk micromachining techniques with front/backside lithographic feature alignment can also provide low loss substrates, locally thinning the wafer underneath the devices. All these solutions are generally costly and involve technical challenges.

So, looking for integrated circuit (IC) compatible processes, porous silicon (PS) seems to be a promising candidate as it can provide localized isolating regions from various silicon substrates.[2]

In this review, we will first present all the possible porous silicon substrates that can be used for RF devices. In particular, we will put the emphasis on the etching conditions leading to high thickness localized PS layers. The second part deals with the intrinsic electrical properties such as the AC electrical conductivity or the dielectric constant. Then, we will describe the performances of widespread RF devices, that is, inductors or coplanar waveguides. Finally, we will describe methodologies used to predict the RF electrical responses of PS isolated devices, based on electromagnetic (EM) simulations.

GENERAL DESCRIPTION OF THE WORK

Communication of thesis with large scientific programs The theme of dissertational operation is confirmed by the order of the Rector of the Belarusian State University of Informatics and Radioelectronics № 28-o from January 24th 2014 and matches to subsection 5.5 «Methods, tools and technologies for information security in the processing, storage and transmission of data using Porous silicon for electrical isolation in radio frequency devices» the priority directions of fundamental and applied scientific examinations of Belarus for 2013–2015, confirmed by the Decision of Council of Ministers of Belarus on April 19th 2010, № 585. The work was carried out in the Belarusian State University of Informatics and Radioelectronics.

Research goals and objectives

The goals of the thesis were to develop setup and test methods of quantum interference devices based on NB films deposited onto porous silicon templates testing soundproof construction elements for protecting speech information from leaking through the acoustic and vibration channels

To achieve this goals it was necessary to solve the following tasks:

1. Develop a interference devices based on porous silicon for electrical isolation in radio frequency devices .

2. Assemble experimental setup.

3. Review devices based on porous silicon, select samples for research.

4. Testing of the proposed method.

The personal contribution of the competitor

All the results presented in the thesis, are obtained by the competitor himself. All the works published by the author contain the purposes and statements of research problems, sampling of research techniques, personal participation in conducting of experiments constructions, analysis and interpretation of the gained experimental data.

Approbation of effects of the dissertation

Major results of the dissertation were presented and discussed at the XIII Belarusian-Russian scientific and technical conference “Technical means for information protection” (Minsk, Belarus, 2015).

Publications on a dissertation theme

Author of the thesis published 2 printed works in the conferences proceedings.

Conclusions

Stationary regime of the nickel electrochemical deposition into the mesoporous silicon template from the Watts bath has been found toobtain continuous Ni NWs. According to the SEM analysis the length and the diameter of NWs have been determined by pore dimensions were equal to 10 μm and 100–120 nm, respectively. The stages of Ni deposition process from nucleation through separated NPs growthto their coalescence in NWs have been carefully studied. The timerequired for the complete filling of pore channels has been fixed at 60 min of electrochemical deposition. The proposed PS template andregimes of the Ni deposition have allowed achieving the maximumvalue of the filling factor about 67%. The PS potential during the electrochemicaldeposition has been found to manifest the filling process of pore volume with Ni. The polycrystalline nature of the Ni NWs hasbeen established by XRD. The lattice parameter of Ni has been determinedto be 0.4–0.5% expanded in comparison with the bulk nickel.Such increasing is significant for cubic dense packing of Ni atoms and might be explained by PS matrix influence. Moreover, the formationof nickel silicide Ni_2Si has been observed at the initial stages ofNi deposition. The synthesized PS templates filled with Ni show themagnetic behavior which was proved by measuring the temperature dependence of the specific magnetization. It has been revealed that thespecific magnetization and the magnetic moment of Ni atoms, as wellas the Curie temperature values are less for sample with the absence ofcontinuous Ni NWs with respect to those known for bulk Ni.We have explained it by formation of nonmagnetic Ni_2Si phase at the initial stages of the deposition.

Further research of the magnetic properties of PS/Ni nanocomposites and their relation to the structure of Ni in PS templates is inprogress now.

LIST OF PUBLICATIONS

1. МАГНИТНЫЙ НАНОКОМПОЗИТ НА ОСНОВЕ ПОРИСТОГО КРЕМНИЯ - XIII БЕЛОРУССКО-РОССИЙСКАЯ НАУЧНО-ТЕХНИЧЕСКАЯ КОНФЕРЕНЦИЯ - ТЕХНИЧЕСКИЕ СРЕДСТВА ЗАЩИТЫ ИНФОРМАЦИИ.р.75 4 - 5 июня 2015 г.МИНСК 2015

Doklady.bsuir.by/m/12-10457/-1-92414.pdf

2. ВЗАИМОДЕЙСТВИЕ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ С МАГНИТНЫМ НАНОКОМПОЗИТОМ НА ОСНОВЕ ПОРИСТОГО КРЕМНИЯ - XIII БЕЛОРУССКО-РОССИЙСКАЯ НАУЧНО-ТЕХНИЧЕСКАЯ КОНФЕРЕНЦИЯ - ТЕХНИЧЕСКИЕ СРЕДСТВА ЗАЩИТЫ ИНФОРМАЦИИ.р.75.4 - 5 июня 2015 г.МИНСК 2015

Doklady.bsuir.by/m/12-10457/-1-92414.pdf