UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF PASSIVE SYSTEM FOR HIGH TEMPERATURE WIRELESS SENSOR APPLICATIONS

MOHAMMAD JAVADIAN SARRAF

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By

MOHAMMAD JAVADIAN SARRAF

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for Degree of Doctor of Philosophy

June 2012

DEDICATION

To my dearest family

Mahnaz, Farbod, Atrina.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF PASSIVE SYSTEM FOR HIGH TEMPERATURE WIRELESS SENSOR APPLICATIONS

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MOHAMMAD JAVADIAN SARRAF

June 2012

Chairman: Mohammad Nizar b. Hamidon, PhD

Faculty: Engineering

Since the first work on surface acoustic wave (SAW) devices was presented in 1970, various aspects of research on these devices started to emerge due to their advantages such as small in size, low power consumption, low sensitivity to electromagnetic noises and wide range of operational temperature. Being passive and having these benefits introduce SAW-devices as the best candidate for constructing a passive wireless sensor system based on them. Operation of this system at harsh environment can be guaranteed by proper selection of materials that are used in SAW-devices fabrication.

In order to reduce power consumption the size of devices in these systems should be as small as possible. Better impedance matching can guarantee better sensitivity and higher readout distance for sensor system. Parasitic elements due to wire bonding

second level interconnection can degrade the impedance matching.

In this thesis, a pure planar second level interconnection method using Double SAW Resonator System (DSAWRS) for passive wireless system is proposed to reduce parasitic effects of wire bonding interconnection. DSAWRS consists of two SAW resonators and a matching circuit for each resonator. A sensor element is added to the circuit as a capacitive or inductive element. The resonator and the sensor element in this system are separated for optimization.

To reduce the size of devices, a single port SAW-resonator with the center frequency of 433.92 MHz has been developed to operate at 400 °C on a new piezoelectric substrate (which is Gallium Orthophosphate ($GaPO_4$)). The resonator has been designed based on $GaPO_4$ with 5° Y-Boule cut with synchronous interdigital transducer (IDT) made from platinum and chromium as adhesion layer. The resonator consists of 50 fingers IDT and two 100 shorted strips reflector, with finger width of 1.3μm.

The common method for matching the resonators is using their equivalent circuits. This method is not applicable for the high temperature. Different types of matching circuits have been studied and a new method for performing the matching process is proposed for the high temperature resonators.

Here, a meander line inductor and interdigital capacitors have been used for implementing inductors and capacitors of the matching circuit. The characteristics of meander line inductors and interdigital capacitors have been studied and a design

method is proposed for each one. DSAWRS employs second level interconnection for the high temperature (400 °C) on alumina with platinum and silver as metal traces using thick film technology. Coplanar waveguide has been used as the transmission line and integrated to DSAWRS on the alumina.

As a conclusion, a new method for design and fabricating the DSAWRS has been proposed and successfully applied on the profile of the second order interconnection that can operate up to 400 °C.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN SISTEM PASIF UNTUK APLIKASI TANPA WAYAR PENGESAN SUHU TINGGI

Oleh

MOHAMMAD JAVADIAN SARRAF

Jun 2012

Pengerusi: Mohammad Nizar b. Hamidon, PhD

Fakulti: Kejuruteraan

Sejak pertama kali peranti permukaan gelombang akustik (SAW) diperkenalkan pada tahun 1970, penyelidikan dari pelbagai aspek tentang peranti ini mula muncul disebabkan kelebihannya seperti bersaiz kecil, penggunaan kuasa yang rendah, kepekaan yang rendah terhadap hingar elektromagnet dan suhu operasi yang luas. Sebagai pasif dan mempunyai manfaat ini memperkenalkan SAW alat-alat sebagai calon yang terbaik untuk membina satu sistem sensor pasif wayarles yang berasaskan kepada mereka. Operasi sistem ini di persekitaran yang keras boleh dijamin dengan pemilihan bahan-bahan yang digunakan dalam fabrikasi SAW alat-alat.

Dalam usaha untuk mengurangkan penggunaan kuasa saiz peranti dalam sistem ini harus menjadi sekecil mungkin. Impedans yang lebih baik pemadanan boleh menjamin kepekaan yang lebih baik dan jarak bacaan yang lebih tinggi untuk sistem sensor. Elemen parasit kerana wayar sambungtara tahap ikatan kedua boleh

merendahkan padanan galangan.

Dalam tesis ini, kaedah saling sambung peringkat kedua satah tulen yang menggunakan Sistem Resonator Dwi SAW (DSAWRS) untuk sistem pasif tanpa wayar dicadangkan untuk mengurangkan kesan parasit saling sambung ikatan wayar. DSAWRS terdiri daripada dua resonator SAW dan litar padanan bagi setiap resonator. Unsur penderia dimasukkan ke dalam litar sebagai elemen kapasitif atau induktif. Resonator dan elemen penderia dalam sistem ini dipisahkan untuk pengoptimuman.

Resonator dengan kekerapan pusat 433.92MHz telah dibangunkan untuk beroperasi pada suhu 400 °C di atas substrat baru piezoelektrik (Ortofosfat Gallium ($GaPO_4$)). Resonator tersebut telah direka berasaskan $GaPO_4$ dengan 5 potongan ° Y-Boule dan transduser interdigital segerak (IDT) yang diperbuat daripada platinum dan kromium sebagai lapisan lekatan. Resonator tersebut terdiri daripada 50 jari IDT dan dua pemantul yang terdiri dari 100 jalur terpintas, dengan lebar jari 1.3μm.

Kaedah biasa untuk memadankan resonator ialah dengan menggunakan litar setara. Kaedah ini tidak dapat digunakan untuk suhu yang tinggi. Pelbagai jenis litar yang sepadan telah dikaji dan kaedah baru untuk melaksanakan proses pemadanan dicadangkan untuk resonator pada suhu tinggi.

Induktor garis liku dan kapasitor interdigital telah digunakan sebagai induktor dan kapasitor dalam litar yang sepadan. Ciri-ciri induktor garis liku dan kapasitor interdigital telah dikaji dan kaedah reka bentuk sesuai telah dicadangkan bagi setiap

satu. DSAWRS menggunakan saling sambung peringkat kedua untuk suhu yang tinggi (400° C) pada alumina dengan platinum dan perak sebagai surih logam menggunakan teknologi saput tebal. Pemandu gelombang sesatah telah digunakan sebagai talian penghantaran dan disepadukan pada DSAWRS pada alumina tersebut.

Sebagai kesimpulan, satu kaedah baru bagi reka bentuk dan fabrikasi DSAWRS telah dicadangkan dan berjaya digunakan pada profil saling sambung peringkat kedua yang boleh beroperasi sehingga 400°C.

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I certify that a Thesis Examination Committee has met on **27 June 2012** to conduct the final examination of Mohammad Javadian Sarraf on his thesis entitled "**Development of Passive system for High Temperature Wireless Sensor Applications**" in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia[P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Mohammad Hamiruce b. Marhaban, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Roslina bt. Mohd. sidek, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Nasri b. Sulaiman, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Michael Kraft, PhD
Professor
Faculty of Engineering
University of Southampton
England
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to Senate of Universiti Putra Malaysiahas been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. Members of the Supervisory Committee were as follow:

Mohammad Nizar b. Hamidon, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Alyani bt. Ismail, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Maryam bt. Mohd.Isa, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

MOHAMMAD JAVADIAN SARRAF

Date 27/June/2012

TABLE OF CONTENTS