MICROSENSORS

Edited by **Igor V. Minin** and **Oleg V. Minin**

INTECHWEB.ORG

Microsensors
Edited by Igor V. Minin and Oleg V. Minin

Published by InTech
Janeza Trdine 9, 51000 Rijeka, Croatia

Publishing Process Manager Sandra Bakic
Technical Editor Teodora Smiljanic
Cover Designer Martina Sirotic
Image Copyright JOANCHANG, 2010. Used under license from Shutterstock.com

First published May, 2011
Printed in India

A free online edition of this book is available at www.intechopen.com
Additional hard copies can be obtained from orders@intechweb.org

Microsensors, Edited by Igor V. Minin and Oleg V. Minin
p. cm.
ISBN 978-953-307-170-1

Contents

Preface

Microsensors are appropriately categorized as “transducers”, which are defined as devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal. The critical physical dimensions of microsensors devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Sensors and microsensors are: force and pressure microsensors, position and speed microsensors, acceleration microsensors, chemical microsensors, biosensors and temperature sensors.

The common trends in sensor technology today are: Miniaturization, Integration: sensor with signal processing circuits for linearising sensor output, etc., sensor with built-in actuator for automatic calibration, change of sensitivity etc., and Sensor arrays: one-function units (to improve reliability), multiple-function units.

The main advantages of microsensors, as it is well-known, are: lower manufacturing cost (mass-production, less materials), wider exploitation of IC technology (integration), wider applicability to sensor arrays, lower weight (greater portability).

Over the last years, advances in microsensors, computing, physics, chemistry, have enabled new and innovative tests that have allow to design a new devices to improve outcomes.

This book is planned to publish with an objective to provide a state-of-art reference book in the area of microsensors for engineers, scientists, applied physicists and post-graduate students. Also the aim of the book is the continuous and timely dissemination of new and innovative research and developments in microsensors.

This reference book is a collection of 13 chapters characterized in 4 parts: magnetic sensors, chemical, optical microsensors and applications.

This book provides an overview of resonant magnetic field microsensors based on MEMS, optical microsensors, the main design and fabrication problems of miniature sensors of physical, chemical and biochemical microsensors, chemical microsensors with ordered nanostructures, surface-enhanced Raman scattering microsensors based on hybrid nanoparticles, etc.

Several interesting applications area are also discusses in the book like MEMS gyroscopes for consumer and industrial applications, microsensors for non invasive imaging in experimental biology, a heat flux microsensor for direct measurements in plasma surface interactions and so on.

Igor V. Minin and Oleg V. Minin
Novosibirsk State Technical University,
Russia

Part 1

Magnetic Sensors

1

Magnetic Microsensors

Căruntu George and Panait Cornel
Faculty of Electronics, Electrotechnics and Computer Science,
Constanta Maritime University,Constanta,
Romania

1. Introduction

In the presence of a magnetic field, the Hall effect takes place in the active region of the transistors, however their magnetic sensitivity is insignificant.Moreover, the Hall effect may interfere with the action of a bipolar transistor in many ways which makes the analysis and optimization of devices much more difficult.
However, there are also magnetotransistors structures in which, under appropriate operating conditions the magnetic sensitivity increases to values useful in practical work. In this way integrated magnetic sensors useful for emphasizing and measuring mechanical and geometrical quantities can be obtained.

The double-collector bipolar magnetotransistors

1.1 The general characterization of the double-collector bipolar magnetotransistors

Figure 1.1 shows the cross section of a double collector *npn* vertical magnetotransistor operating on the current deflection principle [1]. This structure is compatible with the bipolar integrated circuit technology.

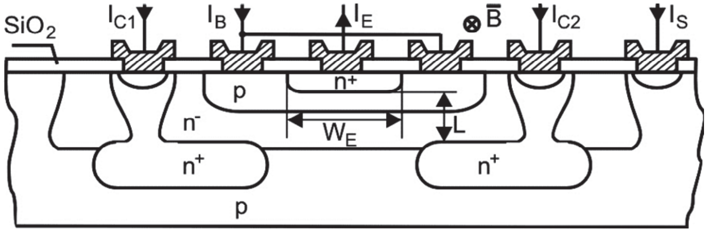

Fig. 1.1. The structure of a double-collector magnetotransistor

The most of the *n* type low-doped epitaxial layer serves as the collector region and is depleted of the charge carriers upon reverse biasing of the collector-base junction. The two collector contacts are realised by splitting the buried layer (n^+). L is the collector-emitter distance, and W_E is the width of the emitter. In the absence of the magnetic field the electron flow injected into the emitter, which crosses the base is symmetrical and the two collector currents are equal: $I_{C1} = I_{C2}$. In the presence of a magnetic field having the

induction $\overline{B}$ parallel with the device surface, the distribution of the emitter electron current becomes asymmetrical and causes an imbalance of the collector currents: $\Delta I_C = I_{C1} - I_{C2}$.
The analysed magnetotransistor operates in the Hall current mode and ΔI_C depends on the Hall transverse current. Assimilating the low-dopped epitaxial layer of the collector region with a short Hall plate, and based on the properties of dual Hall devices it results [2]:

$$\Delta I_C = \frac{I_H}{2} = \frac{1}{2}\mu_{Hn} \cdot \frac{L}{W_E} \cdot G \cdot I_C \cdot B \tag{1.1}$$

where μ_{HCh} is the carriers Hall mobility in the channel, *G* denotes the geometrical correction factor and $I_C = I_{C1}(0) + I_{C2}(0)$.

1.2 The sensor response and the sensitivity related to the bias current

The sensor response is expressed by:

$$h(B) = \frac{\Delta I_C}{(I_{C1} + I_{C2})_{B=0}} = \frac{1}{2}\mu_{Hn}\frac{L}{W_E} \cdot G \cdot B_\perp \tag{1.2}$$

and it is linear for induction values which satisfy the condition: $\mu_H^2 \cdot B_\perp^2 << 1$

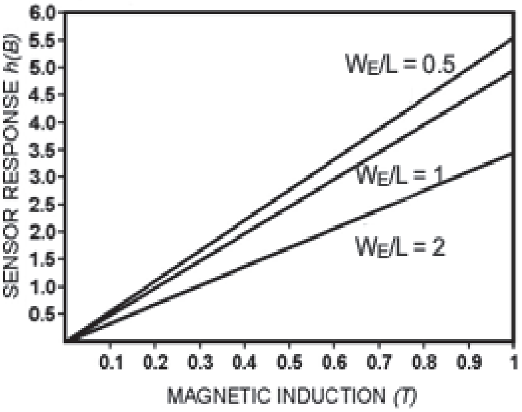

Fig. 1.2. The *h(B)* depending on *B* for three devices of different geometry

In figure 1.2 the geometry influence on h(B) values for three magnetotransistor structures can be seen ratios $W_E / L \ (W_E = 50\mu m)$.

MGT1: $W_E / L = 0.5$, $(L / W_E)G = 0.72$;

MGT2: $W_E / L = 1$, $(L / W_E)G = 0.68$;

MGT3: $W_E / L = 2$, $(L / W_E)G = 0.46$;

It is noticed that the response $h(B)$ is maximum for $W_E / L = 0.5$ structure. Decreasing the emitter-collector distance, $h(B)$ decreases with 37.5% for $W_E = 2L$, as compared to the maximum value. The sensor response decreases with 10.7%, comparative with $W_E / L = 0.5$ structure if the distance between emitter and collector doubles. For the same geometry $W_E / L = 0.5$, the response is depending on material features. In figure 1.3 $h(B)$ values of three sensors MGT1, MGT2, MGT3 are shown, realized on

Si ($\mu_{H_n} = 0.15 m^2 V^{-1} s^{-1}$),

InP ($\mu_{H_n} = 0.46 m^2 V^{-1} s^{-1}$)

GaAs ($\mu_{H_n} = 0.80 m^2 V^{-1} s^{-1}$).

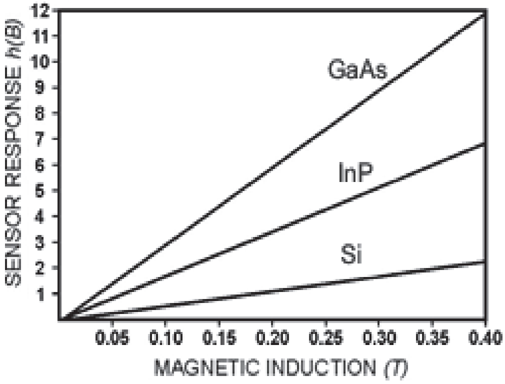

Fig. 1.3. The *h(B)* depending on *B* for three devices on different materials

A magnetotransistor may be regarded as a modulation transducer that converts the magnetic induction signal into an electric current signal.
This current signal or output signal is the variation of collector current, caused by induction $B_\perp$.
The absolute sensitivity of a magnetotransistor used as magnetic sensors is:

$$S_A = \left|\Delta I_C / B\right| = \frac{1}{2} \mu_{Hn} \cdot \frac{L}{W_E} G \cdot I_C \tag{1.3}$$

The magnetic sensitivity related to the devices current is defined as follows:

$$S_I = \frac{1}{I_C} \left| \frac{\Delta I_C}{B_\perp} \right| = \frac{1}{2} \mu_{Hn} \frac{L}{W_E} G \tag{1.4}$$

For a given induction $(B = 0,4T)$ and at given collector current $I_C = 1mA$, the sensitivity depends on the device geometry and the material properties. In table 1.1 the obtained values for five magnetotransistors structures are presented.