poly-SiGe の MEMS センサ応用

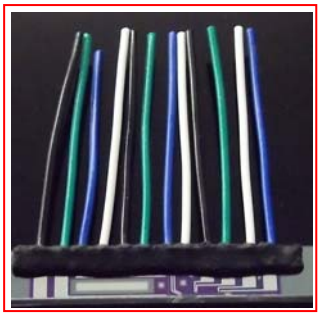


Exhibit #1: Sample to determine the piezoresistivity of a poly-SiGe layer by measuring the resistance changes during 4-point bending tests.

Exhibit #1

KATHOLIEKE UNIVERSITEIT LEUVEN

imec

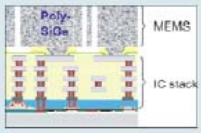
OPTIMIZATION OF THE PIEZORESISTIVE AND ELECTRICAL PROPERTIES OF POLY- SiGe FOR MEMS SENSOR APPLICATIONS

P. Gonzalez[1,2],L. Haspeslagh[1], Kristin De Meyer[1,2] and Ann Witvrouw[1]
[1]imec, Kapeldreef 75, 3001 Leuven (Belgium); [2]KULeuven, Kasteelpark Arenberg 10, 3001 Leuven

INTRODUCTION

Poly-SiGe has emerged as a promising MEMS structural material since it provides the desired mechanical properties at **CMOS-compatible temperature**

Monolithic integration of MEMS on top of CMOS can improve performance, yield and reliability as well as lower packaging and assembly costs



ABSTRACT

•The piezoresistive and electrical properties of boron-doped poly-SiGe for **different doping doses** (from $2 \cdot 10^{13}$ cm^{-2} to $4 \cdot 10^{15}$ cm^{-2}) **and Ge content** (49% and 64%) are evaluated

• With proper tuning of the boron and germanium content, a **gauge factor over 20** and a **TCR as low as 0** are achievable

• Finite-element simulations of a possible **poly-SiGe pressure sensor** were done, showing the effect of sensor area.

EXPERIMENTAL

400nm-thick poly-$Si_{36}Ge_{64}$ and poly-$Si_{49}Ge_{51}$ layers were deposited using **CVD** and doped through ion implantation of boron at 65 keV with dosages between $2 \cdot 10^{13}$ and $4 \cdot 10^{15}$ cm^{-2}

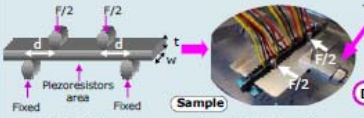
Poly-$Si_{36}Ge_{64}$
- Wafer temperature: 500ºC
- Annealing temperature:570ºC

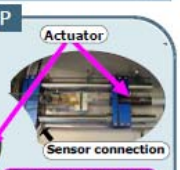
Poly-$Si_{49}Ge_{51}$
- Wafer temperature: 540ºC
- Annealing temperature:620ºC

Sample for piezoresistive measurements with 4 **differently orientated resistors**

MEASUREMENT SETUP

• **Piezoresistivity** is estimated from the resistance variation when stressing the films in a **four point bending fixture**



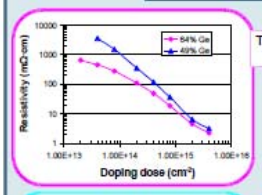


DELAMINATOR TOOL

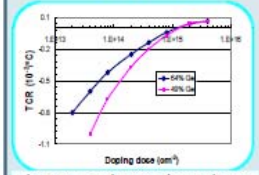
• **Resistivity** is measured on **blanket wafers** using a four-point probe

• **TCR** is calculated by performing four point resistance measurements of patterned resistors in the **temperature range 25-150ºC**

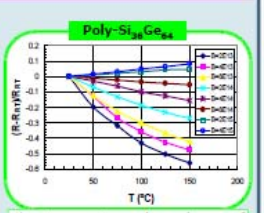
RESISTIVITY AND TCR



The resistivity reduces with increasing B concentration and Ge content



The TCR can be tuned according to specifications, making it positive, negative or even 0



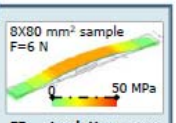
The temperature dependence of resistivity varies from non-linear and negative (thermionic emission) to positive and linear (carrier mobility) by increasing B concentration

PIEZORESISTIVITY

With the measured relative resistance variation and the simulated stress the **piezoresistive coefficients** are calculated

$$\Delta R/R = \sigma\left(\pi_l \cos^2\varphi + \pi_t \sin^2\varphi - \pi_{lt}\cos\varphi\sin\varphi\right)$$

B (cm^{-2})	Poly-$Si_{49}Ge_{51}$		Poly-$Si_{36}Ge_{64}$	
	Π_l (10^{-11})	Π_t (10^{-11})	Π_l (10^{-11})	Π_t (10^{-11})
$4 \cdot 10^{13}$	9.6	4.4	8.8	0.7
$2 \cdot 10^{14}$	12.2	1.9	12.4	1.5
$4 \cdot 10^{14}$	8.9	0.7	13.7	0.94
$8 \cdot 10^{14}$	5.5	0.3	8.6	-0.43
$4 \cdot 10^{15}$	3.8	-0.3	4	-0.5

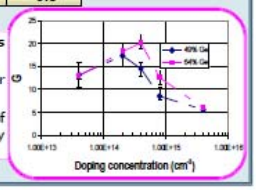


FE simulations are used to determine the value of the stress σ induced in the resistors

• The gauge factor (G) of poly-SiGe, **tails off for high and low doping levels**

•A G_{max}**=20.2** was found, slightly smaller than reported values for poly-Si (22-29)

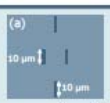
• The possibility to post-process on top of CMOS (higher SNR) might offset the slightly smaller gauge factor



APPLICATION TO A PRESSURE SENSOR

Due to the positive π_t, it is best to place the transversal piezoresistors in the centre of the membrane where the stress is negative

The piezoresistive coefficients for poly-$Si_{36}Ge_{64}$ (with $B=4 \cdot 10^{14}$ cm^{-2}) are used along with **FE simulations** to predict the sensitivity of a **piezoresistive poly-SiGe pressure sensor**



Area	(a)
200×200 µm²	5.2
250×250 µm²	8.6
300×300 µm²	12.75

Obtained sensitivities (mV/V/bar) for the different areas studied. Membrane and piezoresistor thickness are 4 and 0.4 µm, resp.

CONCLUSIONS

The piezoresistive and electrical properties of poly-SiGe were studied as a function of doping concentration and Ge content. The gauge factor of poly-SiGe could be improved by a factor of 3-4 over the state of the art. This optimized film also has a very low TCR, which is ideal for piezoresistive sensor applications. A pressure sensor was proposed as a first application.