Simulations for Optimized Piezoresistors

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ABSTRACT

As a phenomenon, piezoresistive effect is well understood from the theoretical point of view. Experimental characterizations have also been done on a variety of uniformly doped samples. However, for modern LSI structures, with shallow diffused junctions that have steep gaussian profile, and short distances between electrodes, piezoresistive coefficients differ significantly from those for uniformly doped samples.

This paper considers effects of doping profile, electric field level and its distribution on free carrier mobility in order to asses sensitivity of piezoresistors. Simulated performance over temperature range is analyzed as well.

Keywords: Diffused piezoresistors, mobility, shallow junctions.

1. INTRODUCTION

Piezoresistivity is one of the widely exploited physical phenomenon in a variety of sensor devices. A first publication related to this material property, with the basic operating principle applicable to the wire and foil gages, dates back to 1856. That was the time when Lord Kelvin reported that certain metallic conductors subjected to mechanical strain exhibited a corresponding change in electrical resistance [1]. In general, semiconductors show a much larger percentage change in electrical resistance per unit of strain than metals do.

The intent of this article is to analyze simulation elements of piezoresistive devices for better correlation between semiconductor process parameters with the final transducer performance over temperature and pressure.

2. SIMULATIONS

TABLE 1. Matrix of the structures used in the simulation at T=260 K and T=400 K.

	Length [microns]	Bias [V]
1	0.5	0.25
2	0.5	5
3	19	0.25
4	19	5

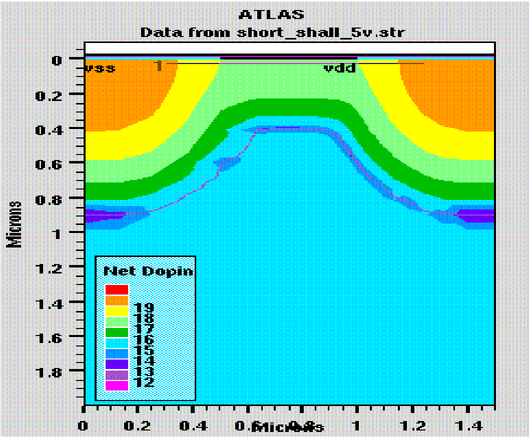

Fig . 1. A cross-section of a ‘short’ (0.5 microns) structure showing doping concentration

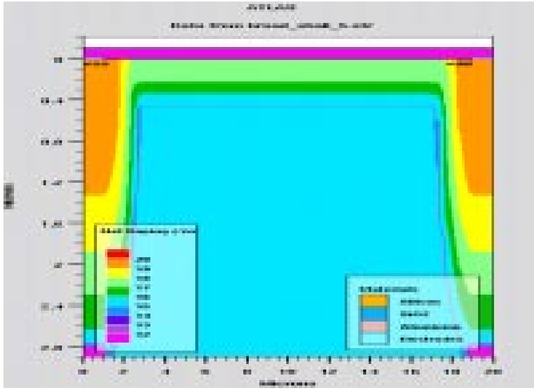

Fig . 2. A cross-section of a ‘long’ (19 microns) structure showing doping concentration.

2.1 Short structure (0.5 microns)

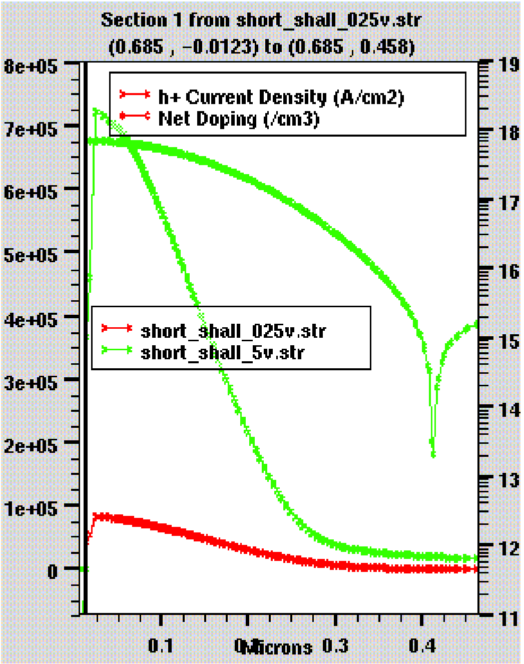

Fig. 3. Current density for Vdd=0.25 V and Vdd=5V with the doping profile over the vertical cutline.

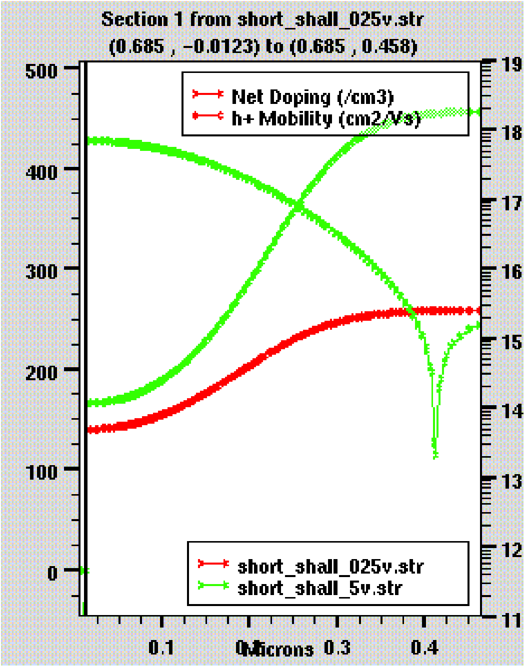

Fig. 4. Hole mobility along the vertical cutline at T=260 K (green line) and T=400 K (red line).

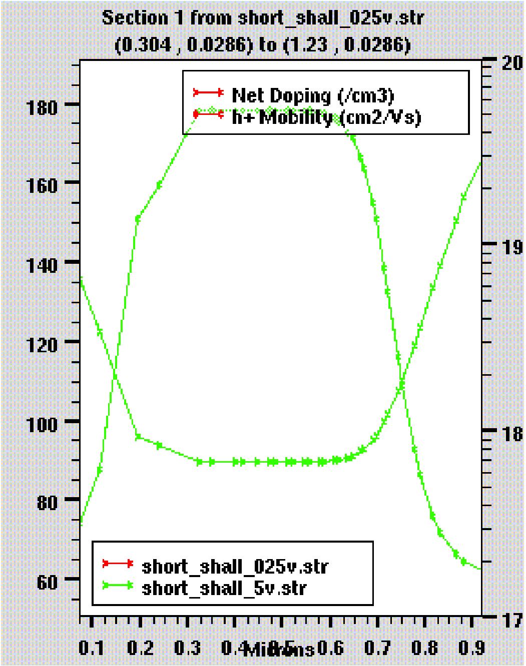

Fig. 5. Hole mobility and doping concentration at T=260 K along a horizontal cutline. Plots overlap for two biases.

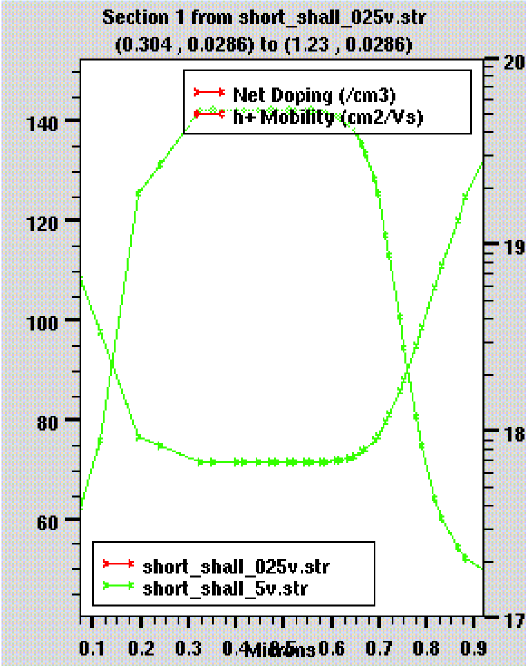

Fig. 6. Hole mobility and doping concentration at T=400 K along a horizontal cutline. Plots overlap for two biases.

2.2 Long structure (19 microns)

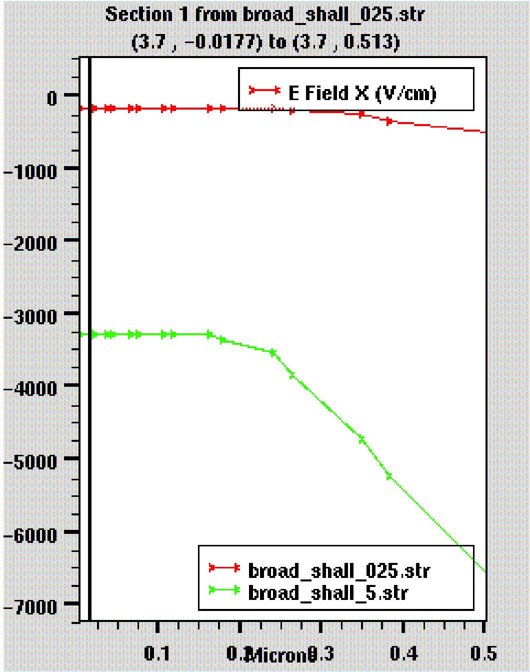

Fig. 7. Electric field in x-direction for a vertical cutline.

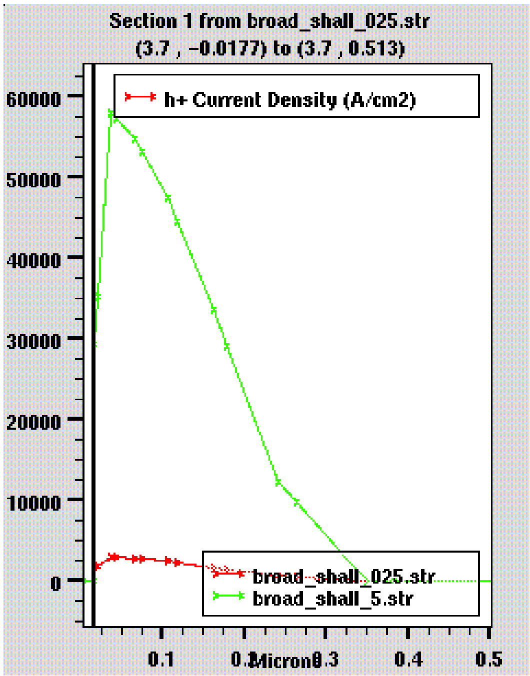

Fig. 8. Hole current density for two biases along a vertical cutline.

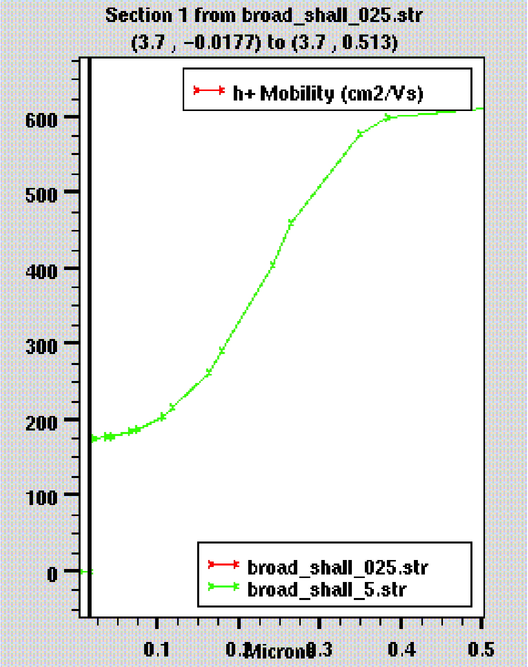

Fig. 9. Hole mobility at T=260 (vertical cutline).

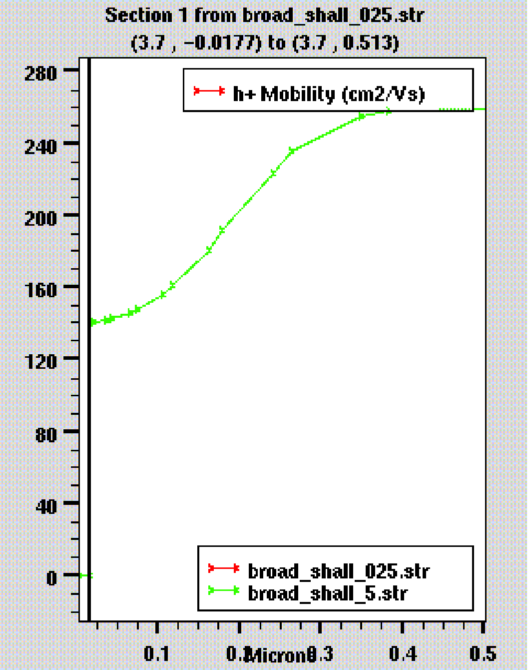

Fig. 10. Hole mobility at T=400 (vertical cutline). It is the same for two biases.

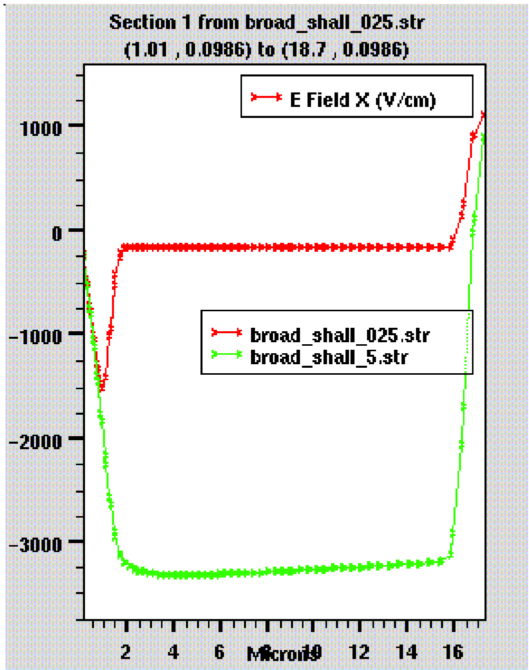

Fig. 11. Electric field in x-direction (horizontal cutline).

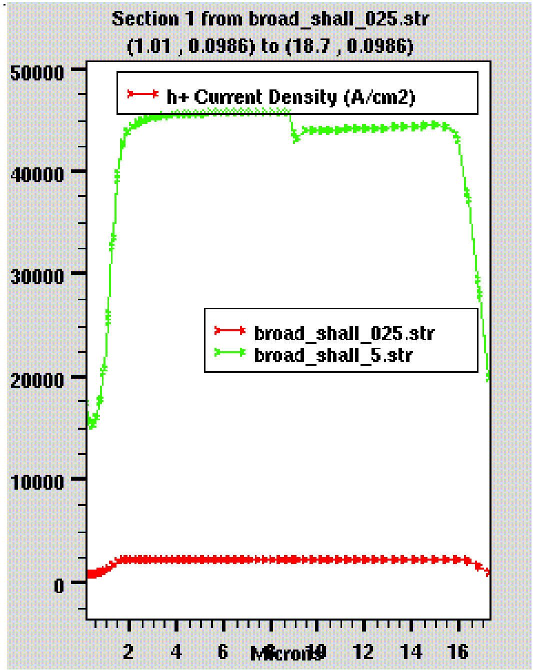

Fig. 12. Hole current density for two biases along a horizontal cutline.

3. SUMMARY

Two different groups of samples were simulated: very short (0.5 micron long piezoresistive p- layer) and relatively long (19 micron long piezoresistive p- layer). Both structures have very shallow junction depth (0.4 microns).

From hole mobility plots for both structures it is clear that electric field, within bias voltages commonly used in applications of this type of devices, has insignificant effect. Thus adjusting length of the piezorezistor with this effect in mind is not going to play an important role.

On the other side, temperature effects are obvious and mobility will depend mostly on the doping concentration in the active p- area. The lower the doping concentration, the higher hole mobility and the larger change over temperature range. Therefore this should be the main consideration for any manufacturing optimization considerations.

At the end, shallow junctions versus deep junctions (0.4 microns vs. 4 microns, for instance) are important only in terms of the doping profile. Namely, with deep Xj structures there is a wider range of the doping concentration contribution to the total current, thus the piezoresistivity will have broader swings over temperature than for shallow Xj structures as in the anbove samples.

4. REFERENCES

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