Electrical Properties and Physical Model of Porous Silicon Layers

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Such significant semiconductor properties as effective doping level and dielectric constant change in porous silicon. These properties determine electric field distribution and avalanche conditions so the key for electrophysical properties of porous silicon lays in breakdown volt-ampere curves.

Breakdown volt-ampere curves for Shotky junction aluminum - porous silicon - 0.1 Ohm*cm n-type silicon [1] are presented on fig. 1. The shape cannot be described as usual breakdown curve. Of course it is possible to explain such shape as a result of composing of a set of diodes with different breakdown voltage, connected in parallel. The distribution of the breakdown voltages is explained by different curvature radius of avalanche centers. But breakdown voltage for porous silicon is significantly higher than for monocrystal one.

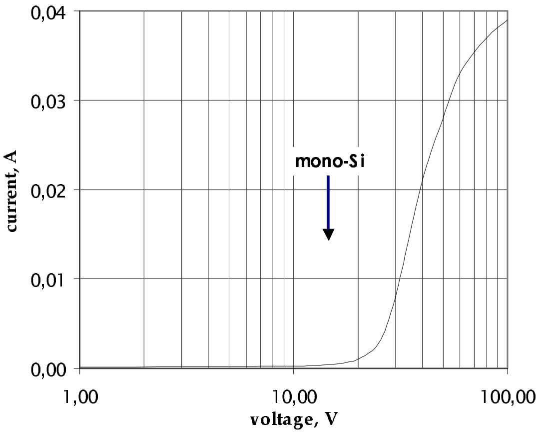

Fig.1

When we considering porous silicon as macro semiconductor material, the space charge density is decreased proportionally to porous silicon density. It correspond to lower effective doping level, so breakdown voltage must be higher. But in porous materials the polarization ability and correspondent dielectric constant decreases too, so electric field at the same charge density is higher, and breakdown voltage must be lower.

Let relative porous silicon density is $\boldsymbol{D}$, dielectric constant of monocrystal silicon is ε_{Si} , than effective dielectric constant ε_D is

$\varepsilon_D = (\varepsilon_{Si}-1)*\boldsymbol{D} + 1$

If space charge density for monocrystal substrate is $\boldsymbol{N}$, than for porous silicon we have the thickness of depletion layer at applied voltage $\boldsymbol{V}$

$W_D \sim \mathrm{SQRT}\,(\boldsymbol{V}\ \varepsilon_D/\boldsymbol{N}\ \boldsymbol{D})$

So it is possible to find the effective $\boldsymbol{N_{eff}}$ at which the thickness of depletion layer in monocrystal silicon at applied voltage $\boldsymbol{V}$ is the same as in porous silicon at the same voltage (the same thickness at the same voltage means that avalanche conditions is the same):

$\boldsymbol{N_{eff}} = \boldsymbol{N}\ \boldsymbol{D}\ \varepsilon_{Si}/\varepsilon_D$

For monocrystal silicon breakdown voltage is approximately proportional to $\boldsymbol{N}^{2/3}$ (in voltage range 8…80 V), so it possible to calculate relative change of the breakdown voltage via $\boldsymbol{D}$. The result is presented in figure 2 (normal line). It is easy to see low increasing (approximately 10% for realistic porosity) breakdown voltage, which cannot explain the experimental data. To forward the model to experimental data we suppose that significant part of silicon wires in silica skeleton are broken, so they are disconnected and can not produce spatial charge. But silicon has high dielectric constant and these wires significantly change macro electrophysical parameters. Below we consider example with total density $\boldsymbol{D}$, but only 1/3 $\boldsymbol{D}$ is perfect wires and 2/3 $\boldsymbol{D}$ is broken wires. So, ε_D is the same, but

$\boldsymbol{N_{eff}} = 1/3\ \boldsymbol{N}\ \boldsymbol{D}\ \varepsilon_{Si}/\varepsilon_D$,

which corresponds to rather realistic breakdown voltage (see fig. 2 – fat line).

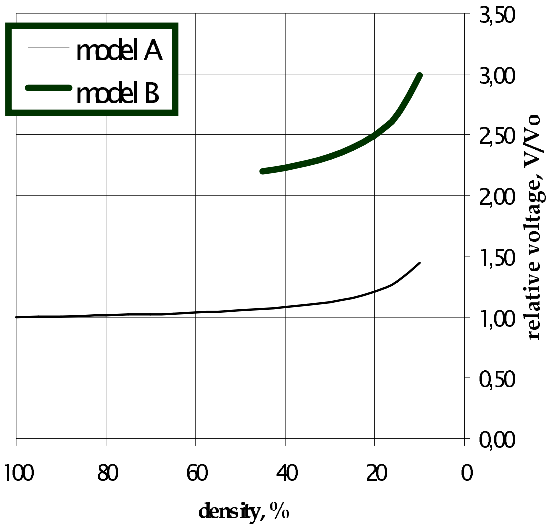

Fig.2

The distribution of the curvature radius of avalanche centers is analyzed by forward and reverse volt-amperes and volt-farads curves. The value of curvature radius is essential for electroluminescence efficiency [2].

1. Lazarouk S., Jaguiro P., Katsouba S., etc./ Applied Physics Letters. – 1996. – Vol. 68. – P.1648
2. Jaguiro P., Ferrari A., Lazarouk S. / Proc. Electrochem. Soc. – 1998. – Vol. PV 97-29- P.194