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Annealing effect on grain boundary width of polycrystalline silicon for photovoltaic application

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Abstract - *Nowadays, LPCVD (Low Pressure Chemical Vapor Deposition) and highly doped polycrystalline silicon films have numerous applications in microelectronic component manufacturing technologies, integrated circuits and solar cells. The complexity of the circuits, and the increasing degree of integration of the components, constantly require improvement and mastery of the properties of this type of material. As part of this work, we are interested in the study of the effect of doping and annealing Effect on grain boundary width of polycrystalline silicon thin films deposited by LPCVD. The results obtained showed, on the one hand, that arsenic doped layers are more resistive than boron doped ones, and on the other hand, and that the diffusion of dopants is generally much greater in grain boundaries than in grains; and considering the importance of the average grain size in the polycrystalline silicon material, which is an important parameter, on which the physical and electrical properties of this material depend.*

Résumé - *Aujourd'hui, le LPCVD (Low Pressure Chemical Vapor Deposition) et les films de silicium polycristallin hautement dopés ont de nombreuses applications dans les technologies de fabrication de composants microélectroniques, les circuits intégrés et les cellules solaires. La complexité des circuits et le degré croissant d'intégration des composants nécessitent une amélioration constante et la maîtrise des propriétés de ce type de matériau. Dans le cadre de ce travail, nous nous intéressons à l'étude de l'effet du dopage et du recuit sur la largeur limite des grains des couches minces de silicium polycristallin déposées par LPCVD. Les résultats obtenus ont montré, d'une part, que les couches dopées à l'arsenic sont plus résistantes que celles dopées au bore et, d'autre part, que la diffusion des dopants est généralement beaucoup plus importante dans les limites des grains que dans les grains ; et considérant l'importance de la taille moyenne des grains du silicium polycristallin, qui est un paramètre important dont dépendent les propriétés physiques et électriques de ce matériau*

Keywords: Polycrystalline silicon - Electrical conductivity - Trap states - Grain boundaries.

1. INTRODUCTION

The polysilicon material has many applications in the manufacturing technology of microelectronic components [1, 2], integrated circuits and photovoltaic generators [3-5]. Circuit complexity and degree of higher and higher integration of components; require constant improvement and control of the properties of this material [6-8].

In many applications, this material is subject to various heat treatments that aim to reduce defects and implanted ions allow to take positions where they are electrically active. On the other hand, as the diffusion of dopants is generally much higher in the grain boundaries than in grains [9-12] and the importance of the average grain size in the polycrystalline silicon material depends on physical and electrical properties of this material.

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This has driven us in this work to study of changes in electrical characteristics of polycrystalline silicon material, subjected to different heat treatments.

2. EXPERIMENTAL

Polycrystalline silicon thin films were deposited by low pressure chemical vapor deposition LPCVD [11] at 670 °C through silane decomposition.

The samples used in this work were 0.688 µm thick polycrystalline silicon films deposited on single-crystal silicon substrate of orientation <111> and resistivity 6 to 12 Ω. cm, with a thin layer (0.1160 µm) of silicon dioxide was used to isolate the films from the substrate.

These samples were highly implanted with Boron and arsenic ions at a dose of 1016 cm^{-2} and energy180 keV. Implantation affected by gas dilution with N_2 which underwent for heat treatments before and after implantation, respectively, at the temperatures ranging from 1000 °C to 1150 °C during 120 min and from 1050°C to 1200 °C during 30 min.

The grain boundary width was examined by a scanning electron microscopy (SEM). The Hall Effect and resistivity measurement were carried out on polycrystalline silicon thin films deposited by LPCVD and doped by boron and arsenic ions.

3. RESULTS AND DISCUSSION

Figure 1 shows that the average size of the grains in the polycrystalline silicon material (not having undergone long heat treatments before implantation), increases with the temperature of the annealing after implantation.

This grain growth is explained by the increase in the coefficient of self-diffusion of silicon in the grain boundaries.

For samples that have undergone a long heat treatment before implantation (1150 °C, 120 min), the average grain size remains constant for temperatures lower than that of annealing before implantation, but increases for higher temperatures; this is due to the temperature of the annealing after implantation, which promotes grain growth, as was shown by Tan *et al.* [13].

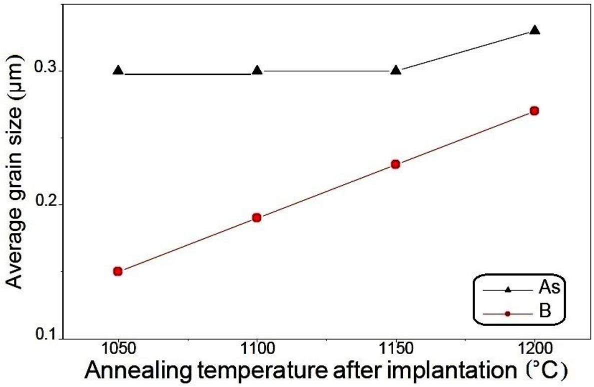

Fig. 1: Average grain size as a function
of annealing temperature after implantation

Figure 2 shows that the average width of the grain boundaries increases as the annealing temperature after implantation increases; this can be explained by the growth of the grains which causes the disappearance of a certain number of them, therefore, the merging of some joints, and consequently the increase of their average width,

On the other hand, the difference between the average grain boundary widths of either arsenic or boron doped films is probably due to the strong presence of arsenic atoms at the grain boundaries, which could disturb grain surroundings during temperature processing.

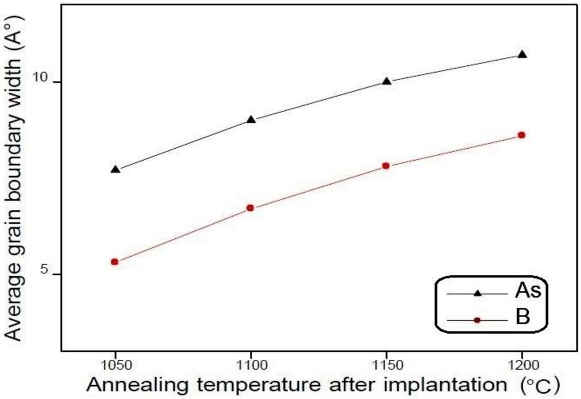

Fig. 2: Average grain boundary width as a function of annealing temperature after implantation.

Figure 3 shows the decrease in resistivity when the annealing temperature after implantation increases. This decrease in resistivity can be attributed to rearrangements of the ring network atoms and to grain growth, and consequently to the reduction of the density of trap states and segregation sites [14].

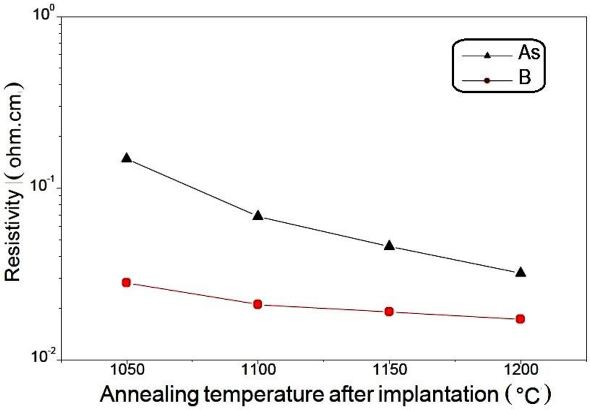

Fig. 3: Resistivity as a function of the annealing temperature after implantation

4. CONCLUSION

This work concerns the study of grain boundary width of polycrystalline silicon, doped with boron or arsenic by ion implantation, and subjected to different heat treatments.

These layers, we characterized them by Hall Effect measurements and SEM.

The results obtained allow us to observe that for the same dopant concentration; arsenic doped layers are more resistive and contain fewer free carriers than boron doped layers. In addition, arsenic atoms have a greater tendency to segregate at grain boundaries than boron atoms.

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