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Abstract

Polly-Silicon Films obtained by $\mu PCVD$ were studied with respect to their structural and electrical properties influenced by rapid thermal annealing (RTA) in vacuum. In addition an annealing in H_2 atmosphere at atmospheric pressure was curried out. The structure and the morphology of the films were studied by Reflection High Energy Electron Diffraction (RHEED) technique and Scanning Electron Microscopy (SEM), respectively. An effect of increase of the crystallinity of the poly-Si films was observed as a result of RTA annealing. These observations coincide well with the measured sheet resistance of the layers. It was found that sheet resistance of the as-deposited films is about $5M\Omega/\Box$ and it decreases to a value of about $1.6M\Omega/\Box$ in dependence on the annealing.

1. Introduction

Poly-crystalline silicon layers are largely used in microelectronics devices [1]. A number of authors [2,3] have intensively studied the properties of the poly -Si thin films used as a gate electrode in MOS devices. The surface morphology and the structure of the poly-Si films depend on the oxygen content as well as on the water vapors content in the gases [4]. Additional thermal annealing of the films is also of importance for the properties of the poly-Si films. The goal of the present work is to study the properties of $\mu PCVD$ poly-Si influenced by rapid thermal annealing.

2.Deposition and measuring techniques

All studied samples were obtained in an industrial type $\mu PCVD$ reactor. The substrates were 3 inch n-type mono crystalline silicon wafers with orientation [100] and resistivity of $4 - 6\ \Omega \times cm$. The standard for the microelectronics technology chemical cleaning of the substrates was applied before and after oxidation. Wafers were oxidized in water vapors at a temperature of $1000°C$. Oxide layers of $0,2\mu m$ thickness were obtained.

For a deposition of poly-Si a pure $100\% SiH_4$ was used. During the deposition the substrate temperature was $T_{sub} = 650°C$, the pressure in the reactor chamber was $P = 0,5torr$, and the flow rate of 100% SiH_4 was 280 l/min. The deposition rate of poly-Si films was 95 $\AA/sec$. The thickness of the studied samples of poly-Si layers was of $4500\AA$.

Rapid Thermal Annealing (RTA) was carried out in a vacuum chamber under 2.10^{-5} torr pressure and the temperature during annealing was in the range of $800°C$ to $1350°C$. For sheet resistance measurements a technique which involves measurement of the current between two mercury probes was used. In order to ensure good contacts the area covered by the mercury was larger

than the area between the mercury probes. The current through the poly-Si was measured by a pico -ampermeter and after that the sheet resistance was calculated.

The structure of the films was studied by the Reflection High Energy Electron Diffraction (RHEED) technique and the surface morphology - by Scanning Electron Microscopy (SEM) using JEOL-5300.

3. RESULTS AND DISCUSSION

In Table 1 the results from the resistance measurements are shown. The sheet resistance of the films changes in the range $5G\Omega/\square$ - $1,6G\Omega/\square$. For as-deposited films, as well as for those, submitted to RTA treatment at $800°C$ for $15sec$,$30sec$, and $1min$ the value of the sheet resistance measurement is in the range of $5G\Omega/\square$. The lowest value of the sheet resistance obtained for $800°C$ was $4,2G\Omega/\square$. When the RTA temperature was increased from $1000°C$ to $1200°C$ but the time of the annealing is no longer than $15sec$, the sheet resistance keeps the same value. If the RTA temperature is $1350°C$ and the annealing time exceeds $30sec$, the sheet resistance is $1,6G\Omega/\square$. For temperatures of $1000°C$ the sheet resistance reaches the values of $2,5G\Omega/\square$ for $3min$ and $5min$, and at $1200°C$ these values are $1,7G\Omega/\square$ even for annealing $30sec$. The tendency which can be seen is that for the higher RTA temperatures - $1200 - 1350°C$, the sheet resistance decreases after the first $30sec$ and keeps this value for annealing up to $5min$.

SHEET RESISTANCE $G\Omega/\square$				
	RTA $T°C$			
TIME	800	1000	1200	1350
$5sec$	5.0	5.0	5.0	4.2
$30sec$	5.0	*	1.7	1.6
$1min$	5.0	4.2	1.7	1.6
$3min$	4.2	2.5	1.7	1.6
$5min$	*	2.5	1.7	1.6

Table 1. Sheet resistance of poly - Si films after RTA.

Some of the samples were annealed in H_2 atmosphere for $5min$ and $15min$ at the temperature of $800°C$. These samples have sheet resistance $2,5G\Omega/\square$ and $50\mu/\square$ respectively. This decreasing of the sheet resistance is due to the hydrogen sorbtion at the surface of the poly-silicon layers.

From the results of the morphology studies it may be concluded that the poly-Si layers consist of small grains with size of $1000\mathring{A}$ and only for temperature of $1350°C$ and annealing time of $5min$ grains with size of $1300 - 1500\mathring{A}$ (Fig.1a) are observed. The RHEED studies of poly-Si layers show that as-deposited layers are polycrystalline (Fig.1b) and when the RTA temperature and annealing time increase the texture of the films becomes better expressed (Fig2a, Fig.2b). For $1350°C$ and

annealing times of $15sec$ and $5min$ (Fig.4b and 4c) this tendency is most evident and this may be the ground for the explanation of the sheet resistance which decrease at these conditions.

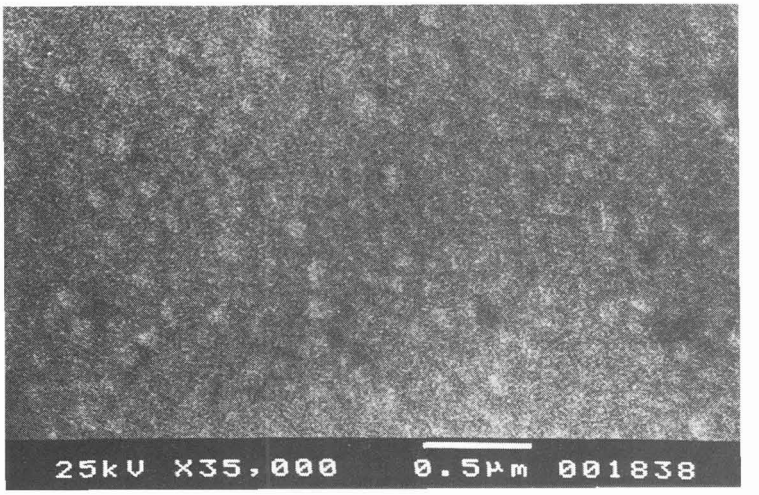

Fig.1a). SEM micrograph of as deposited poly-Si film.

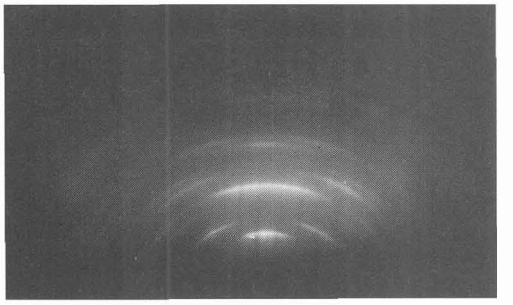

Fig.1b). RHEED of as-deposited poly-Si layer.

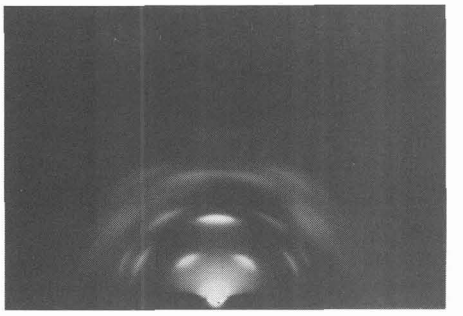

Fig.2a RHEED pattern of poly-Si film (RTA, 800^0C, 1 min).

On Fig.3 the RHEED pattern of poly-Si annealed at $800°C$ for $5min$ in H_2 atmosphere is presented. It can be seen that there is a hallo which is due to the hydrogenation of the poly-Si layers or to the SiO_2 thin layer obtained during annealing because the oxygen concentration in the hydrogen gas used was about 1-3 ppm.

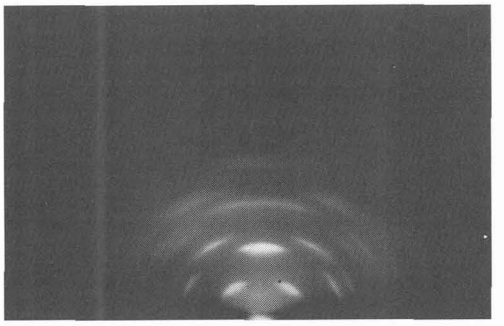

Fig.2b RHEED of poly-Si film (RTA, 1000^0C, 5 min).

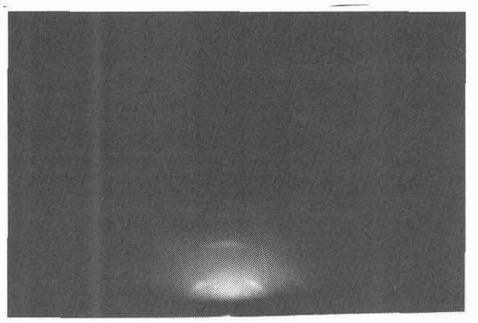

Fig.3. RHEED of poly-Si annealed at 800^0C for 5 min in H_2 atmosphere.

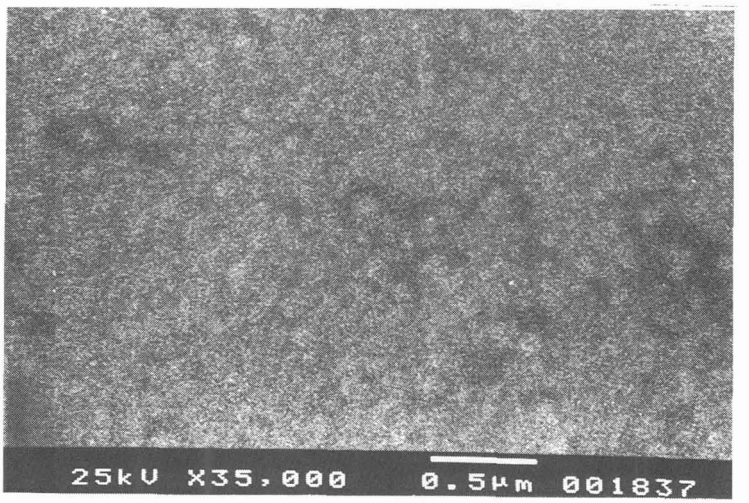

Fig.4a. SEM micrograph of poly-Si film (RTA 1350^0C, 15 sec.

4.CONCLUSION

It is established that the sheet resistance of poly-Si films decrease from a value of $5G\Omega/\square$ to $1.6 - 1.7G\Omega/\square$ for $30sec$ RTA annealing time and temperatures of $1200 - 1350°C$.

Surface morphology is not changed considerably after RTA (grain sizes are about $1000 - 1500\mathring{A}$) but in the films structure an well expressed texture is observed.

In as-deposited poly-Si, annealed in H_2 atmosphere at atmospheric pressure a surface destruction was observed.

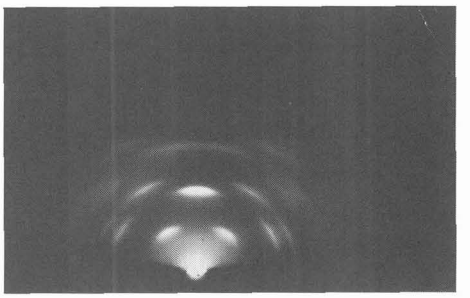

Fig.4b RHEED of poly-Si film (RTA 1350^0C 15 sec).

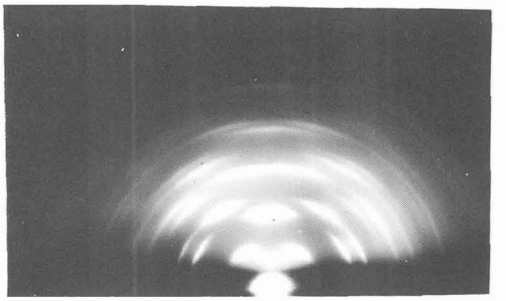

Fig.4c RHEED pattern of poly-Si film (RTA 1350^0C, 5 min).

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