Four-point probe and FTIR characterization of bilayer films based on silicon annealed at □57□C

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Abstract

The present paper focuses on the study of electrical and physico-chemical properties of films deposited by Low Pressure Chemical Vapor Deposition or (LPCVD). These films are composed of two layers, boron doped polysilicon (polySi) and nitrogen doped polysilicon (NIDOS). The results indicate that the resistivity values increases versus increasing of the annealing duration, this can be explained by the formation of B-N complex. However, Fourier Transformation Infrared Spectroscopy Analyses (FTIR) results show, the increase of the absorbance intensity of B-N complex with increasing of annealing duration. Therefore, the formation of B-N bond tends to degrade the electrical properties of polySi/NIDOS by the decrease electrically active boron density in polycrystalline.
Keywords: Bond, boron, nitrogen, resistivity.

1. Introduction

The use of the polycrystalline silicon elaborated by LPCVD have opened a vast field of research to improve the performances of various electronic devices, in particular transistors MOS [1-3]. The main aim of these researches is the improve of the polysilicon gate, to satisfy the requirements of the devices miniaturization and to ensure the good operating conditions of the MOS structure. Among these conditions, it is necessary to be able to maintain the quality of the interface gate/oxide by decreasing the tunnel current in the oxide. And in order to avoid the boron impurity which diffuses deeply in the oxide coating, several solutions have been proposed [4-7]. In order to improve the oxide quality of MOS component, the authors in the present work focus on the study of electrical and physical-chemical properties of a new bilayer film polySi/NIDOS annealed at 850°C for different durations.

2. Experiments

2.1. Samples elaboration

The samples consist of two polysilicon layers deposited by low pressure chemical vapor deposition (LPCVD), on oxidized single crystal silicon substrates (P-type, 0.025-µm-oxide thick). The first layer deposited from disilane (Si_2H_6) and ammonia (NH3) (about 0.2-µm-thick), was in-situ nitrogen doped. On this later, a second polysilicon layer deposited by the disilane and boron trichloride (BCl_3) was also in-situ boron doped (about 0.13-µm-thick). Finally the samples were thermally annealed at 850°C for different duration. (See figure1).

Fig.1. Sample structure.

2.2. Films Characterization

The purpose of the 4-point probe is to measure the resistivity of films. The measurement was performed on EPS-08 alessi apparatus (Fig.2), with "S" is an equidistance of 1 mm between the four aligned points, and W is the polySi layer thickness. Moreover, infrared (IR) transmission spectroscopy was performed on Avatar-360 FTIR spectrometer. The spectra were acquired between 4000 and 400 cm^{-1}. This technique is used to evaluate the evolution of the chemical structure with the annealing conditions.

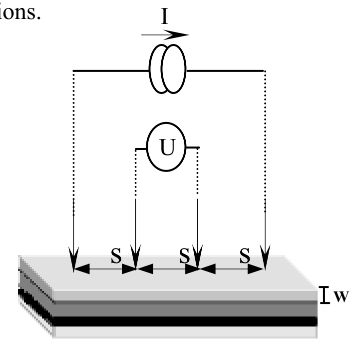

Fig.2. Resistivity measurements with the four probes method.

3. Experimental results

3.1. Electrical characterisation results

Figure 3 shows the evolution of resistivity values at 850°C with annealing duration. One can notice that resistivity increases according to annealing duration. The values of resistivity are around $4x10^{-3}$ Ω cm for period's ≤ 120min. beyond 120min we see a slight increase resistivity up to $8x10^{-3}$ Ω cm.

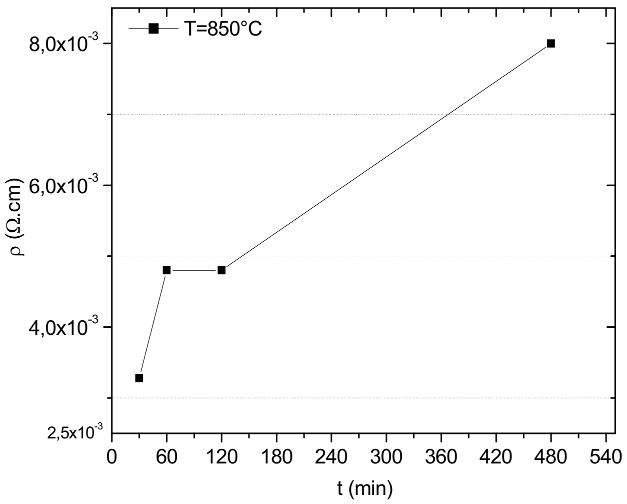

Fig. 3. Evolution of the resistivity versus annealing duration.

This can be explained by a slight decrease in the electrical activity of boron atoms. This phenomenon can be attributed to the formation of B-N complexes. These complexes make the boron displacement more difficult in the crystal by preventing it from reaching substitution sites, which decreases its electrical activity. This result highlights the influence of the nitrogen atoms on the electrical activity of boron, while keeping the good conductivity of the film [8].

3.2. Physicochemical characterisation results

Figure 4 show the IR absorption spectra recorded between 4000cm^{-1} and 400 cm^{-1} of films PolySi/NIDOS at 850°C for different duration.

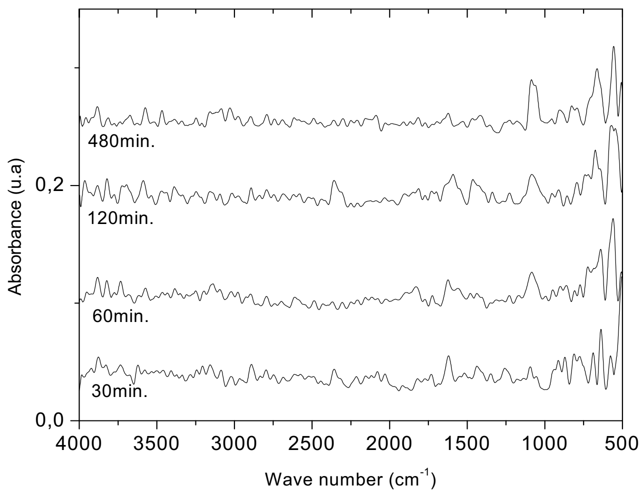

Fig. 4. PolySi/NIDOS spectra of samples annealed at 850°C for different duration.

The results obtained by Fourier transformation infrared spectroscopy analyses allow characterizing the various chemical bonds of the structure. The results showed the appearance of several bonds in the material. The main peaks appear in the wave number located between 600cm^{-1} and 1700cm^{-1} (see figure 5). The peak located around 730cm^{-1} and 790cm^{-1} assigned to B-N-B bond [9,10,11] and the bonds located at 910 cm^{-1}, 950cm^{-1}, 860 cm^{-1}, 1150 cm^{-1},1250 cm^{-1} et 1320 cm^{-1} were assigned to Si-N bond [12,13,14]. Moreover the peaks located around 808, 1382, 1400, 1450 et 1610 cm^{-1} are attributed to B-N [14,15,16,17,18].

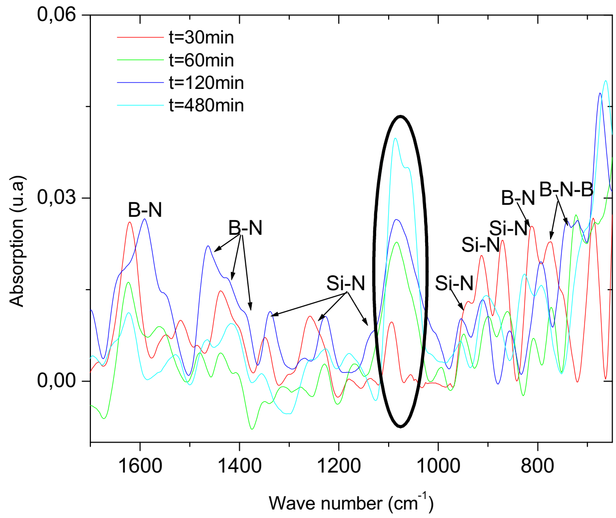

Fig. 5. The principal peaks appear in the wave number located between 600cm^{-1} and 1700cm^{-1} for PolySi/NIDOS films.

Figure 5 showed that the intensities of B-N-B and Si-N decrease when the annealing duration increases. This can be explained by the dissociation of these bonds, which can improve the films conductivity by boron atom detachment in Silicon matrix. Moreover, we find a strong bond around 1075 cm^{-1} increases with duration, which requires a deconvolution (Fig.6).

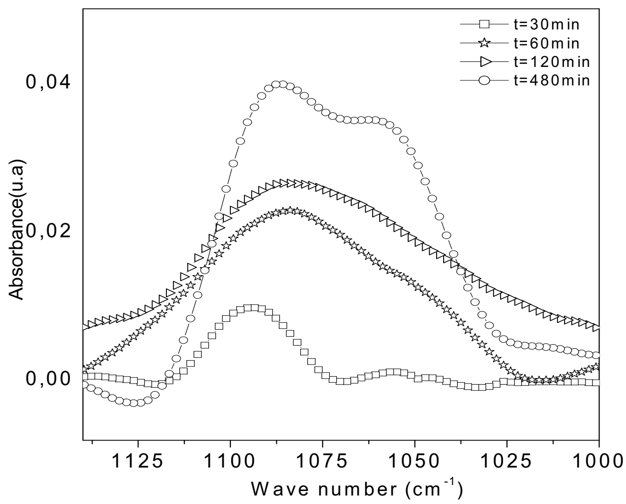

Fig. 6. Zoom of large bond located between 1000cm^{-1} and 1150cm^{-1} .

The deconvolution of theses curves are reported in figures 7 (a,b,c and d), we observe the emergence of two new absorbance peaks located at 1050 and 1083 cm^{-1} respectively, assigned to the B-N [15,16].

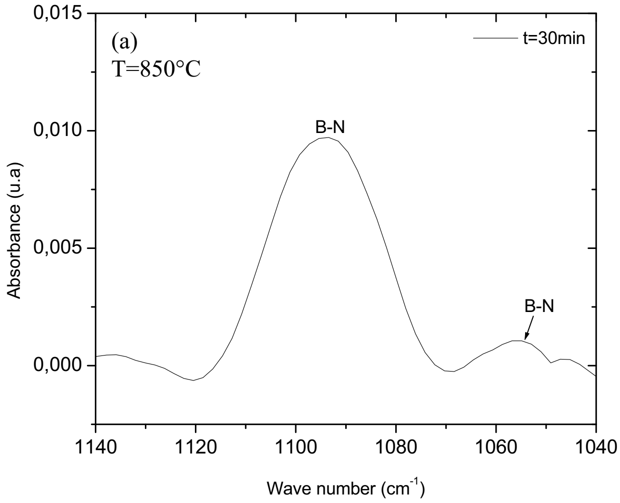

Fig. Ka. Deconvolution of the absorption band located between 1000 cm^{-1} and 1150 cm^{-1}.

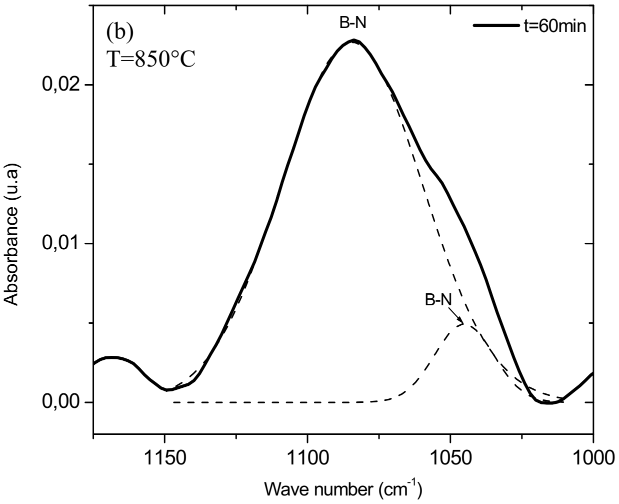

Fig.Kb. Deconvolution of the absorption band located between 1000 cm^{-1} and 1150 cm^{-1}.

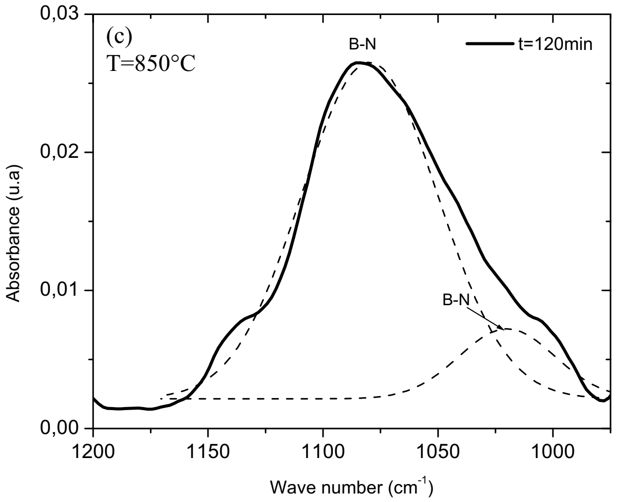

Fig. Kc. Deconvolution of the absorption band located between 1000 cm^{-1} and 1150 cm^{-1}.

The deconvolution results (Fig.8 a and b) show the increasing of the B-N bond intensity located at 1058 cm^{-1} and 1083 cm^{-1} after 120 min. This explains by the increase of the B-N concentration in the films.

These results can be re-explained by the FTIR analysis conducted by Chao et al [18] on polycrystalline films implanted boron and nitrogen. Which have found also that the increase of the density of the complex B-N opposes the diffusion of boron atoms. So, that fortifies our conclusion about the resistivity measurements of the polySi/NIDOS films, which showed a slight increase in resistivity attributed to a weak electrical inactivation of boron.

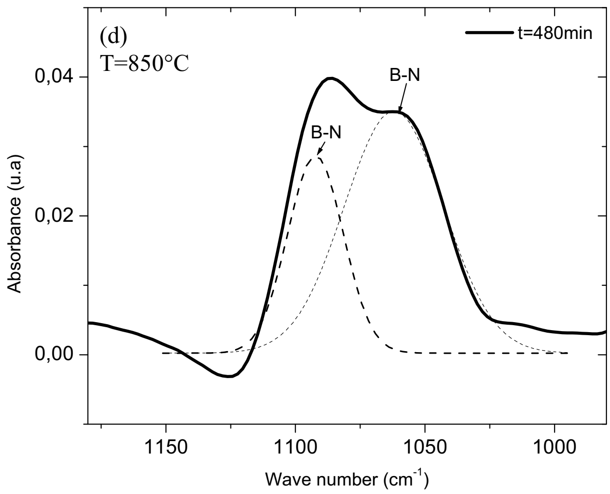

Fig. Kd. Deconvolution of the absorption band located between 1000 cm^{-1} and 1150 cm^{-1}.

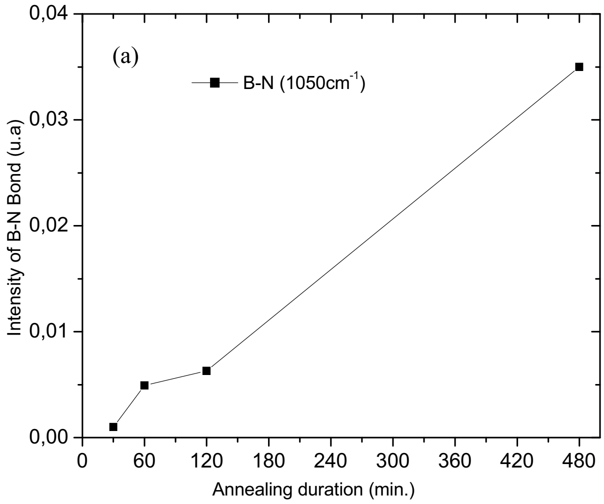

Fig. □a. Evolution of the intensity of B-N peaks located from 1050 cm^{-1} to 1083 cm^{-1} as a function of annealing duration.

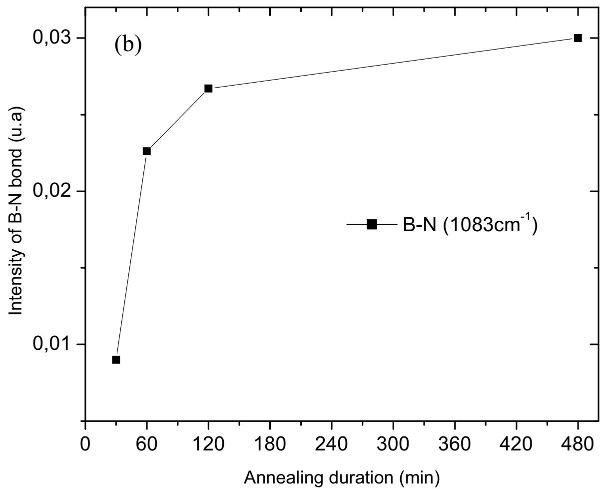

Fig. b. Evolution of the intensity of B-N peaks located at 1083 cm^{-1} as a function of annealing duration.

4. Conclusion

Four-point probe and FTIR characterization of bilayer films deposited by LPCVD have been presented. The resistivity results indicated that films have better resistivity when the film is annealed at duration bottom 120 min. After 120 min. the resistivity slight increase. This increase of the resistivity has been explained by electrical inactivation of boron in the films. The FTIR confirms the resistivity results by the increases of the B-N bonds in the complex form. From the obtained results one can suggest the use of this material as gate structure for micro-electronics applications when the annealing duration is little or equal 120 min.

5. References

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