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Experimental Study Of The Boron Redistribution In Two Series Of Bilayer Films Silicon-Based

Lynda SACI [1], Ramdane MAHAMDI [2], Farida MANSOUR [1], and Pierre TEMPLE-BOYER [4]

[1]LEMEAMED Laboratory, Department of Electronics University Mentouri
Constantine 25000, Algeria
[2] Departement of Electronics University Hadj Lakhdar Batna, 05000, Algeria.
[3] CNRS; LAAS; 7 avenue du colonel Roche, F-31077 Toulouse, France.
[4] Universite de Toulouse; UPS, INSA, INP, ISAE; LAAS; F-31077 Toulouse, France.
lynda_saci@ieee.org

Abstract: *The present work focuses on the study two sets of films bilayers obtained by Low Pressure Chemical Vapor Deposition (LPCVD), for use as material to MOS gate structures (transistors, chemical sensor ISFET, etc.). The first series of films are composed by two layers, silicon amorphous un-doped layer (poly1) and polysilicon boron doped in situ (poly2). The second series are constituted by boron doped polysilicon (polySi) and nitrogen doped polysilicon (NIDOS). These films (poly1/poly2/SiO_2 and polySi/NIDOS/SiO_2) are annealed in tem the same conditions of deposit and annealing. The boron concentration is monitored by secondary ion mass spectrometry (SIMS). The superposition between the SIMS profiles of poly1/poly2/SiO_2 and polySi/NIDOS/SiO_2 films have shown that low thermal annealing budget at 600°C/2h, ensures long boron redistribution to the interface poly2/SiO_2. At the contrary, a high thermal budget the second layer (poly2) was recristallyzed and reached to the doped oxide. For polySi/NIDOS films, SIMS profiles confirmed the presence of low nitrogen ($X = 1\%$) which can effectively suppress the boron penetration at the interface NIDOS/SiO_2 by the formation of the complex BN detected by FTIR analysis.*

Keywords: : *SIMS, FTIR, NIDOS, polysilicon, interfac.*

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1. Introduction

The use of polysilicon prepared by LPCVD opens a wide area of research to improve the performance of various electronic devices, especially MOS transistors [1-3]. The research aims to improve the polysilicon gate, to meet the miniaturization of devices and to ensure good performance of MOS structures. Among these conditions, it is necessary to be able to maintain the quality of the interface gate / oxide. To avoid the deep boron diffusion in the oxide layer, several solutions have been published [4-7]. In this paper, we will give our contribution in this field by the experimental study of the boron redistribution in two new series of bilayers films based on polysilicon (Poly1/Poly2/SiO_2 and PolySi/NIDOS/SiO_2) by SIMS technique. These profiles will be studied and discussed for different annealing conditions.

2. Experimental procedure

The two series of bi-layer films (poly1/poly2/SiO_2 and polySi/NIDOS/SiO_2) are deposited on oxidized single crystal silicon substrates (N type, 25nm of thermal oxide SiO_2) in LPCVD furnace.

The first series of films poly1/poly2/SiO_2 consists of silicon amorphous un-doped layer (poly1 about 0.05 µm) obtained from disilane (Si_2H_6), onto which is deposited, from (Si_2H_6) and the boron trichloride (BCl_3), a layer of polysilicon boron doped in situ (poly2 thickness 0.13 nm).

The second series of films (polySi/NIDOS/SiO_2), the Thin NIDOS layer (about 0.2-µm-thick) is in-situ nitrogen doped silicon obtained from mixture of disilane Si_2H_6 and ammonia NH_3 gases. 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).

The weak heat treatment of deposit films (poly1/poly2 /$SiO_2$and polySi/NIDOS/SiO_2) should lead to a uniform doping in the gate and to negligible boron diffusion. Finally, thermal anneals were performed in a conventional furnace under nitrogen (N_2), in temperature range from 600 to 850°C for different durations, to recrystallize the structure and to activate the doping impurity. To be noted that under such anneals, the amorphous layer is fully crystallized, giving a random oriented polysilicon (Poly2). On the contrary, the in situ doped polycrystalline layer (Poly1) is textured, <110> oriented, and do not rearrange [8,9]. Finally, Experimental secondary ion mass spectrometry (SIMS) boron profiles are carried out using an ionic probe of type ‘‘CAMECA

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IMS4F6'' to evaluate the distribution of B atoms as a function of the samples depth. In order to highlight the nitrogen effect of in the second series, the polySi/NIDOS/SiO_2 films was performed by FTIR analysis to the aid of a device type 360 Avatar. This technique allows determining the different chemical bonds it also shows the evolution of the peaks depending on the annealing conditions..

3. Results and discussion

3.1. SIMS profiles

Figure 1 shows the superposition between the SIMS profiles for the films PolySi/NIDOS/SiO_2 Poly1/Poly2/SiO_2 before thermal annealing. We observe a good superposition in both areas. This can be explained by:

(i) **Zone1 (poly1 and PolySi)**: is polysilicon doped with boron in situ in both series of films.

(ii) **Zone 2 (Poly2 and NIDOS)**: is amorphous silicon in the two series of films: undoped in the first one, and in-situ doped with nitrogen in the second with a nitrogen content of 1% in the NIDOS layer

Figure 2 shows the superposition of the experimental SIMS profiles of the poly1/poly2 /SiO_2 and polySi/NIDOS/SiO_2 films annealed at 600°C/2h. We note that the superposition of the experimental SIMS profiles of the films is satisfactory in both areas. So at this annealing condition the redistribution of boron in two films produced in the same way. This can be explained by a structural or morphological merger of the two series of films. In addition, we can say that the effect of nitrogen does not appear at 600°C/2h.

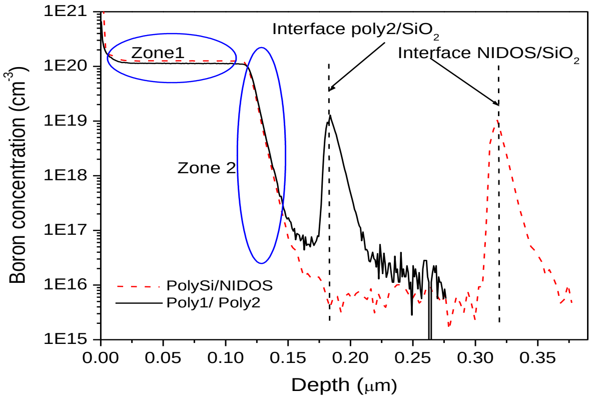

Figure 1. Superposition of SIMS profiles before annealing.

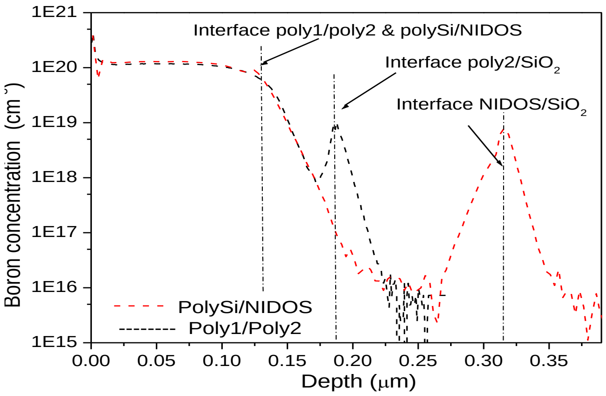

Figure 2. Superposition of SIMS profiles after annealing at 600°C/2h.

Figures 3, 4 and 5 shows the superposition of the experimental SIMS profiles of the two series of films treated at 600°C/8h, 700°C/30min and 700° C / 2h.

We note that the superposition of SIMS profiles in the first zone is very close. So the boron redistribution almost occurs identical in poly1 and polySi layers.

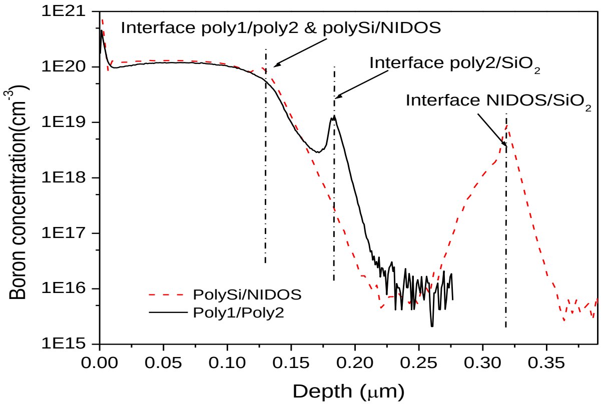

Figure 3. Superposition of SIMS profiles after annealing at 600°C/8h.

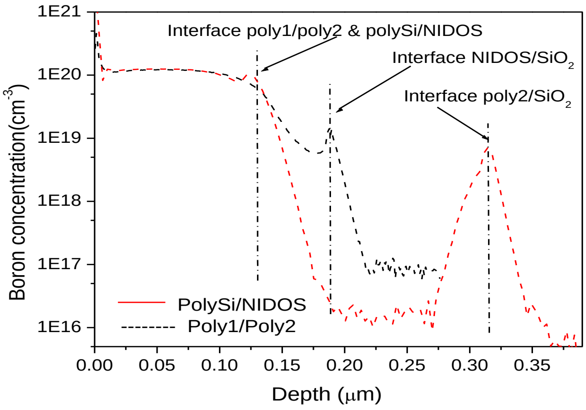

Figure 4. Superposition of SIMS profiles after annealing at 700°C/30min.

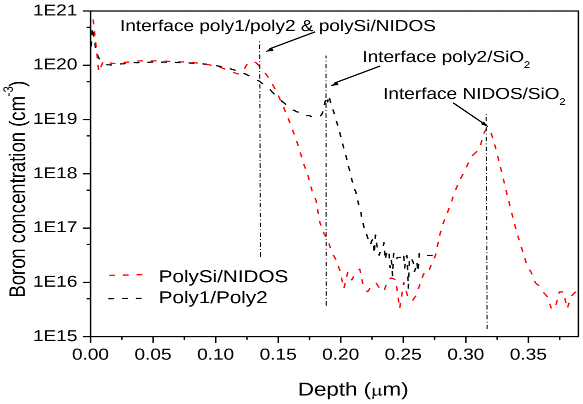

Figure 5. Superposition of SIMS profiles after annealing at 700°C/2h.

This can be explained by the similarity of the texture layers. By cons, in the second zone, it is clear that The SIMS profiles do not follow according temperature increasing. We notice a shifting of SIMS profiles along the depth right axis. This shifting is very pronounced in the poly2 than NDOS layer according temperature increasing. This can be explained by:

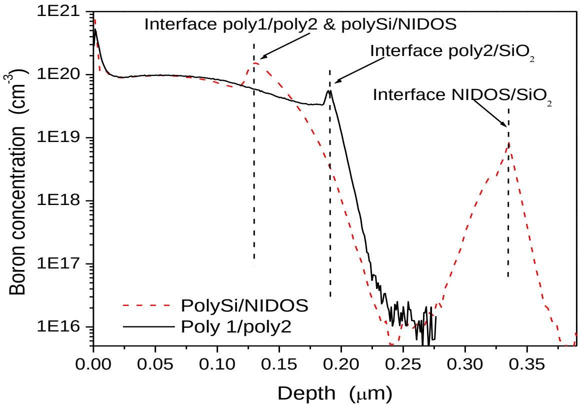

Figure 6. Superposition of SIMS profiles after annealing at 850°C/15min.

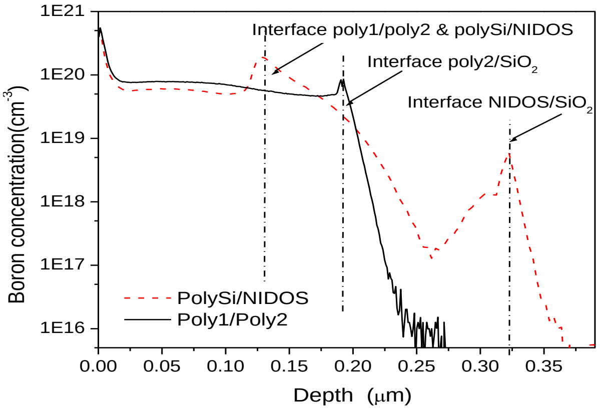

Figure 7. Superposition of SIMS profiles after annealing at 850°C/60min.

In the poly2 layer, the increase of the annealing temperature up to 700°C influences the boron redistribution by more prolonged rearrangement, but it always remains far from the interface Poly2/silicon oxide. In this case, the boron diffusion was also slowed down, due to the presence of Poly2 layer, because the defects found in Poly2 will disappear after thermal annealing at highest temperature. This can explain why at 850 °C (fig.6 and 7), the boron reaches the interface Poly2/SiO$_2$ easily, which degrades the MOS structure reliability [10].

- In the amorphous NIDOS layer, the presence of nitrogen atoms reduces the boron diffusion according to annealing conditions (fig. 6 and 7), because this amorphous layer is fully crystallized, giving a random oriented polysilicon by the presence of N and leading to the formation of clusters/complexes containing N atoms [10-14]. From this observation, we may conclude that the B redistribution occurs far from the NIDOS/SiO$_2$ interface according temperature increasing, this indicating an improvement of the SiO$_2$ quality.

3.2. FTIR results

The FTIR analysis was carried out after the heat treatment.

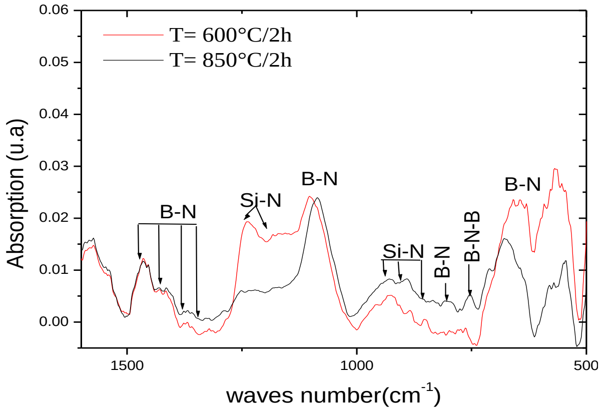

Figure 8. Superposition of FTIR spectrums of the polySi/NIDOS/SiO$_2$ films.

The figure 8 show The IR absorption spectra of the polySi/NIDOS/SiO$_2$ films annealed at 600°C and 850 cm^{-1} for a period of two hours.

We are interested the bonds related to nitrogen atom, which located from 600cm-1 to 1500 cm^{-1} (fig. 8). This zone revealed the formation of various peaks as, The peak situated around 1400, 1321, 1080, 1040 and 626 cm^{-1}, which can be associated to BN bonds [8-12] and the peak located at 752 cm^{-1}, which is assigned to the B-N-B bond [13-15]. Moreover, the absorption bonds located approximately at 1250, 1320, 900, 950, and 860 cm^{-1} assigned to the Si-N bond [16-18].

From this figure we observe that the absorption intensity of the peaks B-N-B and Si-N decrease and increasing of the absorption intensity of the BN peaks. This can be interpreted by the dissociation of the Si-N and B-N-B bond encourages the formation of the BN as complex form. In addition, we note that according the temperature increasing the absorption intensity of the BN complex become more important, which can effectively suppress the boron penetration at the interface NIDOS/SiO_2 and improves the oxide quality.

4. Conclusions

In this work the boron concentration in the two series of bilayers film obtained by LPCVD (poly1/Poly2/SiO_2 & polySi/NIDOS/SiO_2) deposited onto oxidized monocrystalline silicon has been investigated by experimental SIMS profiles. The fitting between SIMS profiles show the redistribution of boron in the two kinds of samples according annealing condition.

At 600 ° C/2h we can use any series of films as gate MOS structure due to the agreement of both SIMS profiles. This may be explained by the absence of the nitrogen effect. Beyond these conditions, the second layer poly2 of (poly1/poly2/SiO_2) films was recrystallized and the boron reached to the oxide. But in the polySi/NIDOS films the SIMS profiles confirmed the presence of low nitrogen which can effectively suppress the boron penetration at the interface NIDOS/SiO_2 even at 850°C which improves the oxide quality. This result is confirmed by the remarkable presence of the BN complex during annealing increasing using FTIR analyses. Finally, and according to the above results, one can propose the use of this bilayer material polySi/NIDOS/SiO_2 as a MOS gate structures (transistors, ISFET chemical sensor, etc.) as one of possible application.

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