Experimental Study of the Boron Redistribution in Bilayer Films Silicon-Based by SIMS Technique

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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 and polySi/NIDOS) 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 and polySi/NIDOS 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.

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 and polySi/NIDOS) 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 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), 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 and polySi/NIDOS) 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 IMS4F6’’ to evaluate the distribution of B atoms as a function of the samples depth.

3. Results and discussion

Fig. 1 shows the superposition of SIMS profiles for the films Poly1/Poly2 and PolySi / NIDOS respectively before annealing. We observe a good superposition in the two zones. This can be explained by:

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

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

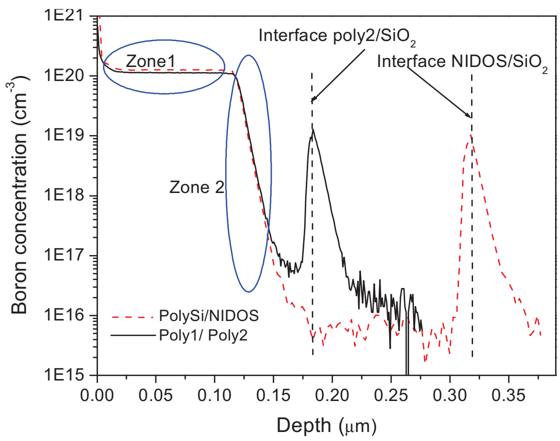

Fig. 1: superposition of SIMS profiles before annealing.

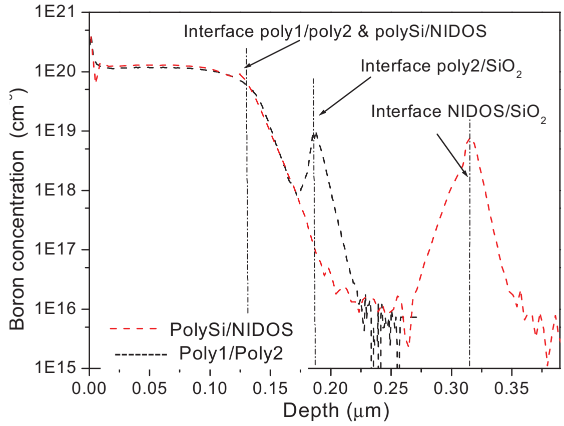

Fig. 2: Superposition of SIMS profiles after annealing at 600°C/2h.

Figure 2 shows the superposition of the two experimental SIMS profiles studied at 600 ° C/2h. We note that the superposition is satisfactory in both areas. So at this temperature 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, the effect of nitrogen does not appear at 600 ° C/2h, because of the good agreement of both SIMS profiles.

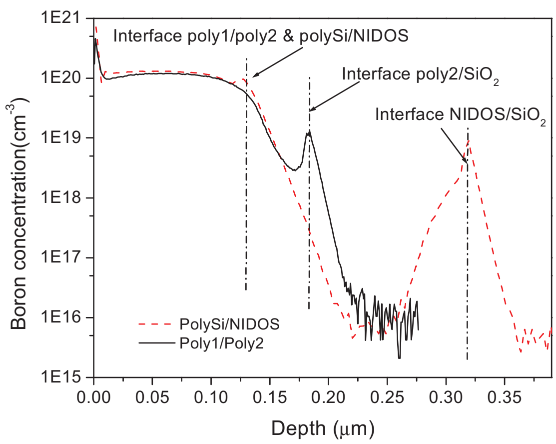

Fig. 3: Superposition of SIMS profiles after annealing at 600°C/8h.

Figures 3, 4 and 5 illustrate 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.

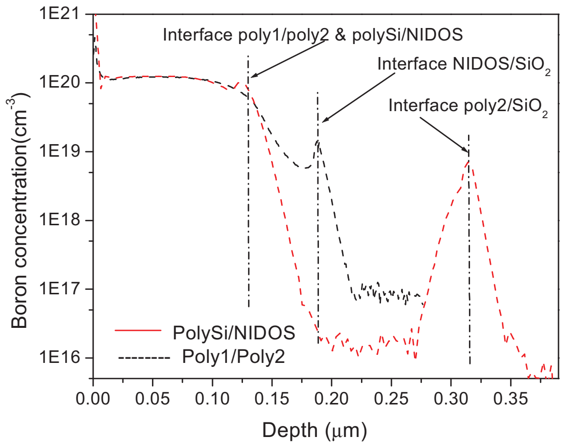

Fig. 4: Superposition of SIMS profiles after annealing at 700°C/30min.

We note that the superposition in the first zone is always respected. This can be explained by the same homogeneity of the two layers poly1 and polySi. So, the redistribution of boron occurs in much the same way, in the first zone. By cons, in the second zone, it is clear that increasing the temperature affected the redistribution of boron in a different way for both amorphous poly2 and NIDOS layers.

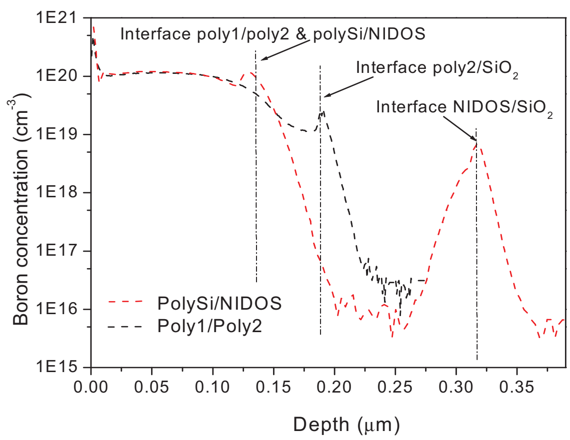

Fig. 5: Superposition of SIMS profiles after annealing at 700°C/2h.

According to the figures (3, 4 and 5), we notice a shift of the profiles to the right depth axes. This discrepancy is pronounced in the poly2 compared by NIDOS laye. This can be explained by:

-In the poly2 layer, the increase of the annealing temperature up to 700°C influences the redistribution of boron by more prolonged redistribution, 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].

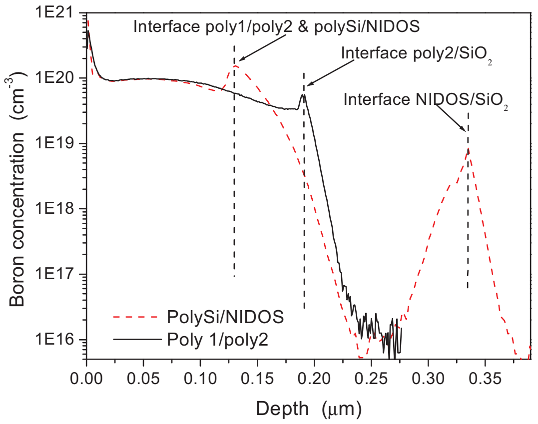

Fig. 6: Superposition of SIMS profiles after annealing at 850°C/15min.

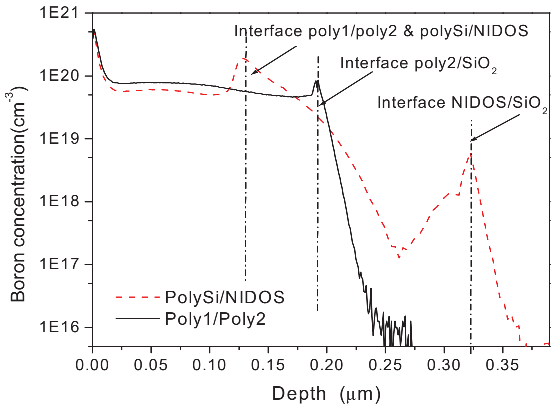

Fig. 7: Superposition of SIMS profiles after annealing at 850°C/60min.

-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 indicating an improvement of the SiO_2 quality.

4. Conclusion

In this work the boron concentration in the two series of bilayers film obtained by LPCVD (poly1/Poly2 & polySi/NIDOS) 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 poly 2 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. 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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