ION SYNTHESIS OF SOI STRUCTURES WITH LEAD-SILICATE INSULATOR

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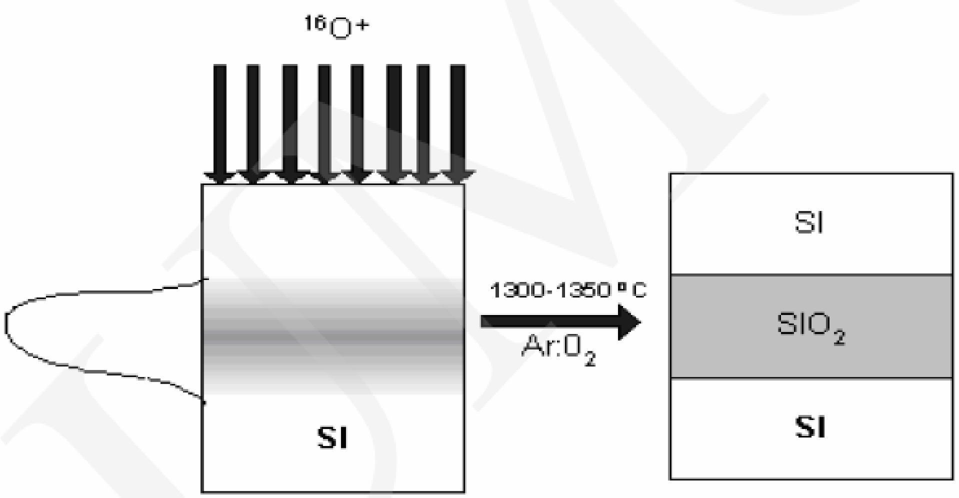
Separation by Implantation of Oxygen (SIMOX) is one of leading methods to produce SOI wafers

1. High-Dose material
   (standard SIMOX process)
   Stochiometric Doses:
   (1.2−2)×10^{18} O^+/cм^2
   BOX(Buried OXide): 400 nm

2. Low- Dose material
   (ITOX-process)
   Substochiometric Doses:
   (3-5)× 10^{17} O^+/cм^2
   BOX: 90 nm (implanted oxide)+ (10-20) nm (internal oxidation)

3. Modified Low-Dose material
   (DIBOX -process)
   Two-stage implantation
   Substochiometric Doses:
   (2-3)× 10^{17} O^+/cм^2
   BOX (Defect-Induced) : 55 nm

There are two essential stages within method: implantation and annealing



SIMOX by Katsuoshi Izumi, Peter L.F.Hemment, Atsushi Ogura, Harold J. Hover, Devendra K.Sadana. Institution of Engineering and Technology, 2004 p.160

Ion synthesis of SOI structures with silicate insulators

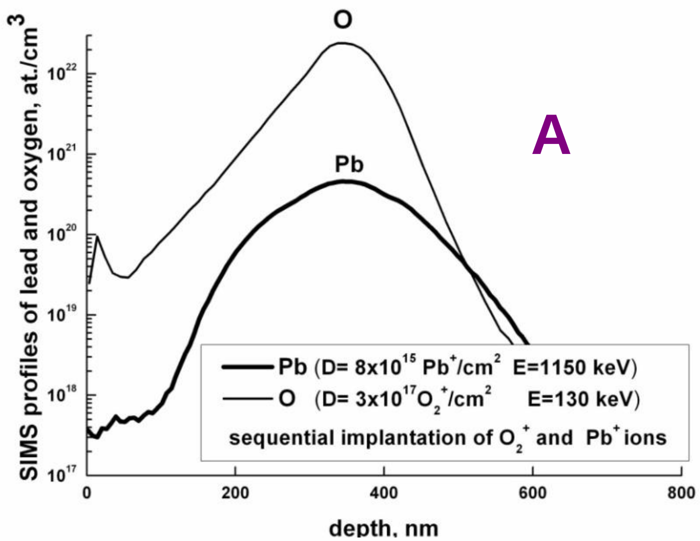
With the aim of further improving the process, specialists of Valiev Institute of Physics and Technology (Yaroslavl Branch) proposed a method based on the transition to the formation of a buried silicate layer instead of an oxide one. It provides for the implantation of a glass former ion in addition to a reduced dose of oxygen. Boron was previously tested as a glass former element [1-4]. In this case, it was possible to significantly reduce energy costs at an annealing stage and to offer devices with new circuit solutions [3]. This paper presents the results of an experimental study of the ion synthesis of SOI structures with a lead-silicate insulating layer.

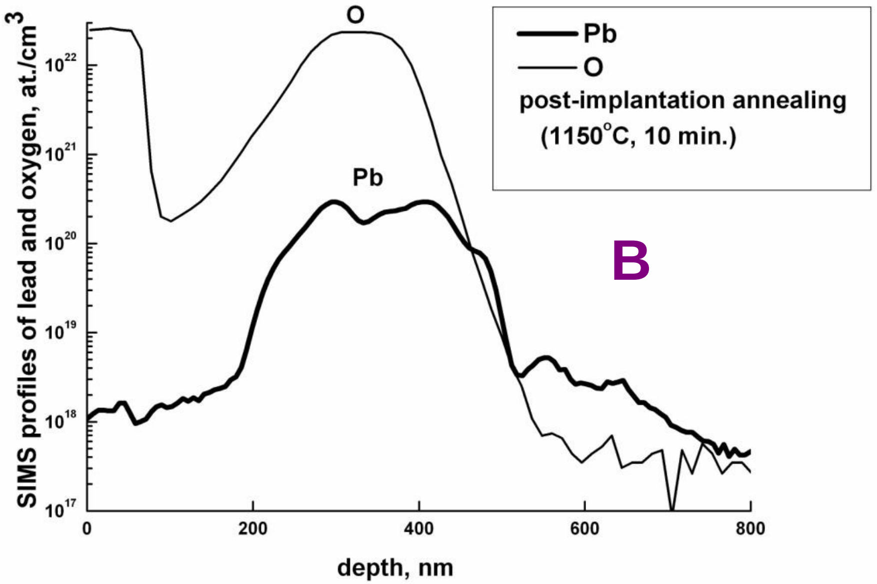
- 1. Ed.Yu. Buchin, Yu.I. Denisenko, S.A. Krivelevich, and R. V. Selyukov. Diffusion and phase formation in ternary silicate systems framed by an ion bombardment.// Micro- and Nanoelectronics 2005, edited by Kamil A. Valiev, Alexander A. Orlikovsky; Proc. SPIE, V. 6260, 626007, 2006. doi.org/10.1117/12.677013
- 2. RU Patent 2193803C2, 2001, Jan. 09. Method of ion synthesis in silicon of a buried insulator layer
- 3. RU Patent 2235388, 2002, Nov. 10. Method of manufacturing a MOS transistor with local sections of a buried insulator
- 4. Ed.Yu. Buchin, Yu.I. Denisenko. Ion synthesis of silicon-on-insulator structures with a lead-silicate insulating layer//Technical Physics Letters, 2021, Vol. 47, No. 7, pp. 733–736. doi.org/10.21883/PJTF. 2021.14.51188.18773

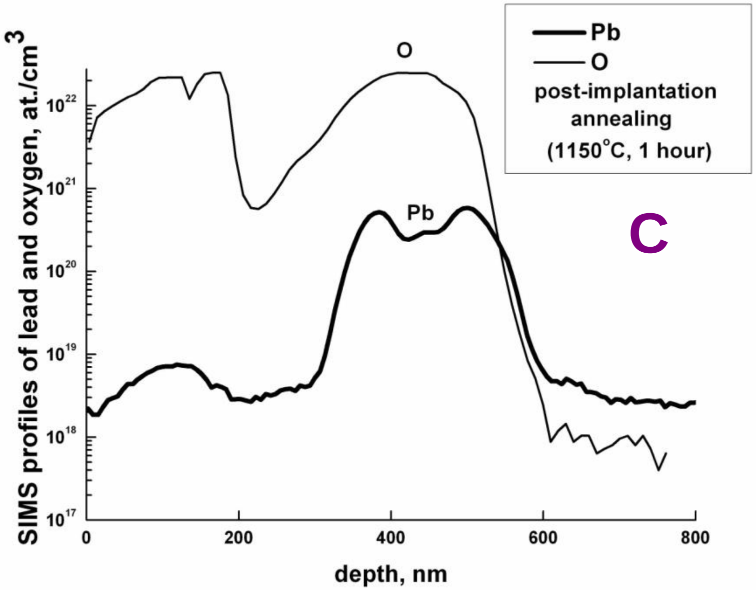
Ion synthesis of SOI structures with lead-silicate insulating layer

The experiments were carried out with n-type (100)-oriented silicon substrates (4.5 Ohm·cm). At beginning they were irradiated with molecular oxygen ions at a dose of 3×10^{17} O_2^+/cm^2 (at an energy of 130 keV) and at a temperature of the substrate of 550°C. On the second stage, the lead ions were implanted with a dose 8×10^{15} cm^{-2} (at an energy of 1150 keV) and at room temperature of the substrate. So the atomic ratio of implanted oxygen and lead was of 75:1. Then the substrates were annealed in oxygen-content ambient at a temperature of 1150°C in the temporal range from 10 minutes to 8 hours.

Formation of SOI with lead-silicate insulator layer (annealing process at 1150°C up to 1 hour)

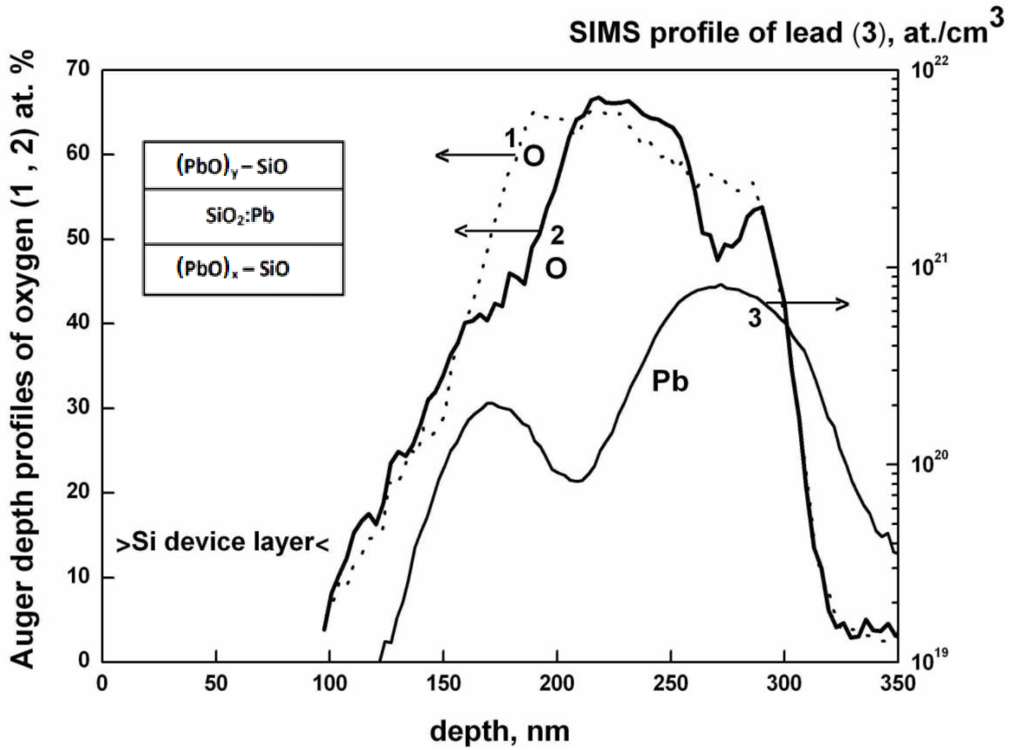






The figures show SIMS profiles of the distribution of main implanted components. The lead is non-uniformly distributed over depth, and its highest concentration observed at the boundaries with silicon. This is due to a segregation of the lead into inhomogeneous regions between adjacent phases. As a result, a three-layer insulator structure is formed. In its central part, the oxygen content reaches the stoichiometric level of SiO_2 - 67 at.%.

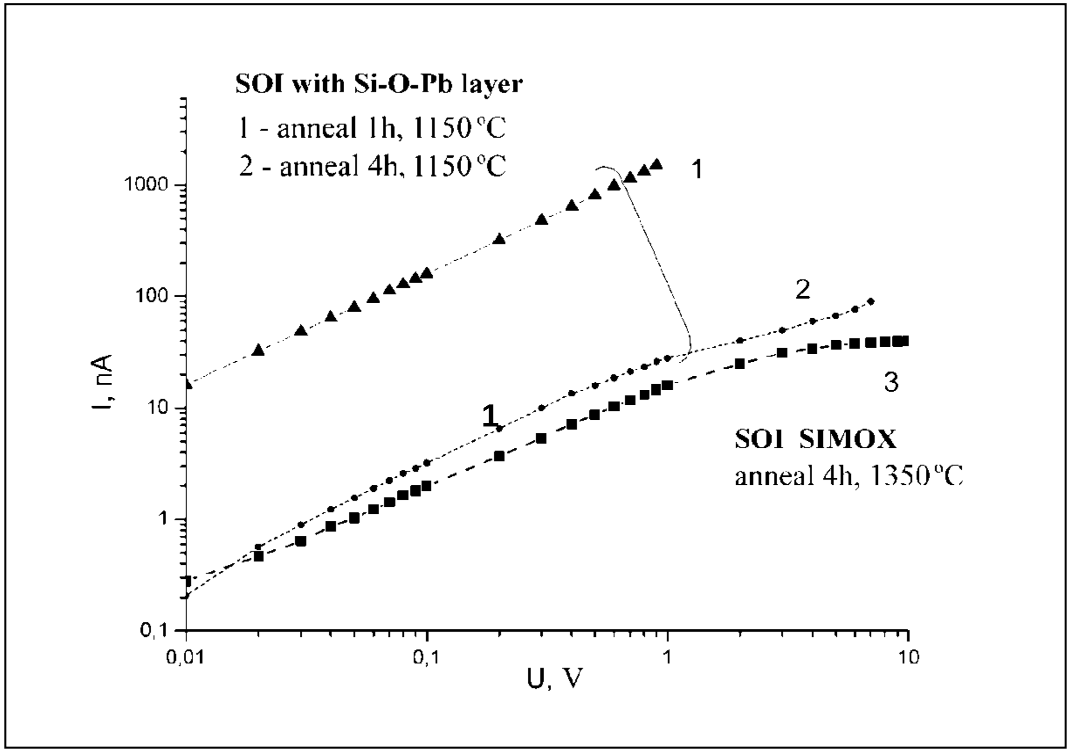
Formation of SOI with lead-silicate insulating layer (annealing process at 1150°C up to 8 hours)



SIMS profile of lead (curve 3) and profiles of AES oxygen analysis (left: curve 1 and 2) for implanted samples after annealing at 1150°C for 8 hours. Curve 1 corresponds to the reference sample (without lead ion implantation).

The figure shows the SIMS profile of the distribution of lead (curve 3) and the profiles of the layer-by-layer Auger analysis of oxygen (left: curves 1 and 2) for samples annealed for 8 hours in an atmosphere of 90% Ar + 10% O_2. Depletion of the left peak of lead is clearly observed, which is associated with its intense out-diffusion to the surface of the structure. That is, this annealing time is excessive. The optimum formation time for a lead silicate insulator is about 4 hours, while its insulating properties are close to the standard SIMOX SOI.

Current-voltage characteristics of experimental SOI structures with a lead-silicate insulator



The figure shows the current-voltage characteristics of experimental samples (1, 2) in comparison with the standard SIMOX structure (3) with a BOX layer thickness of 0.37 μm. As shown the electrical breakdown characteristics of SOI structures with a lead-silicate insulator are close to those of standard SIMOX structures. In this case, the annealing temperature is 200°C lower for the same annealing duration.

Conclusion

For the first time in the practice of ion synthesis, SOI structures with buried insulating layers based on lead silicate systems have been obtained. The structures were formed upon implantation of substoichiometric doses of oxygen and subsequent implantation of lead ions. Studies have shown that glass-forming ions act as activators of the formation of a buried layer, in the central part of which the oxygen content is close to the stoichiometric composition of SiO_2. By changing the amount of lead, it is possible to regulate the radiation resistance of SOI structures and the optical properties of the buried layer. We believe that these structures can find application both in microelectronics and in microphotonics.