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THE IMPACT OF THE METHOD OF UNDERLAY SURFACE PROCESSING ON THE DEVELOPMENT OF DEFECTS IN EPITAXIAL COMPOSITIONS IN THE COURSE OF SILICON PHOTO-TRANSDUCERS PRODUCTION

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Abstract. For the production of silicon photo-transducers (PhT) the acquisition of epitaxial compositions (EC) with high resistivity of working layer [1]. One of the main parameters characterizing the quality of EC is the density of dislocation and other structural defects. Great impact on the development of defects during epitaxial growth is produced by the quality of underlay preparation before that. Multiple research of relatively thin (less than 20-30 microns) epitaxial layers [2,3] demonstrated, that contamination or damages of underlay surface cause the development of defects of wrapping, counterparts, macroscopic protuberances in the growing layer. During inverted epitaxy there are no high requirements as for structural perfection of epitaxial layer as far as in PhT, produced on the basis of EC for which inverted silicon structures (ISS) serve with the working layer of mono-crystal substrate. Therefore in inverted epitaxy it is the problem of the development in the course of defects growth not in epitaxial layer, but in underlay, that becomes the major one. The processes of the development of defects in underlay in the course of growing thick (approximately 300 microns) epitaxial layer are scarcely researched by now. Scientists sustained the idea that when using dislocation-free underlays for growing in the working layer of ISS there are dislocations with the density of 10^3 sm^{-2} and more. Thus, investigation of the factors that determine the development of dislocations in underlay in the process of epitaxy, has now gained great practical value [4-7].

Keywords: silicon photo-transducers; dislocations; defects; swirl-defects; inverted silicon structures; epitaxial compositions.

Materials and Methods. This research aims at the study of correlation between the density of structural defects in underlay and EC layer grown and the method of mechanical surface processing. For the research the underlays of 260 mcm wide with crystallographic oriented surface {111}, made of dislocation-free silicon mono-crystals with 10-50 Ohm*m resistivity. Structure defects were revealed by means of selective etching and were examined with the help of metallographic and raster electronic microscopes.

Underlays underwent various methods of operator side surface (on which the growth took place) processing: chemical mechanical polishing (CMP) with 1-2 mcm and 20 mcm of removed layer, mechanical polishing (MP) with diamond paste with abrasive grit of 1,0 mcm and 0,5 mcm. Methods of processing of rear underlay sides were also different: chemical mechanical polishing, grinding, gettering – grinding with loose abrasive followed by shallow mechanical polishing. After growing the ISS were ground and polished both sides with CMP method to get 80 mcm of operator side of underlay and 170-180 mcm of grown layer side. The results of research of the density of dislocations in both ISSs are mentioned in Table 1.

Table 1

Average density of dislocations in ISS, grown on
dislocation-free swirl-free underlay

Method of underlay surface processing		Density of dislocations x 10^{-3}, sm^{-2}	
Operator side	Rear side	In the operator layer of ISS	In the supporting layer of ISS
Chemical-mechanical polishing with the depth of remote layer of 1-2 mcm	Chemical-mechanical polishing	1	4
	Mechanical polishing	1	8
	Gettering	0,4	6
	Grinding	4	20
Chemical-mechanical polishing with the depth of remote layer of 20 mcm	Mechanical polishing	0,3	5
Mechanical polishing with the size of abrasive grit of 1,0 mcm	-	2	7
Mechanical polishing with the size of abrasive grit of 0,5 mcm	-	1	20

It was proved that in all examined ISSs operator layer contains dislocations, which density lies in the interval of $3*10^2$ - $4*10^3$ sm^{-2} , thus worked-out technology of growing will ensure relatively high level of structural perfection of ISS. Nevertheless there is still a potential for further improvement of ISS quality, one of them being, as it is obvious from the Table 1, the improvement of the way of mechanical processing of underlays surface. In the cases when operator side of an underlay underwent chemical mechanical polishing, the density of dislocations in underlay after growing was in average lower compared to one after mechanical polishing. The exception is underlays with ground rear side. The best results were obtained by the authors in the course of CMP method application with enlarged to 20 mcm width of removed layer of $3*10^2$ sm^{-2}.

The method of processing of rear underlay side also influences the quality of operator layer of ISS. Under the same processing of operator side of underlay grinding of its rear side leads to the growth of density of dislocations in operation layer of ISS in average by 4,5 times, while gettering – visa versa, leads to 2,5 times diminishing in comparison with mechanical polishing of rear side. At the same time application of rear side of ISS in comparison with mechanical polishing does not demonstrate bright improvement of ISS quality.

The degree of structural perfection of supporting (grown) layer of ISS also depends on the method of processing of both operator and rear underlay sides. One can see in Table 1 that mechanical polishing of operator underlay side, compared to CMP, stipulates noticeable increase of the density of dislocations in the supporting layer, while in the operator layer of ISS it is practically identical. The same result of increasing the density of dislocations in the supporting layer can be also achieved by means of grinding of the rear side of underlay in comparison with other methods of its processing. It is the density of wrapping defects in the grown layer that depends far more significantly on the methods of operator underlay side processing, that is increased from $5*10^3$ sm^{-2} (in average, according to the samples examined) with CMP and $2*10^4$ sm^{-2} with mechanical polishing.

Great impact on the development of structural defects in the course of inverted epitaxy is produced by swirl-defects in dislocation-free underlays. Regardless of the method of underlay surface processing, in all ISSs grown over underlays, containing swirl stripes of micro-defects of A-type, identical in form and distribution stripes with high density of dislocations and wrapping defects in a supporting layer (Fig. 1) and with increased density of dislocations in operator layer can be observed. The impact of swirl stripes on the development of dislocations in both operator and supporting layers of ISS are illustrated by experimental data, systematized in Table 2.

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Table 2

Correlation of dislocation density in the locus of swirl-defect and in remaining scope of ISS (the method of processing of operator underlay side is CMP)

Method of rear side of underlay processing	Operator layer of ISS	Supporting layer of ISS
Chemical mechanical polishing	5	3
Mechanical polishing	170	8
Gettering	18	2

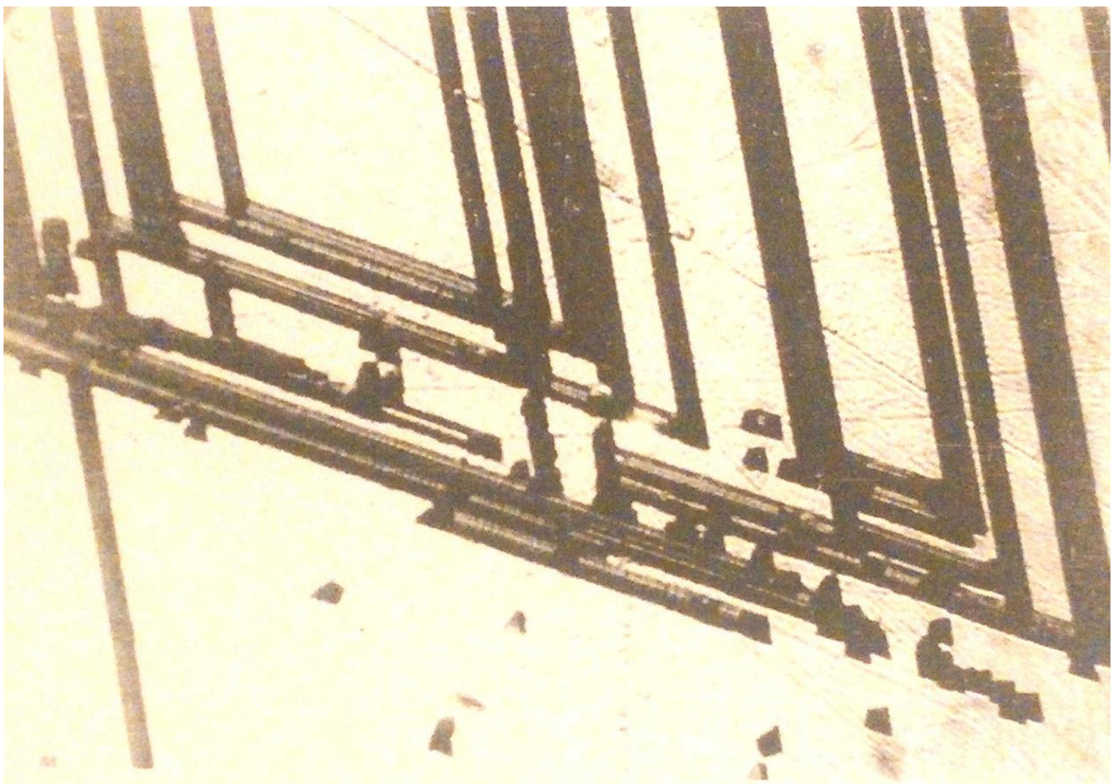

Fig. 1. Aggregation of wrapping defects and partial dislocations, revealed by means of selective etching, on the locus of epitaxial layer above the stripe of swirl-defect

The authors assumed (Table 2), that swirl-defects produce the greatest effect on the development of dislocations in operator layer of ISS. The fact that in operator layer of ISS there are stripes of high-density dislocations increases several times the average value of dislocation density of this layer, i.e. they significantly decrease the quality of ISS.

Results. The research of the development of defects in EC (silicon structures with dielectric isolation (SSDI)) demonstrated that while using dislocation-free underlays, A-micro-defects, contained in them, generate dislocations, starting with technological operation of the production of isolating layer of silicon dioxide. As we can see from Fig. 2, dislocations are developed in places of intersection of micro-defects stripes with dividing grooves. In this case micro-defects serve as a source and concentration of tension in the grooves – as stimulus of the generation of dislocations in mono-crystalline well. In the proceeding operation of deposition of polycrystalline silicon layer thermo-high-resiliency tension incease generation processes, while dislocation density rises to 10^4 sm $^{-2}$.

Fig. 2. Figures of dislocations etching on micro-relief grooves of SSDI.

Discussion. The empirical results obtained leads to the conclusion that it is advisable to apply dislocation-free underlays without micro-defects stripes of A-type for the production of PhT on EC basis with low density of dislocations. Under all equal conditions the best quality of EC is achieved by means of thorough chemical-mechanical polishing of operational side of underlay and gettering of the rear side.

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