FORMATION OF SPECIAL GRAIN BOUNDARY JOINTS IN PHOSPHORUS-DOPED POLYSILICON FILMS UNDER ANNEALING

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Introduction

An essential element of the structure of polycrystalline films, together with grain boundaries, are the joints of grain boundaries, that are a kind of linear defects. Joints are of great importance for controlling the properties of materials, that is due to their significant influence on the electrophysical, optical, mechanical and other properties from the point of view of practical applications [1]. Joints are the least studied structural element in polycrystals.

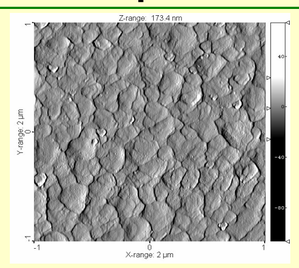
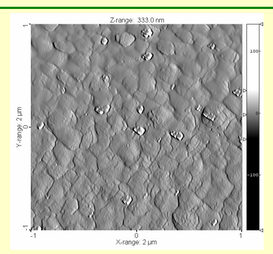
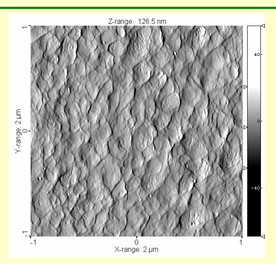
The aim of this work is to study the mechanisms of the formation of special joints of grain boundaries in phosphorus-doped polysilicon films during annealing.

Experimental

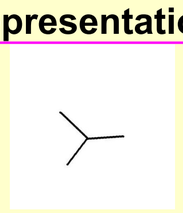
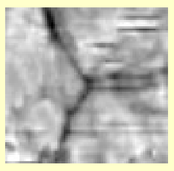
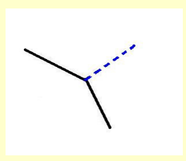
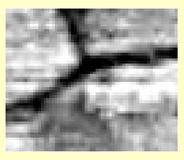
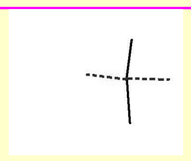
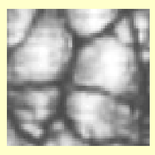
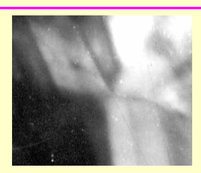
Polysilicon films were obtained by low-pressure chemical vapour deposition on thermally oxidized (100 nm oxide thickness) (100) Si wafers. The deposition temperature was equal to 630^{0}C. The film thickness was 500 nm. The films were doped with phosphorus and annealed at temperatures from 950^{0}C to 1200^{0}C. for 30 minutes. The structure of the films was studied by transmission electron microscopy (TEM). Surface morphology was analyzed by atomic force microscopy (AFM).

Results

AFM images of the surface of polysilicon films

As-deposited	900^{0}C	1150^{0}C
		

Examples of some grain joints

Joint types	Schematic representations	AFM images	TEM-images
3a			
3b			
4c			

The relative number of triple and multiple joints of grain boundaries in polysilicon films depending on the annealing temperature

Joint types / Annealing temperature, ^{0}C	Ggrain boundary joints, %						
	Triple			Multiple			
	3a	3b	3c	4a	4b	4c	5
As-deposited	45,2	22,3	16,1	3,2	3,2	6,5	3,2
900℃	26,7	26,7	20	6,7	13,3	6,7	-
1150℃	22,5	32,5	32,5	2,5	7,5	2,5	-

_____ - grain boundaries of the general type

_ _ _ - special grain boundaries

The relative number of joints of grain boundaries of the general type and special joints in polysilicon films depending on the annealing temperature

Joint types / Annealing temperature, ^{0}C	Ggrain boundary joints, %	
	General type (3a)	Special (3b+3c+4a+4b+4c+5)
As-deposited	45,2	54,8
900℃	26,7	73,4
1150℃	22,5	77,5

Conclusion

1. The most probable mechanism for the formation of special joints of grain boundaries in polysilicon films upon annealing is the splitting of grain boundaries. Grain boundaries can split if their misorientation is the sum of rotations that lead to the formation of low-energy boundaries.
2. Multiple twinning is a characteristic feature of the formation of the structure of polysilicon films. The interaction of high-order twins leads to the formation of special joints of grain boundaries.
3. During the grains growth under annealing, random contacts of special boundaries take place, that leads to an increase in the relative number of special joints.

References

1. K. H. Kim, J. Y. Lee, Y. G. Yoon, S. K. Kim, H. U. Cho, Y. M. Cho, Y. J. Kim, and B. D. Choi vol. 20, pp. 93-98, 2020.

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