Dielectric Film Influence on Stress-Migration

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The purpose of this work is to clarify the relation between dielectric film characteristics and stress-migration(SM). It has been considered that the dielectrics deposition temperature induced stress, caused by the difference of the expansion coefficients to Al, is the main factor for SM. However, the authors found that Al diffusion into dielectrics, Al recrystalization and dielectrics flexibility are also significant for SM.

30 kinds of dielectric films were deposited on Al or Al-Si wirings formed on oxidized Si wafers. Especially, sputter-SiO2, whose film charactaristics are not influenced by deposition temperature, was deposited with following ways - (A)RT depo., (B)100C depo., (C)200C depo., and (D)RT depo. after 300C anneal. To evaluate the material dependence, (E)SiO, (F)SiON and (G)SiN were depositted by PECVD under the same conditions except process gas. These wafers were annealed at 400C for 10min, then held at 175C(N2) for 7000 hours to evaluate the SM. The sample preparation conditions and results are shown in the tables.

Sample(A) and (B) show more open failures than (C). In spite of the same deposition temperature as (A), (D) shows no failure. In case of the PECVD samples, (E) shows many, (F) shows few and (G) shows no failure. All of the other samples show no failure.

The differences between the results of sample(A), (B) and (C) can be explained by the Al atom diffusion into dielectrics[1] and dielectrics flexibility. In case of (A) or (B), high tensile stress is generated by the Al diffusion into dielectrics during the annealing after the deposition. On the contrary, in case of (C), as the diffusion occurs during deposition, the stress is lower than that of (A), because the dielectrics is flexible until it becomes a certein thickness. No failure in sample(D) can be explained as follows. When Al film is heated up, the Al stress becomes compressive but, over 200C, is reluxed by hillock formation and Al recrystalization. If the wirings is covered with dielectrics, this stress reluxation (only by recrystalization) causes the high tensile stress after cooled down. However, in case of (D), the tensile stress is lower than (A), because the Al is already recrystalized by the annealing before the deposition. The differences between the results of (E), (F) and (G) can be also explained by the Al diffusivity.

In conclusion, the best way of dielectrics formation against SM is, "depositting low Al diffusivity dielectrics at low temperature after stress reluxation."

(Reference)

[1] A.Tanikawa and H.Okabayashi,"AEM Observation of passivation films for Al Metallization", Ext. abst. of The Jap. Soc. of Appl. Phys. Autumn 1989 p628

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Tables Typical data of dielectrics deposition conditions and open failures after 7000H held in 175℃ (N2).

Experimental① Pure Al (W=0.8μm)

	Method	Material	Thickness	Pre Heat <Time>	Depo Temp. <TIME>	Stress (MPa)	Failures (%)
	PECVD	SiO2	0.5μm	280℃<10'>	280℃<10'>	100	0
	PECVD	SiON	0.5	280℃<10'>	280℃<10'>	300	0
	PECVD	SiN	0.5	280℃<10'>	280℃<10'>	700	0
	Spin-on	Polyimide	0.5	—	—	50(T)*2	0
(A)	Sputter	SiO2	0.5	—	RT <3'>	300	17
(B)	Sputter	SiO2	0.5	100℃<1'>	100℃<3'>	300	21
(C)	Sputter	SiO2	0.5	200℃<1'>	200℃<3'>	300	2
(D)	Sputter	SiO2	0.5	300℃<60'>*1	RT <3'>	300	0

*1:Annealed by furnace

*2:T is for tensile stress, others are compressive

Experimental② Al-1%Si (W=0.8μm)

	Method	Material	Thickness	Pre heat <Time>	Depo temp. <Time>	Stress (MPa)	Failures (%)
(E)	PECVD	SiO2	0.5μm	280℃<10'>	280℃<10'>	100	23
(F)	PECVD	SiON	0.5	280℃<10'>	280℃<10'>	300	2
(G)	PECVD	SiN	0.5	280℃<10'>	280℃<10'>	700	0
	PECVD	TEOS	0.5	390℃<6">	390℃<1'>	100	0
	AP-CVD	PSG	0.5	400℃<10'>	400℃<10'>	100(T)	0
	ECR-CVD	SiO2	0.5	—	RT <1'>*5	200	0
(A)'	Sputter*3	SiO2	0.5	—	RT <3'>	300	75
(A)'	Sputter*3	SiO2	1.0	—	RT <3'>	300	27
	Sputter*4	SiO2	0.5	—	RT <3'>	100	0

*3:The same deposition conditions as (A)

*4:No bias

*5:Set temp. is RT but wafer temp. becomes 300～350℃ during depo.

No failure in polyimide and (no bias) S-SiO2 can be explained by film flexibility.