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Influence of corona charging on the electrical properties of Si-SiO_2 interface

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Outline

- Purpose of the work
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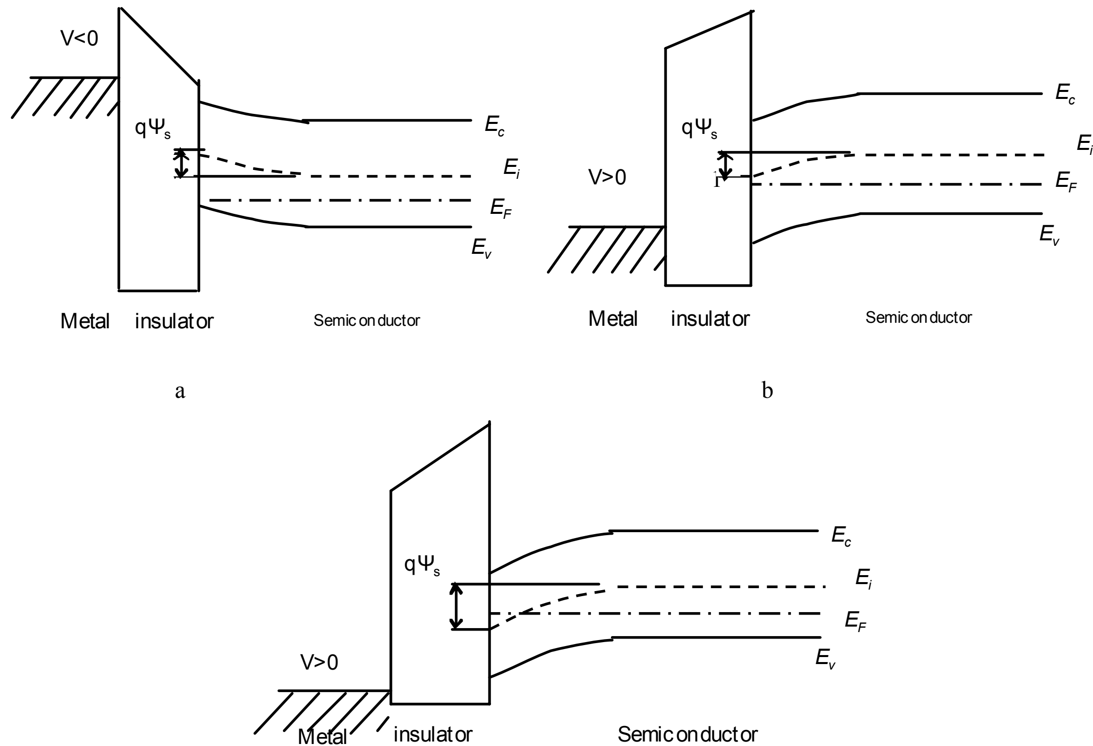
Purpose of the work



Corona charging or an external power charge influences the Si surface potential and passivation properties

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Purpose of the work

Requirement:

For corona charging to be ‘safely’ applied as a field passivation, it must not introduce any defects.

*Stesmans reported EPR active Si surface defect by corona charging

(*Stesmans et al., Applied Physics Letters, 2003. **82**(17): p. 2835-837.Microelectronic Engineering, 2004. **72**(1-4): p. 55-60.)

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Experimental details

- FZ, p-type, (100) high resistivity wafers were used for effective lifetime (PCD) measurements.
- Cz, p-type, low resistivity wafers were used for Si interface defect density (C-V) measurements.

- Thermal oxidation (at 1000°C) to grow 50 nm oxide.
- Some samples were lightly phosphorous diffused ($\sim 300\Omega/\square$)
- Forming gas annealing for passivation (on all samples)
- Corona charging (standard setup, both + and – charging)
- IPA dip to remove surface charge
- Thermal anneal (in N_2 or forming gas at 400°C)

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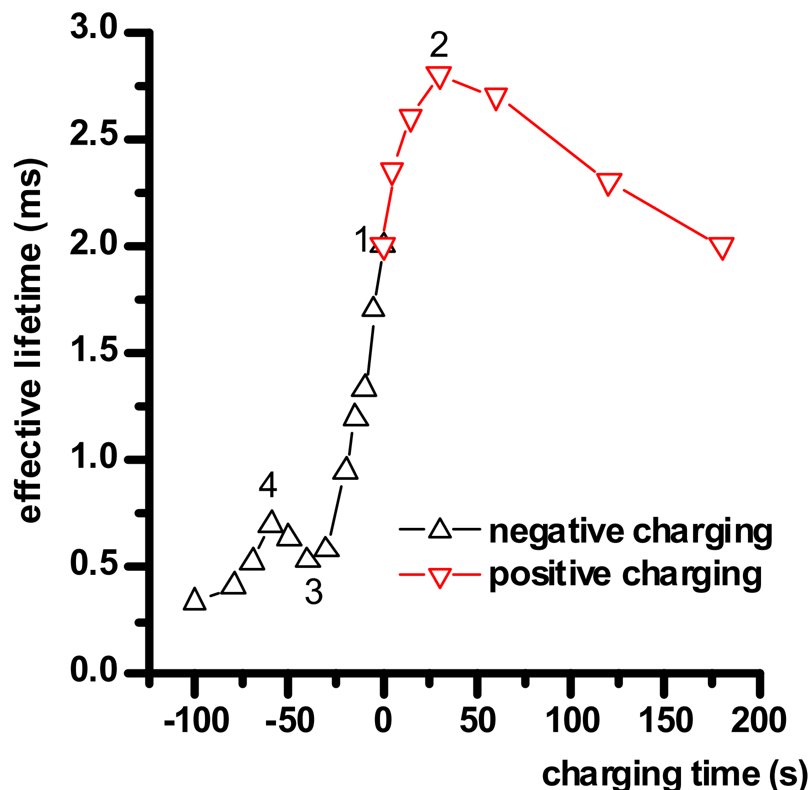
Results: Direct corona deposition damage



Two wafers with identical lifetimes

Start at point '1' for both +ve and –ve corona charging

Lifetimes measured at the injection level of $4 \times 10^{15} cm^{-2}$

SiO_2/Si with Forming gas annealing

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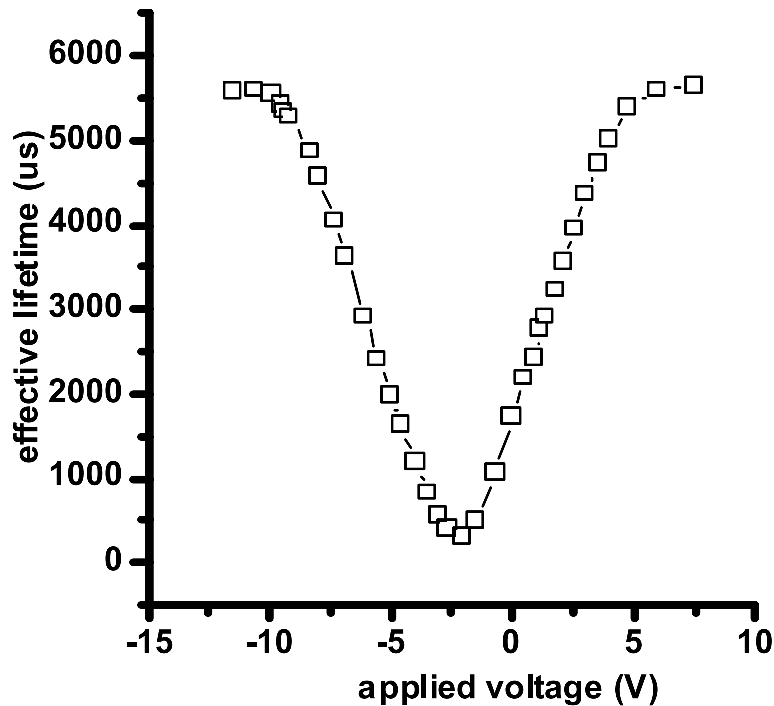
Results: Direct corona deposition damage

Lifetime with external applied voltage



Compare the lifetime change caused by an external applied voltage and following corona charging. The damage introduced by corona-charging can be observed

SiO_2/Si with Forming gas annealing

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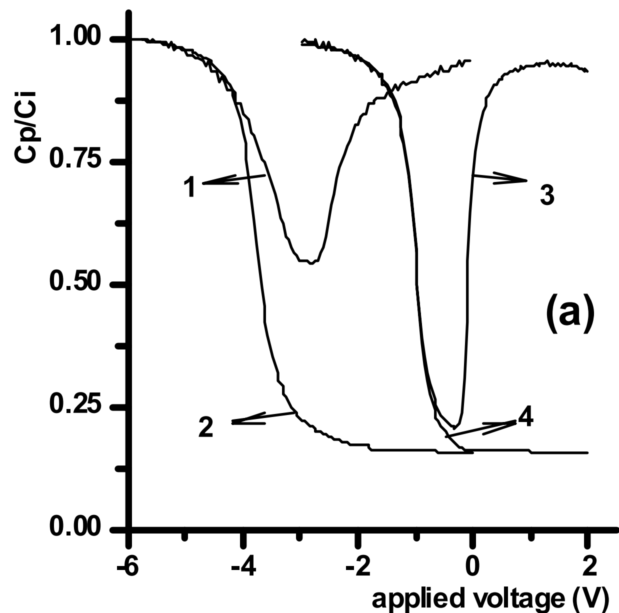
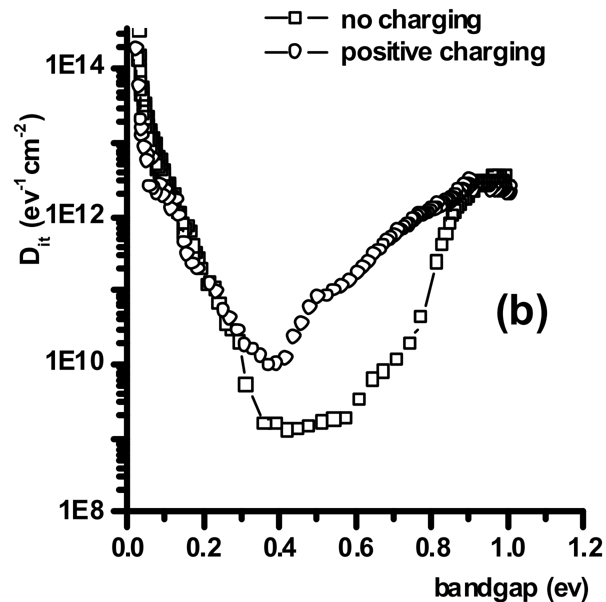
Results: Direct corona deposition damage





Comparison of C-V curves, (a), and D_{it} distribution, (b), within the Si forbidden band gap between the 'as oxidized' (1 & 2) and 26 minutes positively corona-charged MOS structures (3 & 4).

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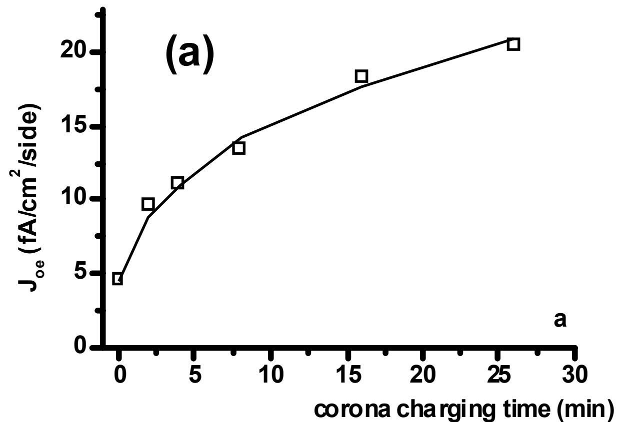
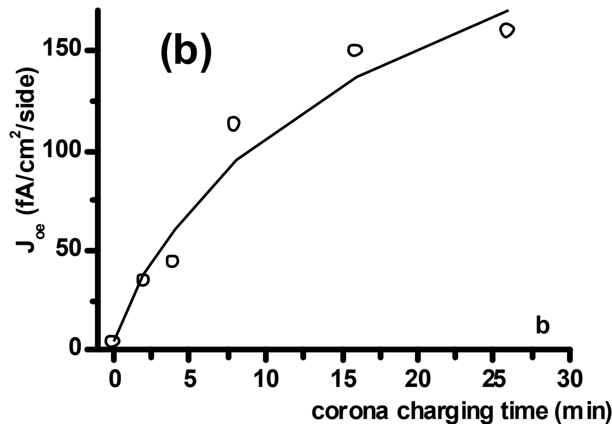
Results: IPA clean influence





Effective lifetime for FGA'ed SiO_2/Si samples after:

(a) positive corona charging
(b) negative corona charging.

An IPA rinse was carried out before measurements. All measurements were taken at the injection level of $4x10^{15}/cm^2$.

Negative charging produces more damage to the Si surface

SiO2/Si with Forming gas annealing

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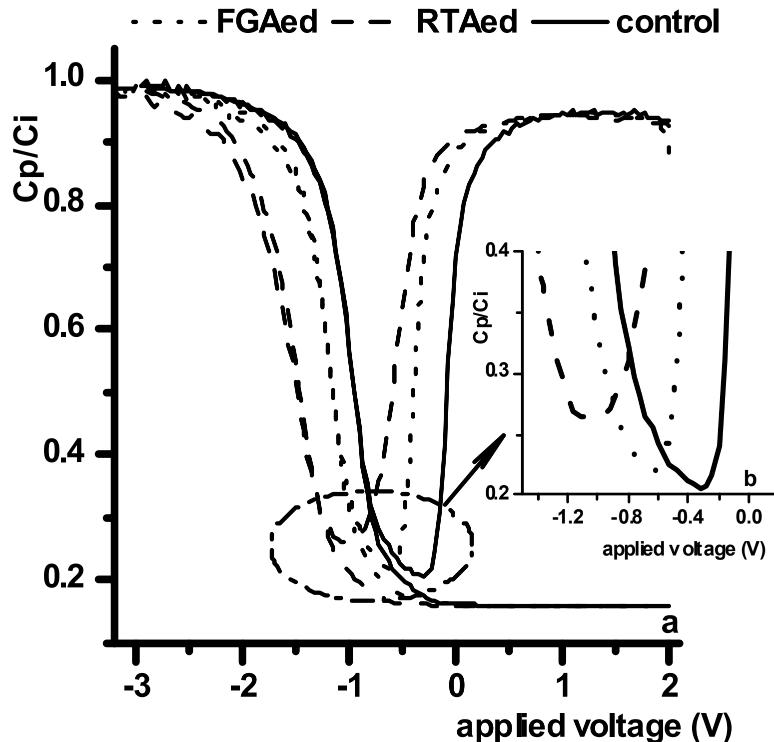
Results: Thermal anneal influence



- Rapid Thermal Anneal (RTA) at 400°C for 30 seconds and Forming Gas Annealing (FGA) at 400°C for 30 min were performed after the corona charging for 26 minutes.

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Results: Thermal anneal influence

	As oxidized	RTA		FGA	
		+charged	- charged	+ charged	- charged
V_{fb} (V)	-0.997	-1.58	-1.40	-1.3	-1.2
Q_i ($\times 10^{11}$cm^{-2})	+2.73	+4.50	+3.40	+3.80	+3.30
Mid gap D_{it} ($\times 10^{10}$ ev^{-1} cm^{-2})	0.160	1.60	4.00	0.400	0.470
J_{oe} (fA/cm^2/side)	4.50	8.56	21.2	5.80	6.10

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Nature of the Corona Damage

- The corona charges are generated by ionizing air molecules into charged species, particularly $(H_2O)_nH^+$ or CO_3^-
- Plasma H has the effect of causing damage to the Si-SiO_2 interface. Thermal annealing can reduce or repair some of the damage.

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Conclusion

- Corona charging influences the Si surface potential
- Direct corona charging introduces extra Si surface defects
- Negative corona charging causes more damage than positive corona charging
- Thermal anneal (in N2 or Forming gas) removes most of the damage.

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