Modifications of the growing film by energetic particles (2)

- Sputtering of the substrate or growing film
  - May be useful for cleaning it prior to film deposition.
    - Usually done by back sputtering. Reverse the electrical connections to the anode and cathode.
  - Change the composition of composite materials if the sputter yield of atoms differs
  - Sputters atoms from the top of trenches and smoothen topographies
- Displacement cascades
  - Create interstitials in the material, which enhances diffusion.
  - Interstitials can relax strain in certain cases.
  - Mixing of layers of deposited materials. Can be used to avoid phase separations.

Modifications of the growing film by energetic particles (3)

- Enhanced adhesion due to fast particles
  - Surface can be cleaned using fast particles
  - Surface bonds can be broken and the deposited film can chemically bond to the surface
  - Surface can be made rough resulting in an "interlocking" of the substrate and the film
  - Short range intermixing of the film and the substrate

Modifications of the growing film by energetic particles (4)

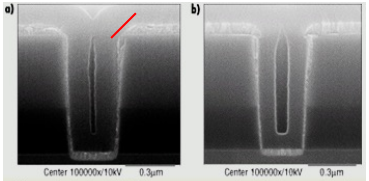


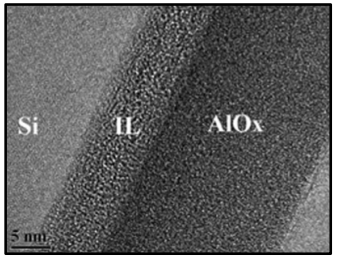
Figure 6. Ionized PVD base coverage in 2.6:1 aspect ratio holes, with a) Ti and b) TiN.

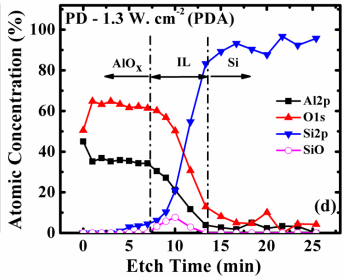
- Notice the deposited film at the top corners of the trench
  - Due to higher sputtering rate at the corners by fast moving particles
- Step coverage

Trikon technologies, UK

Modifications of the growing film by energetic particles (5)

XPS data



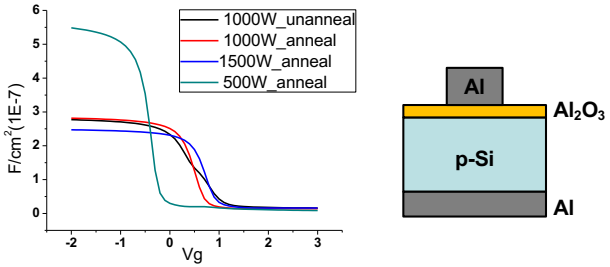


Al_2O_3 deposited by pulsed DC sputtering of Al in O_2 + Ar gas mixture.

See the interface between Si and Al_2O_3

Bhaisare et al., IEEE J. Photovoltaics, 2013
Bhaisare et al., IEEE PVSC conference, 2013

Modifications of the growing film by energetic particles (6)



Al_2O_3 deposited by pulsed DC sputtering.

High power sputtering increases film damage, reflected as a positive shift in the CV.

Meenakshi, IITB-NF/NCPRE

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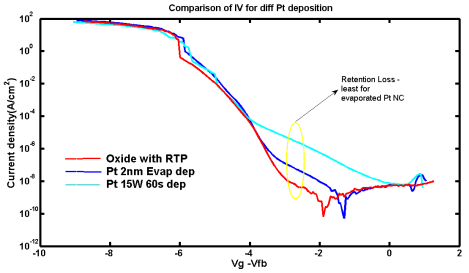
Modifications of the growing film by energetic particles (7)



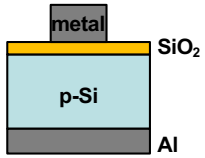


Illustration of sputter damage in SiO_2.

Sunny Sadana, IITBNF

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Modifications of the growing film by energetic particles (8)

- Surface events (< 15 eV)
  - No bulk damage to the film
  - Increased surface diffusion due to the energy transferred from the energetic particle to the surface atoms
  - Decomposition of small clusters of atoms on the surface
  - Stimulate chemical reactions and desorption from the surface

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Applications in VLSI

- PVD deposition of Ni, Co or Ti for salicide processes
- PVD deposition of TiN or TaN for contact plugs as diffusion barrier
- PVD of Cu as seed for electroplating

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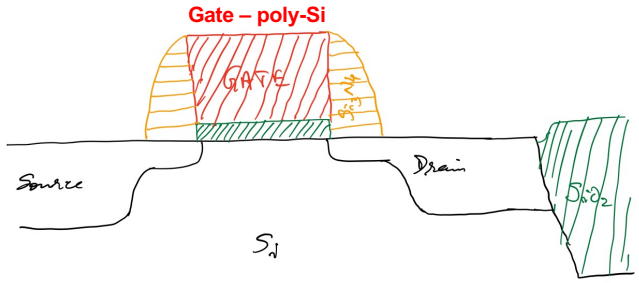
Salicide Process



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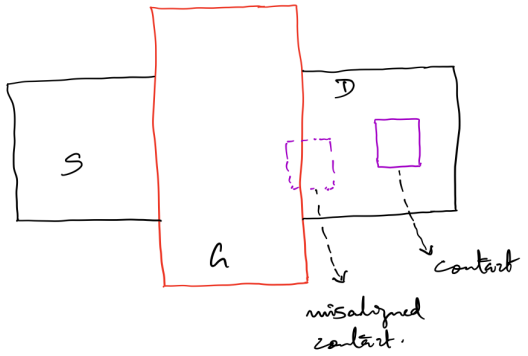
Contacts to MOSFETs



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Salicide Process

- A metal silicide is formed after source/drain implant anneal in a CMOS process
- The process is self aligned and hence the name
- The implant screening oxide if any is etched in HF
- Sample loaded into PVD chamber
  - Sputter the wafer using Ar to remove any native oxide => Degas chamber in a PVD system => hardly any selectivity between materials
  - Or etch the oxide in HF in a chamber integrated with the deposition chamber
  - Or reactive Ion Etching may be used for removing the native oxide
  - Sputter deposit pure Ti or Co or Ni as per the requirement
- RTP at a suitable temperature to form a low resistance phase of silicide

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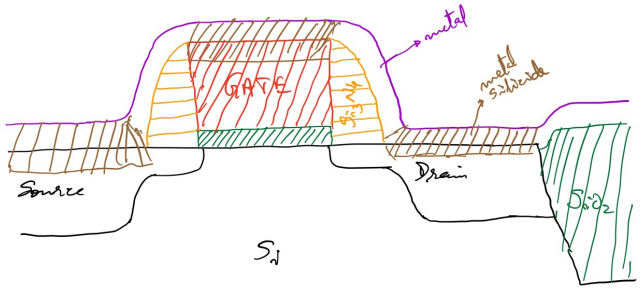
Salicide Process (2)



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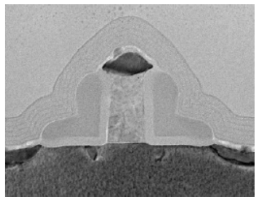
Salicide Process (2)

- Metal reacts with Si but not with Si_3N_4 or SiO_2
- Wet etch the unreacted metal
- Second RTP to convert silicide to lower resistance phase



Thompson et al., Intel technology journal, vol. 6, no. 2, 2002

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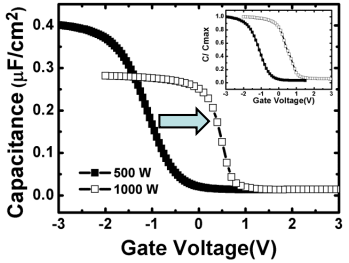
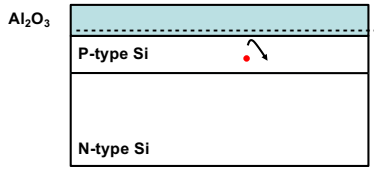
Aluminum Oxide by Pulsed DC Sputtering





- Higher power deposition leads to higher density of negative charges in the dielectric
- Negative charges are useful for passivation of p-type surfaces in solar cells

Meenakshi Bhaisare, IITBNF

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References

PVD:

- John E. Mahan, "Physical Vapor Deposition of Thin Films", John Wiley and Sons, 2000.
- Donald L. Smith, "Thin Film Deposition: Principles and Practice, McGraw Hill, 1995.
- Angus Rockett, "Material Science of Semiconductors", Springer Verlag, 2008.
- Meenakshi Bhaisare et al., Nanoscience and Nanotechnology Letters, vol. 4 (6), pp. 645, 2012.

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