Vapor Phase Doping of Boron in Silicon

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Outline

- Motivation
  - SNF
  - Broader sense
- Methodology
  - Epi
  - Sheet resistance measurement
- Deposition @ $900^{o}C$
- Conclusion

Doping Predep Furnace

- POCl3 (Phosphor)
  - Tylan 6, works OK
  - BOE remove oxide

- BBr3 (Boron)
  - Tylan 5
  - Not working, hard to remove oxide

- Vapor phase doping
  - Epi2
  - B_2H_6 in H_2 environment
    - 100ppm – 0.01ppm
  - No epitaxy growth

- Interesting application
  - DUV / EUV photodiode
    - 2nm p+ type layer
    - 193nm → absorption length: 5.5nm
  - Alternative to ion implantation
    - TED-free (Transient Enhanced Diffusion)
    - Selective area doping → oxide hard mask
    - Sidewall doping

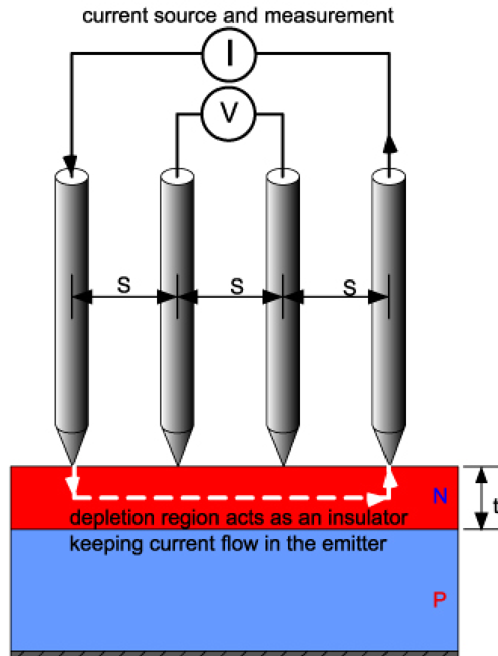
Methodology – Epi

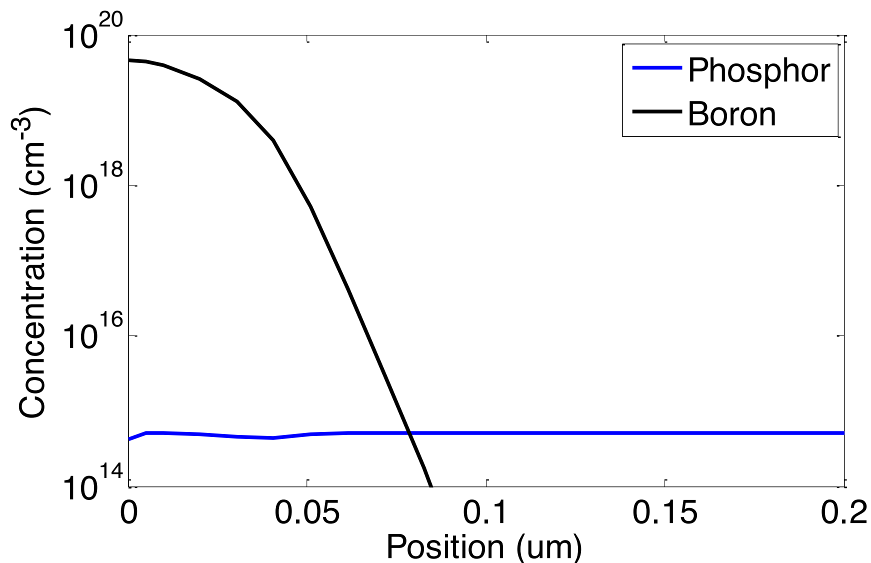
- **Temperature**
  - 700°C / 800°C / 900°C
- **Pressure**
  - 10-100 Torr
- **B_2H_6 flow rate**
  - 100ppm – 0.01ppm
- **B_2H_6 flow time**
  - 1s – 30min

Methodology – Epi

- **Temperature**
  - ~~700°C~~ / 800°C / 900°C → significance difference in doping dynamics
- ~~**Pressure**~~
  - ~~10-100 Torr~~ → Doesn't matter
- **B_2H_6 flow rate**
  - 100ppm – 0.01ppm → Less important
- **B_2H_6 flow time**
  - 1s – 30min → More important

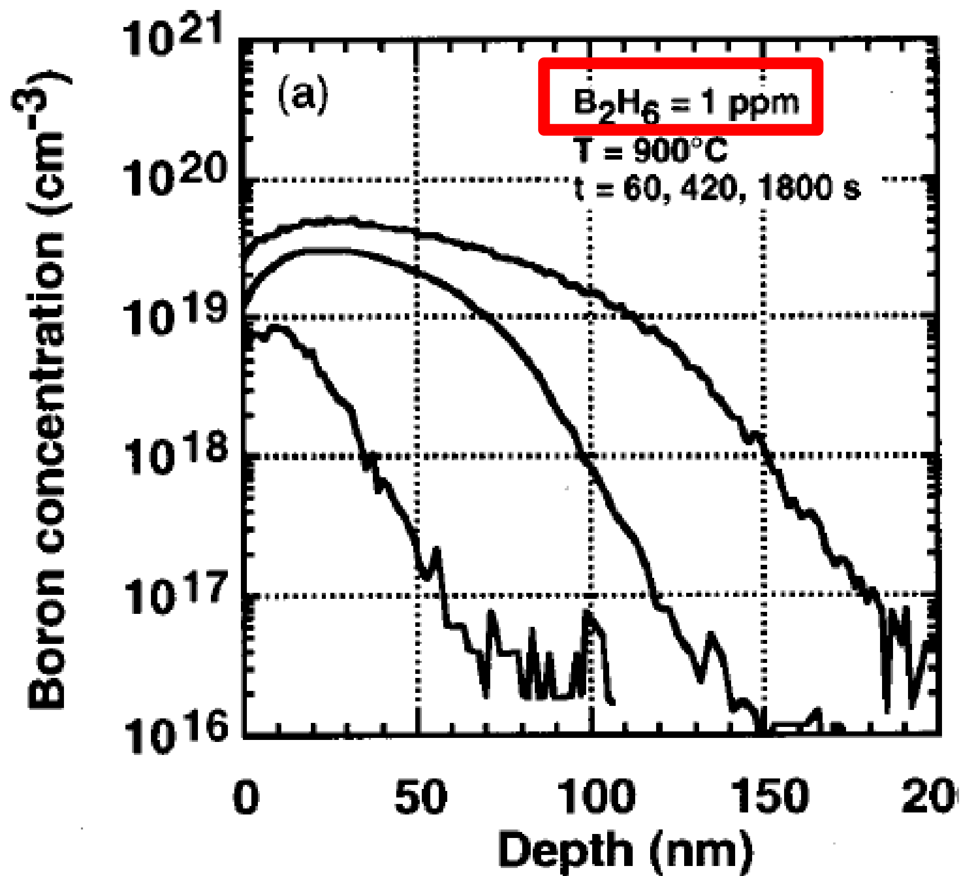
Methodology -Four point probe

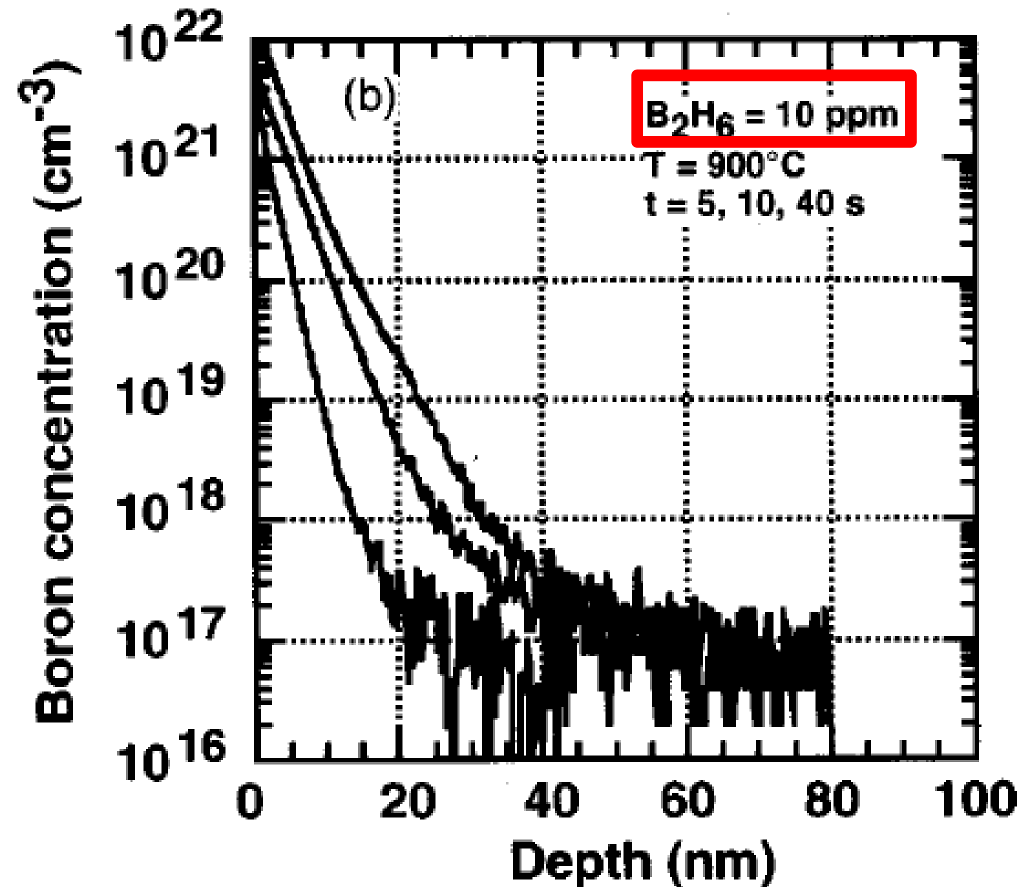




- Test wafer
  - C test
  - Phosphor: $6x10^{14} – 1x10^{15}$ cm^{-3}
- Sheet resistance
  - 1,048 Ohm/[]

Doping @ 900°C





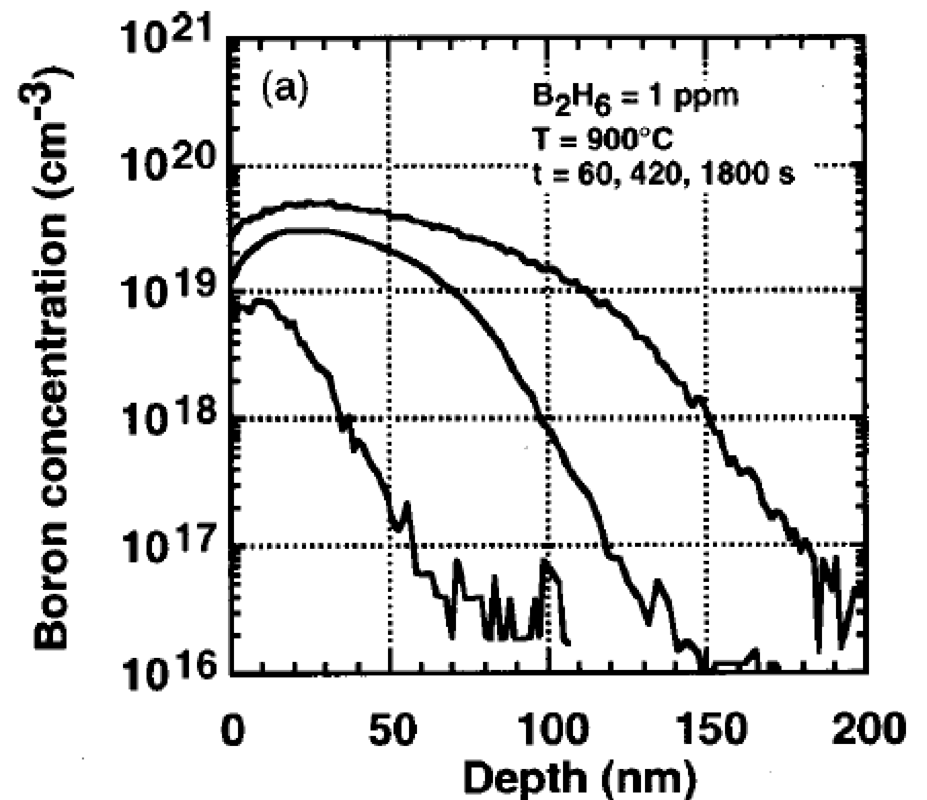
Doping at 900dC could potentially make all Boron electrically active

B_2H_6 <1ppm, Boron is electrically active

B_2H_6 >10ppm, Boron segregates on surface → not α-B, B_xSi

Modelling

- Constant C_s
  - Erfc(x)
- Diffuse to Si
- Out-diffusion from Si



Experiment result

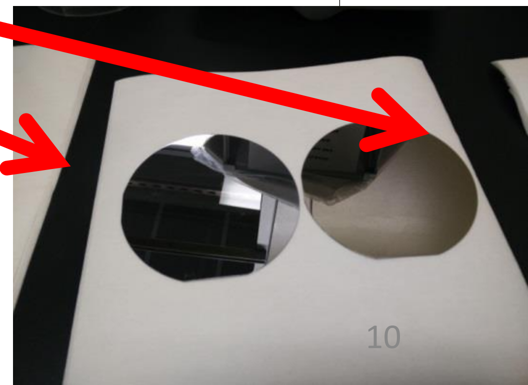
66ppm
1ppm
0.1ppm
0.01ppm

Sheet resistance (Ohm/[])

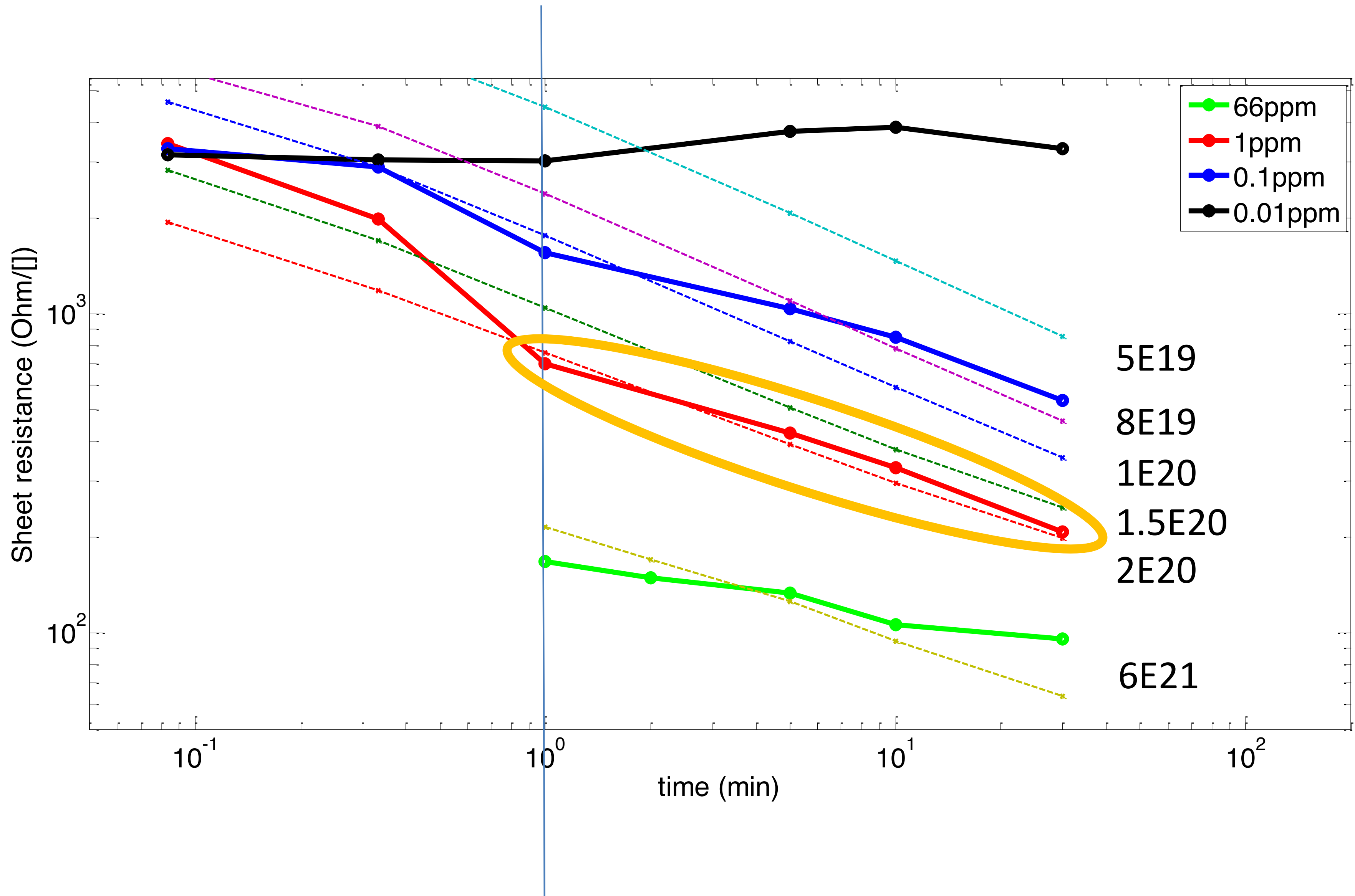
10^3
10^2

10^{-1} 10^0 10^1

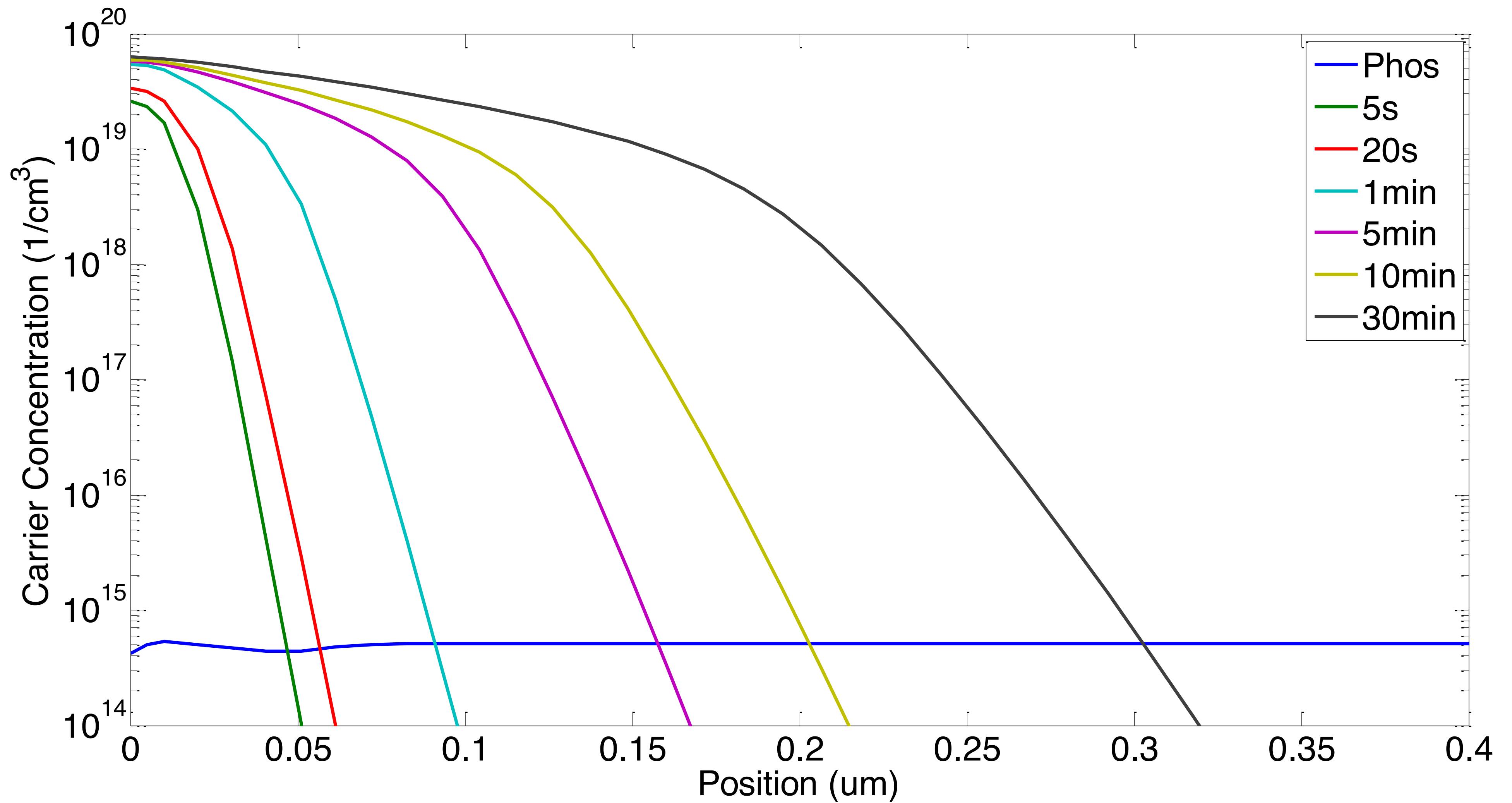
time (min)



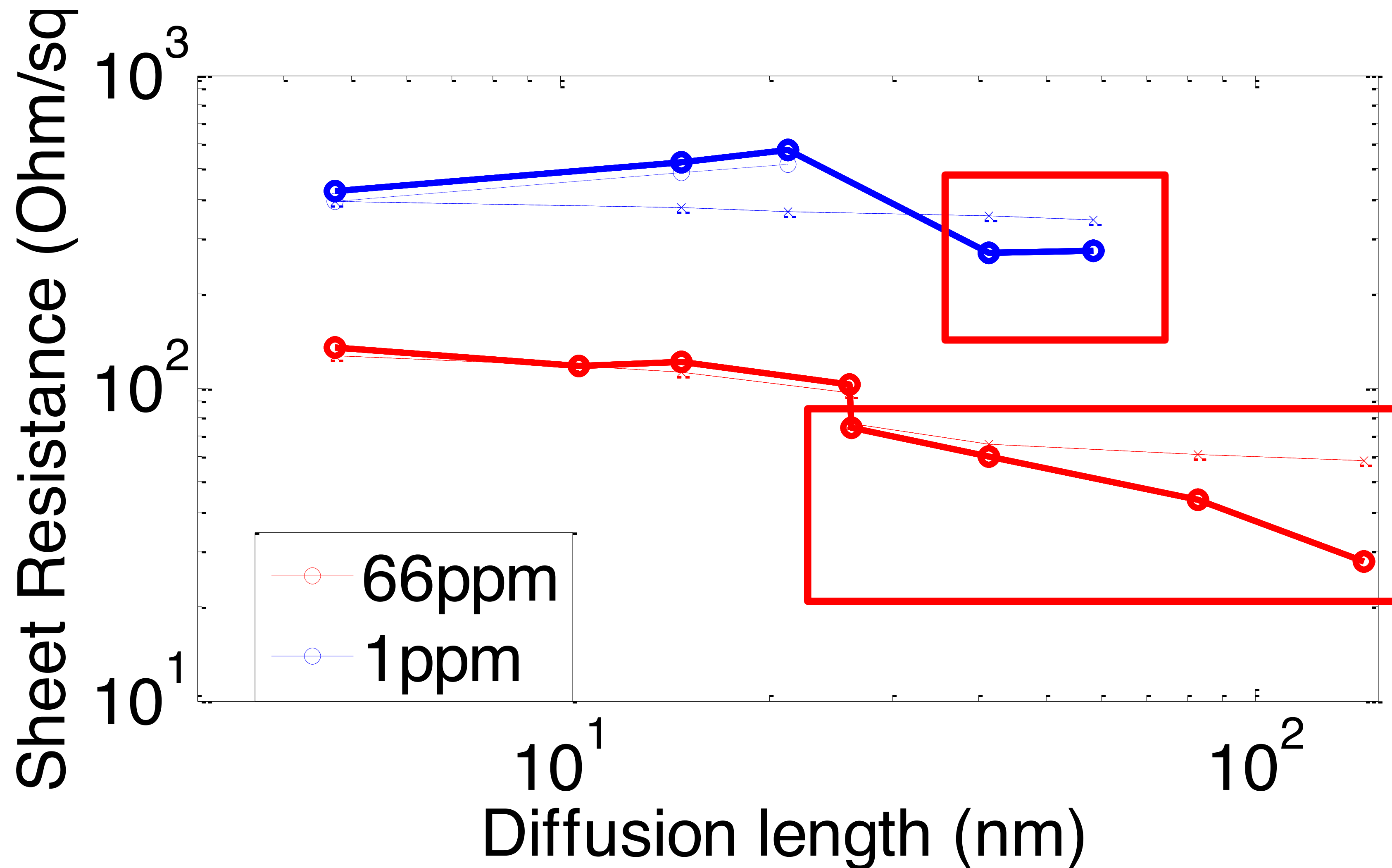
Fitting results



1ppm B_2H_6



Anneal (epi)

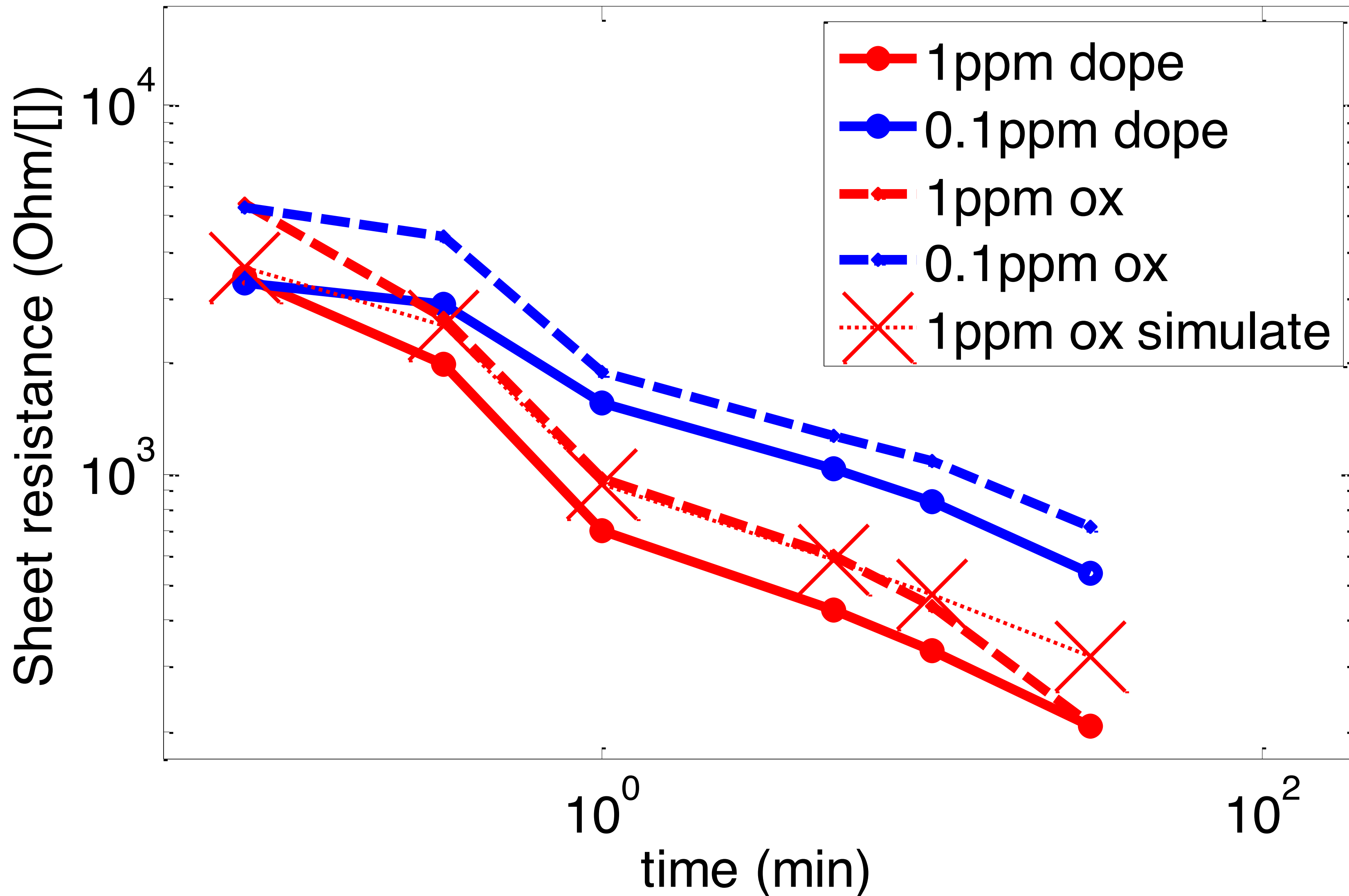


1ppm / 66ppm 5min doping at 900°C

1ppm out-diffusion dominate in H_2 annealing

Both has more doping when annealed at 1000°C

Anneal (oxidation furnace)



Wet oxidation: target at 100nm oxide

Simulation match good

Conclusion

- 2nm B_xSi
  - 700°C | 6ppm | 1s-5s
  - No oxidation
- Boron doped in Silicon
  - 900°C | 0.1ppm – 1ppm | 5s – 30min
  - Oxidation OK
- Simulation code

- Variation
  - On wafer: < 3%, clear under green lamp

// Ackowledgements

- Project Mentor:
  - Maurice Stevens
  - Ted Berg
- Theoretical consulting
  - Prof. Ted Kamins
  - PI: Prof. James Harris
- EE412 Organizers
  - Dr. Mary Tang
  - Prof. Roger Howe

Thank you for your time! ☺