Comparison between PEALD-TiN films using $TiCl_4$ or TDMAT as Ti-precursor

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abstract

For some years, thin films of Titanium Nitride (TiN) have been interesting for applications in microelectronics due to its semiconductor properties. To produce films in the nanometerrange mostly atomic layer deposition (ALD) – technique is used. This poster compares PEALD-TiN films deposited under comparable conditions with titanium tetrachloride ($TiCl_4$) or Tetrakis-(dimethylamino)-titanium (TDMAT) as Ti-precursor.

experimental setup

Reactor:

- ALD 150 (FHR)

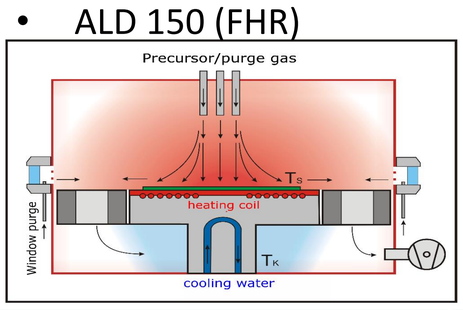


Fig. 1: schematic of used remote-plasma reactor

Substrate and Samples:

- Silicon with native oxide (SiO_2) about 2 nm thick
- Pieces of 1 cm x 1.5 cm size
- At least two samples per deposition central and decentralized on carrier

Deposition:

- Plasma enhanced
- Plasma-power: 300 W
- NH_3 as reaction-gas
- Substrate-temperature: 170 °C - 180 °C

Measurement:

- Ex situ ellipsometry
- Four-point-probe resistance measurement
- X-Ray photoelectron spectroscopy
- X-Ray reflectometry

$TiCl_4$

- Kept at room temperature
- No carrier gas
- Purge-flow: 500 cm³/min

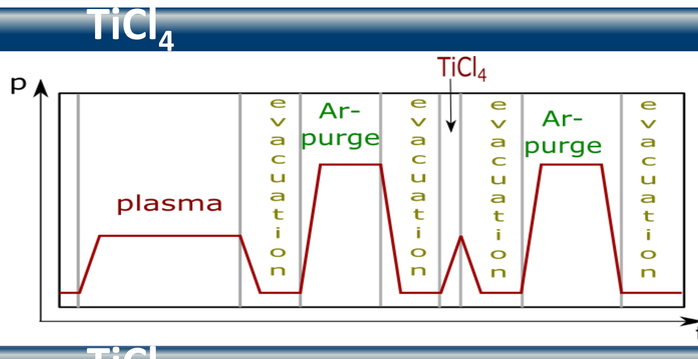


Fig. 2: schematic cycle for TiN ALD-deposition with $TiCl_4$

TDMAT

- Kept at 60 °C
- Carrier-gas Argon 20 cm³/min
- Purge-flow: 300 cm³/min

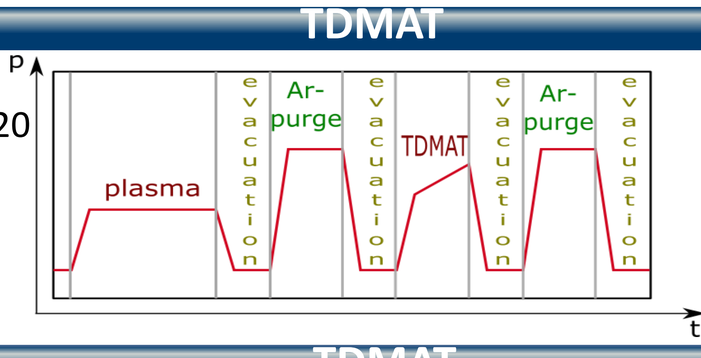


Fig. 3: schematic cycle for TiN ALD-deposition with TDMAT

Results and Discussion

Deposition conditions

$TiCl_4$

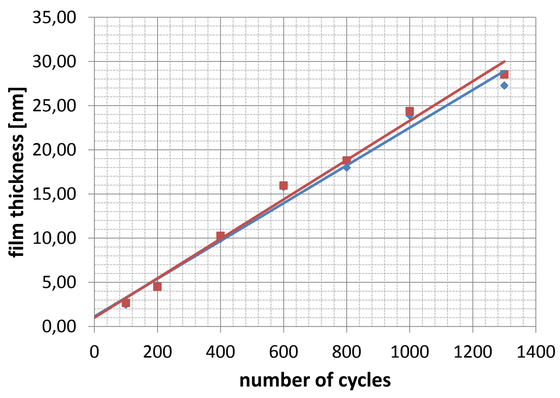


Fig. 4: linearity of growth at 180 °C; 0.5 s $TiCl_4$; 1.0 s plasma

- $TiCl_4$-puls higher than 0.1 s and NH_3-puls higher than 0.5 s results in self-limited growth

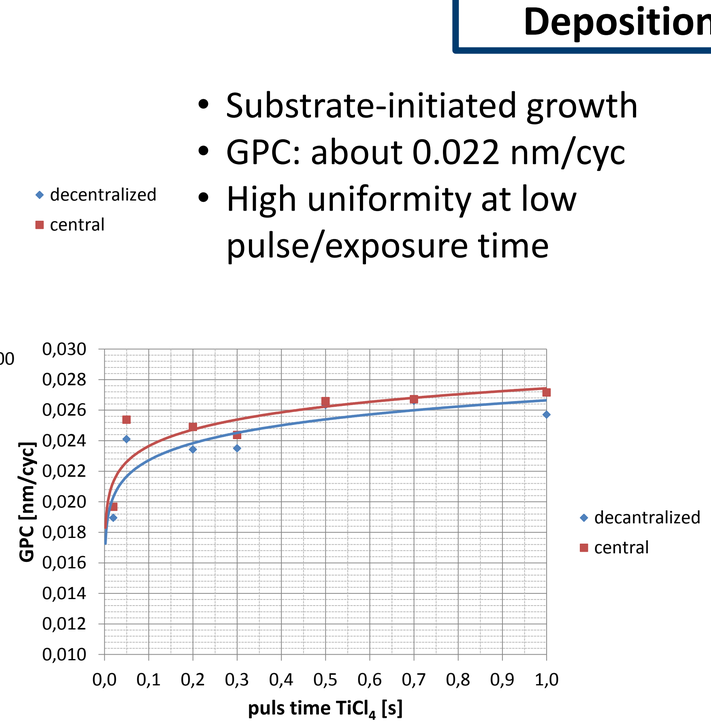
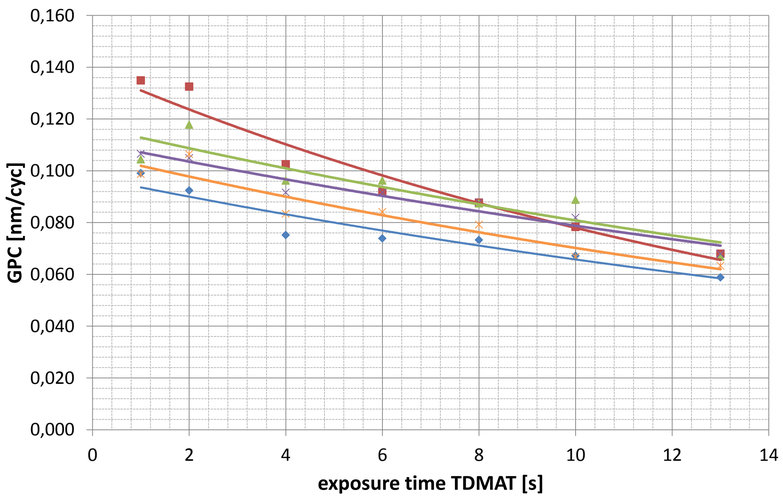


Fig. 5: adsorption of $TiCl_4$ at 180 °C; 1.0 s plasma

- Substrate-initiated growth
- GPC: about 0.022 nm/cyc
- High uniformity at low pulse/exposure time

TDMAT

- TDMAT-puls: higher than 1.5 s → self-limited growth
- GPC: between 0.06 nm/cyc and 0.13 nm/cyc



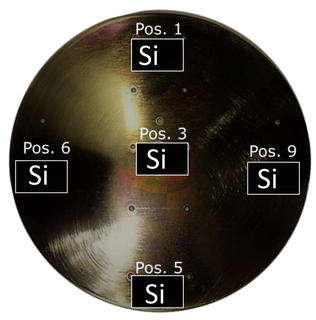
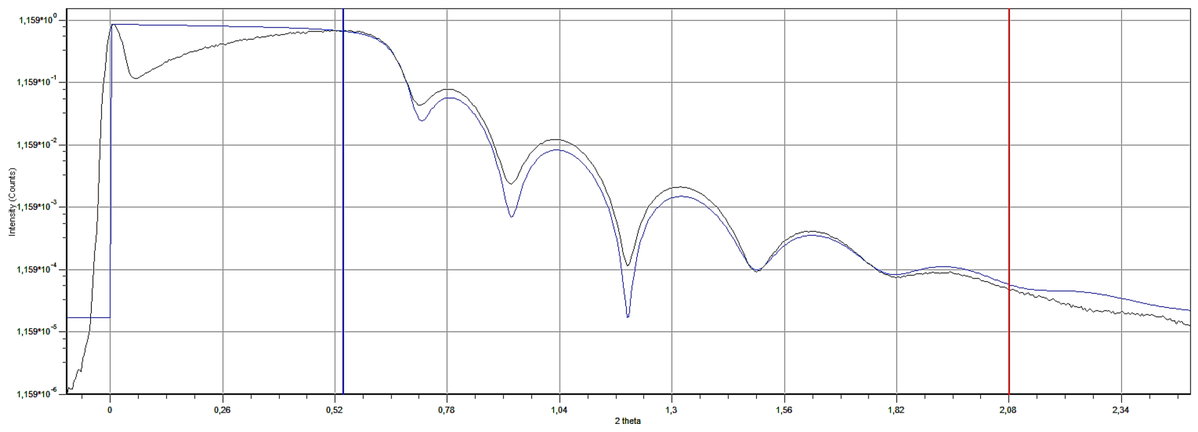


Fig. 7: sample arrangement

Fig. 6: GPC over TDMAT exposure, at 170 °C; 2 s TDMAT-pulse ; 20 s plasma

- Uniformity gets better with longer exposure time
  - Larger molecules → more time to find the right position
  - Desorption at higher exposure times → lower GPC

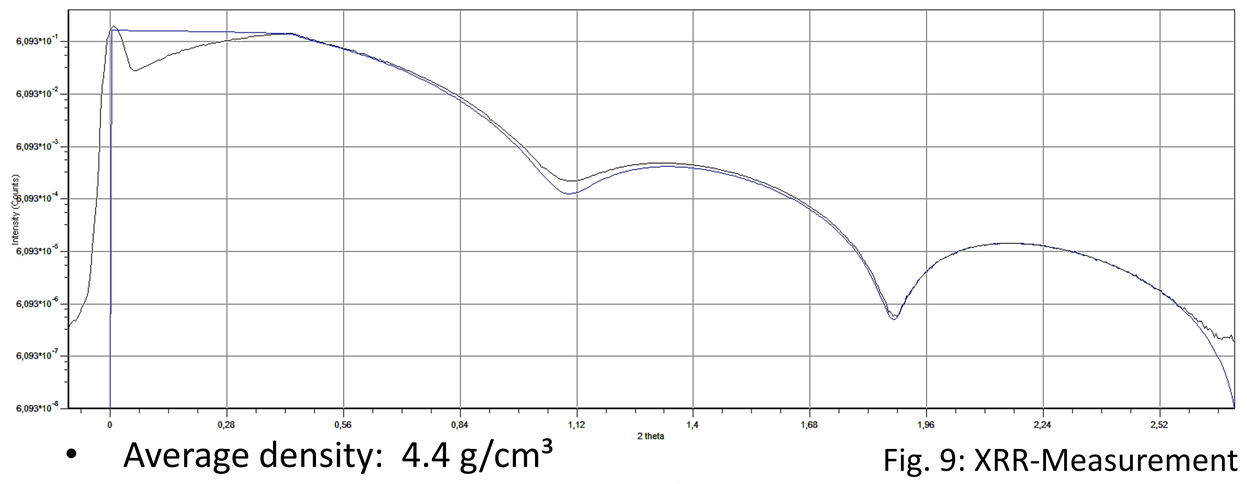
Film properties



- Average density: 4.9 g/cm³
- Average sheet resistance: 490 µΩ/cm at 10 nm- 12 nm layer thickness

Fig. 8: XRR-Measurement of a 26 nm thick TiN-film deposited with $TiCl_4$

	atom concentrations in 6 nm depth by XPS				
element	N	O	Cl	Ti	N/Ti-ratio
atomic-%	42.8	21.65	1.55	34	1.2585



- Average density: 4.4 g/cm³
- Average sheet resistance: 2810 µΩ/cm at 10 nm – 12nm layer thickness

Fig. 9: XRR-Measurement of a 9.9 nm thick TiN-film deposited with TDMAT

	atom concentrations in 6 nm depth by XPS				
element	C	N	O	Ti	N/Ti-ratio
atomic-%	11.15	28.75	30.5	29.65	0.9696

Conclusion

- Process easier to establish
  - Thermally more stable precursor
  - Shorter exposure time needed
- Deposition results in:
  - More uniform films
  - Lower sheet resistance
  - Higher density
- Lower GPC → longer processes
- Vacuum system damaging reaction products
- Stable process established
- Slightly lower oxygen contamination

- Process more difficult to establish
  - Thermally instable precursor
  - Long exposure time needed
- Deposition results in:
  - Less uniform films
  - Higher sheet resistance
  - Slightly lower density
- Higher GPC → shorter processes possible
- Stable process still in development
- High carbon and oxygen contamination

Literature

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