DARTWARS
Detector Array Readout with Traveling Wave AmplifieRS

NbTiN Films

Sputtering Optimisation

Short Report

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07/10/2022

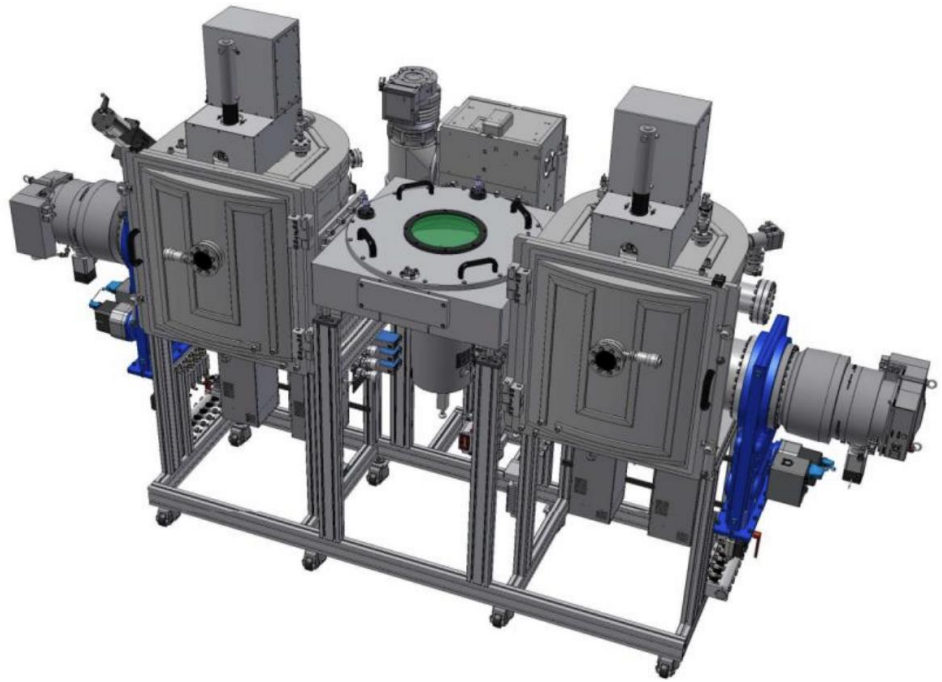
UPDATED on 31/10/2022

Sputtering deposition @ FBK (CR-M)

- Load-lock chamber + 2 deposition chambers → vacuum ~1e-8 mbar
- Upwards sputtering
- Nb(0.80)Ti(0.20) target
- *Example of recipe for NbTiN films:*

Parameter	Value
Power (P)	600 W
Pressure (p)	3e-3 mbar
Ar flow (f_{Ar})	50 sccm
N_2 flow (f_{N2})	7 sccm
Chuck temperature (T)	400 °C
Deposition time (t)	4 minutes

PVD Kenosistec 800 C



Optimising NbTiN deposition

1) How the relevant figures of merit (T_C, R_S, L_K) depend on the sputtering parameters?
2) Can we reach the goal values, i.e. T_C ~ 14 K and L_K ~ 10 pH?

Fab run	Variable parameters	Fixed parameters
DWT2 (11 wafers) Blank (i.e. no litho)	P [W], p [mbar], N_2 flow [sccm]	Ar flux [sccm], T [°C], t [minutes]
DWT3 (4 wafers) Litho: KIDs mask	t [minutes]	P [W], p [mbar], Ar flow [sccm], N_2 flow [sccm], T [°C]
DWT3-bis 2 (2 wafers) Litho: KIDs mask	t [minutes]	P [W], p [mbar], Ar flow [sccm], N_2 flow [sccm], T [°C]

Run DWT2: Recipes

Wafer	P [W]	p [mbar]	N2 flow [sccm]
DWT2/T1	700	2e-3	5
DWT2/T2	700	3e-3	4
DWT2/T3	700	3e-3	5
DWT2/T4	700	3e-3	6
DWT2/T5	1200	3e-3	5
DWT2/T6	700	3e-3	7
DWT2/T6B	700	3e-3	7
DWT2/T7	700	3e-3	8
DWT2/T8	700	3e-3	6.5
DWT2/T9	700	3e-3	7
DWT2/T10	600	3e-3	7

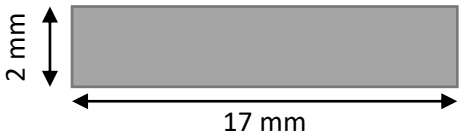
For all wafers:

Ar flux = 50 sccm
t = 6 minutes
T = 400 °C

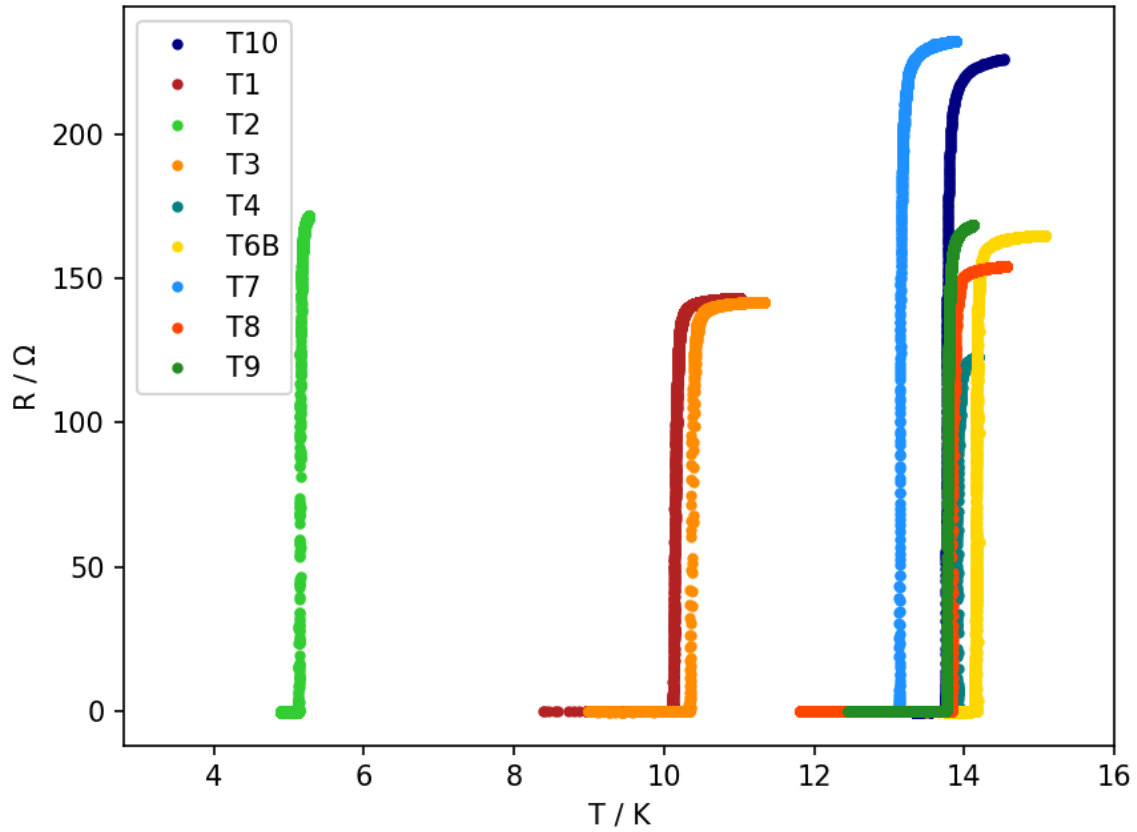
Run DWT2: Measurement results

DARTWARS
Detector Array Readout with Traveling Wave AmplifieRS

Wafer	P [W]	p [mbar]	f_{N2} [sccm]	R_S @RT [Ω/sq]	T_C [K]	R_S @lowT [Ω/sq]	L_K [pH/sq]
DWT2/T1	700	2e-3	5	19.43	10.16	17.88	2.43
DWT2/T2	700	3e-3	4	-	5.15	21.5	5.77
DWT2/T3	700	3e-3	5	-	10.38	17.75	2.36
DWT2/T4	700	3e-3	6	-	13.9	15.63	1.55
DWT2/T5	1200	3e-3	5	14.34	< 4.2	-	-
DWT2/T6	700	3e-3	7	31.11	11.34	34.75	4.23
DWT2/T6B	700	3e-3	7	19.19	14.17	19.63	1.91
DWT2/T7	700	3e-3	8	26.9	13.16	29.75	3.12
DWT2/T8	700	3e-3	6.5	18.64	13.86	19.25	1.92
DWT2/T9	700	3e-3	7	19.86	13.77	27.75	2.78
DWT2/T10	600	3e-3	7	26.35	13.77	21.13	2.12



Run DWT2: Plots



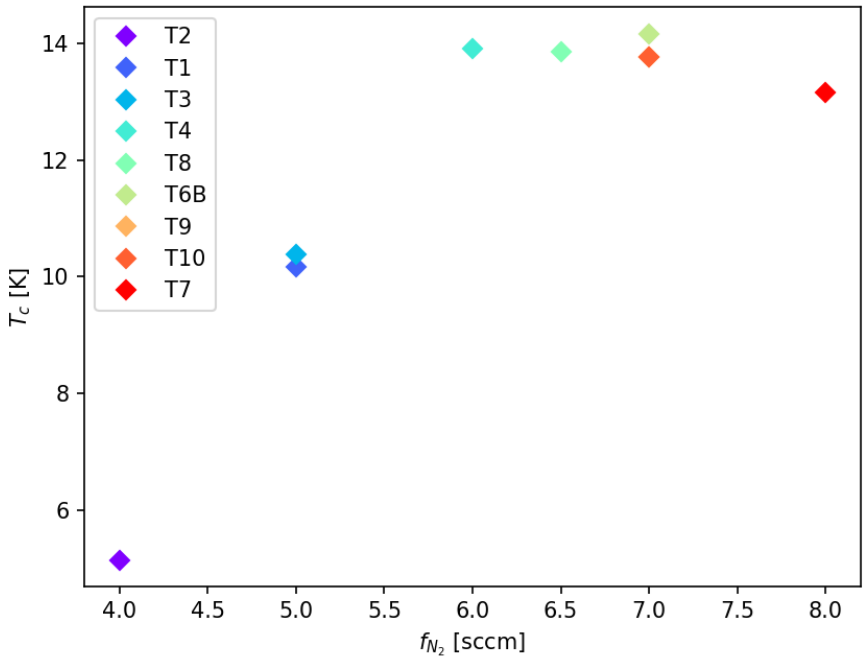
W	P [W]	p [mbar]	f_{N2} [sccm]
T1	700	2e-3	5
T2	700	3e-3	4
T3	700	3e-3	5
T4	700	3e-3	6
T5	1200	3e-3	5
T6	700	3e-3	7
T6B	700	3e-3	7
T7	700	3e-3	8
T8	700	3e-3	6.5
T9	700	3e-3	7
T10	600	3e-3	7

For all wafers:

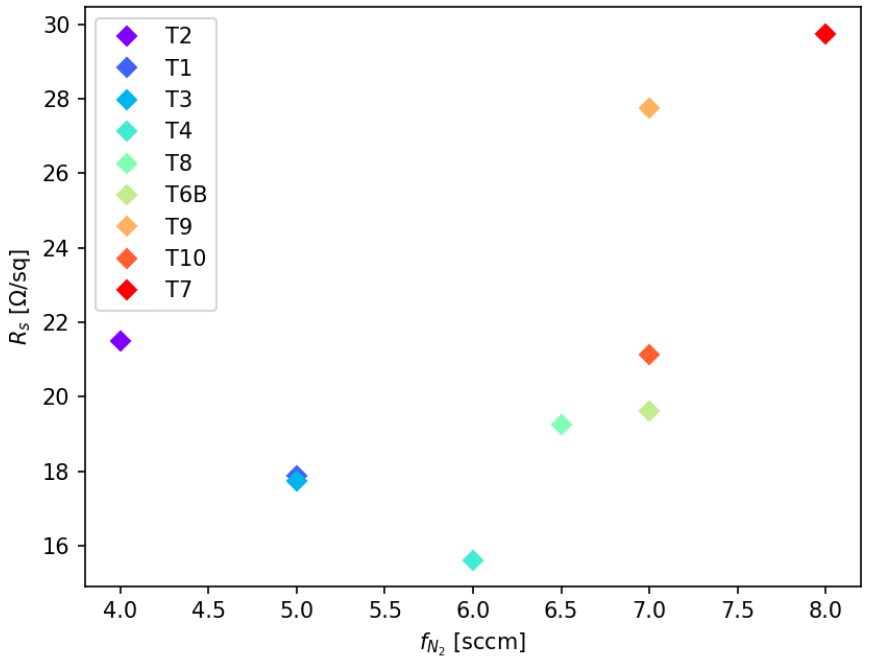
Ar flow = 50 sccm
t = 6 minutes
T = 400 °C

Run DWT2: Plots

T_C vs f_{N2}



R_S vs f_{N2}

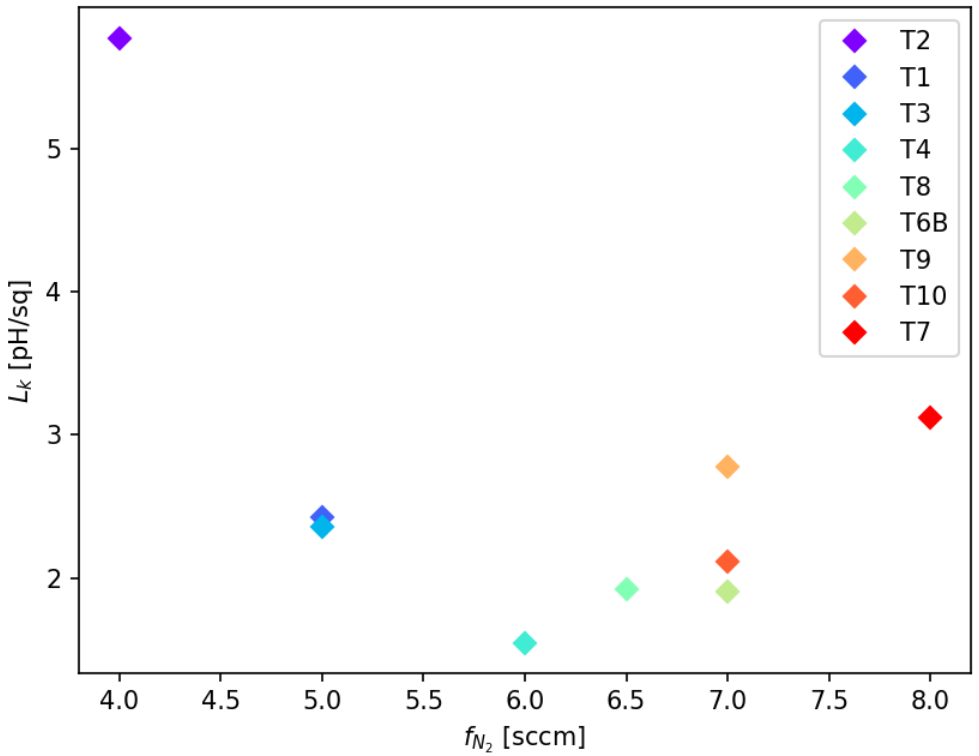


W	P [W]	p [mbar]	f_{N2} [sccm]
T1	700	2e-3	5
T2	700	3e-3	4
T3	700	3e-3	5
T4	700	3e-3	6
T5	1200	3e-3	5
T6	700	3e-3	7
T6B	700	3e-3	7
T7	700	3e-3	8
T8	700	3e-3	6.5
T9	700	3e-3	7
T10	600	3e-3	7

Ar flow = 50 sccm
t = 6 minutes
T = 400 °C

Run DWT2: Plots

L_K vs f_{N2}

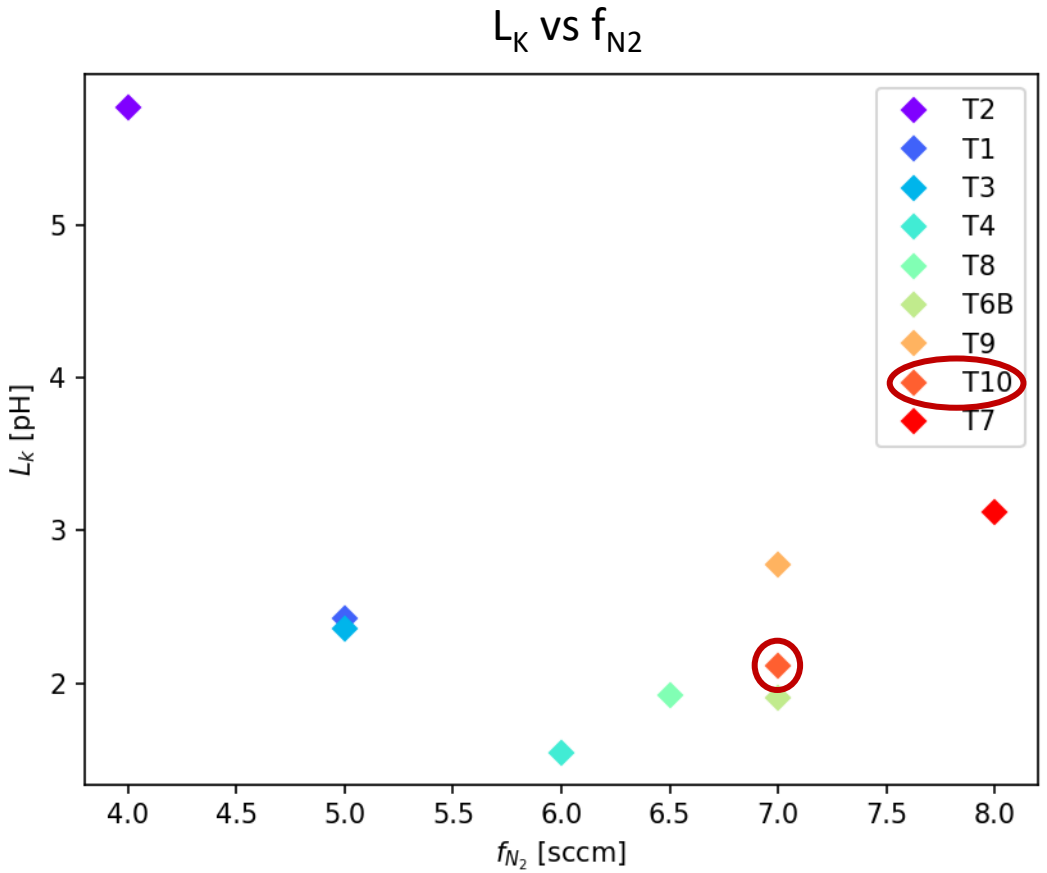


$$L_K(0) = \frac{R_S \cdot \hbar}{\pi \cdot T_C \cdot k_B \cdot 1.762}$$

W	P [W]	p [mbar]	f_{N2} [sccm]
T1	700	2e-3	5
T2	700	3e-3	4
T3	700	3e-3	5
T4	700	3e-3	6
T5	1200	3e-3	5
T6	700	3e-3	7
T6B	700	3e-3	7
T7	700	3e-3	8
T8	700	3e-3	6.5
T9	700	3e-3	7
T10	600	3e-3	7

Ar flow = 50 sccm
t = 6 minutes
T = 400 °C

Run DWT2: Plots



$$L_K(0) = \frac{R_S \cdot \hbar}{\pi \cdot T_C \cdot k_B \cdot 1.762}$$

W	P [W]	p [mbar]	f_{N2} [sccm]
T1	700	2e-3	5
T2	700	3e-3	4
T3	700	3e-3	5
T4	700	3e-3	6
T5	1200	3e-3	5
T6	700	3e-3	7
T6B	700	3e-3	7
T7	700	3e-3	8
T8	700	3e-3	6.5
T9	700	3e-3	7
T10	**600**	**3e-3**	**7**

Ar flux = 50 sccm
t = 6 minutes
T = 400 °C

Run DWT3 & DWT3-bis: recipes

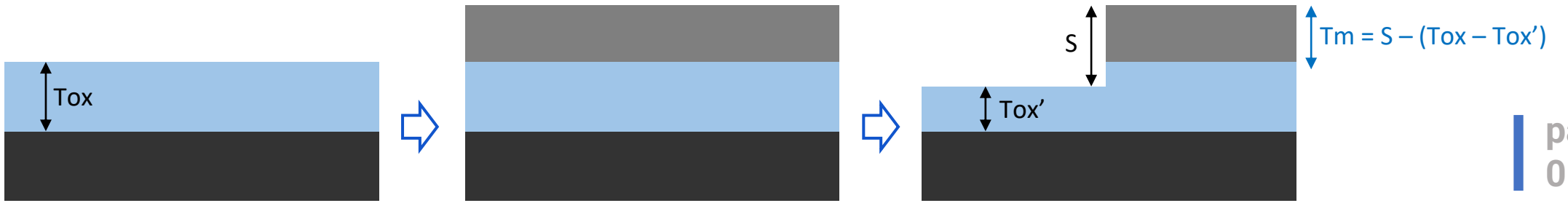
Wafer	t [minutes]
DWT3/w1	6
DWT3/w2	2
DWT3/w3	9
DWT3/w4	4
DWT3-bis/w1	3
DWT3-bis/w2	2.5

→ *Comparison with DWT2/T10 to test reproducibility*

For all wafers:

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Lithography with KIDs mask → more precise measurement of thickness:

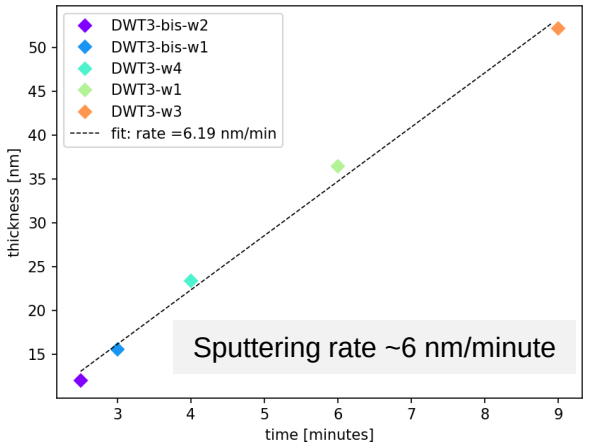


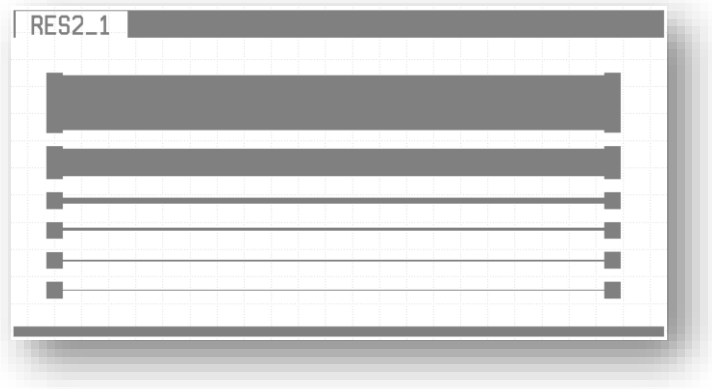
Run DWT3 & DWT3-bis: Results

Wafer	t [minutes]	Thickness [nm]	R_S @RT [Ω/sq]	T_C [K]	R_S @lowT [Ω/sq]	L_K [pH/sq]
DWT3/w1	6	36.41	29.37	13.45	32.4	3.32
DWT3/w2	2	?	92.22	12.03	125	14.7
DWT3/w3	9	52.19	16.87	14.07	18	1.75
DWT3/w4	4	23.38	38.25	13.35	44	4.70
DWT3-bis/w1	3	15.53	50.50	12.88	62	6.64
DWT3-bis/w2	2.5	12.04	64.97	12.45	86	9.53

For all wafers:

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

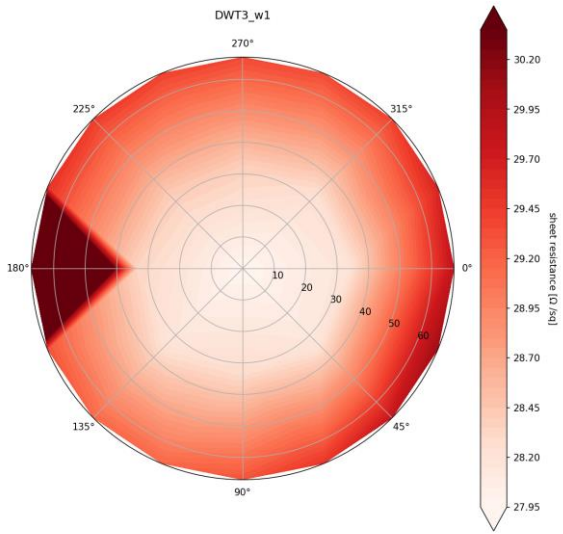




Run DWT3: Plots

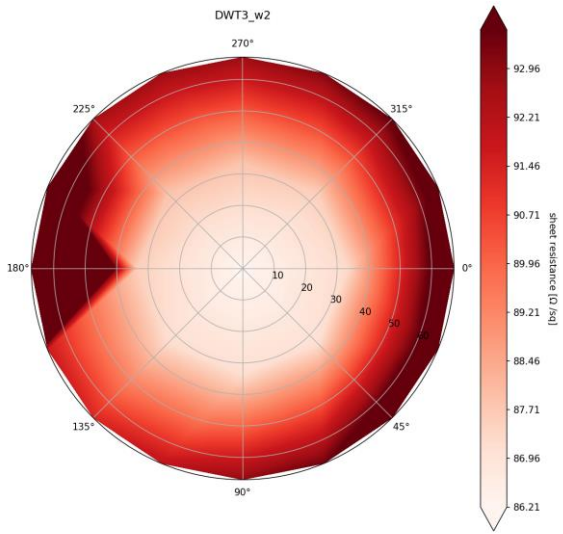
Homogeneity of film thickness from sheet resistance measurements

6 minutes



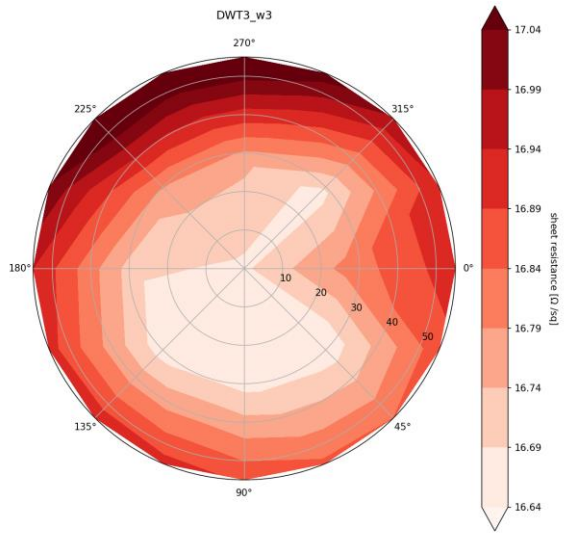
Total variation: 34.15 %
Variation excluding flat area: 6.54 %

2 minutes



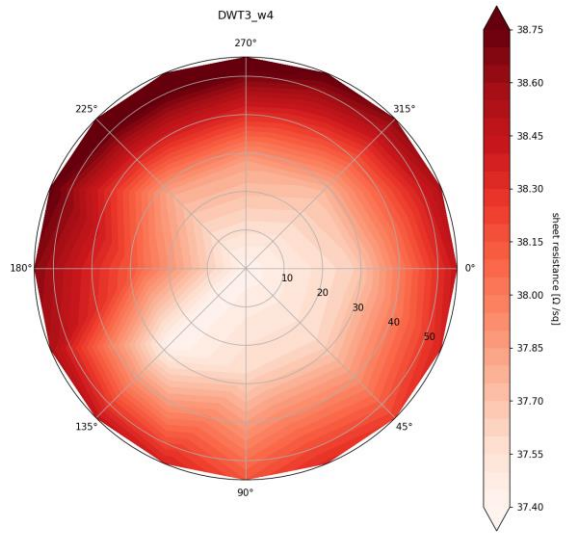
Total variation: 33.39 %
Variation excluding flat area: 8.9 %

9 minutes



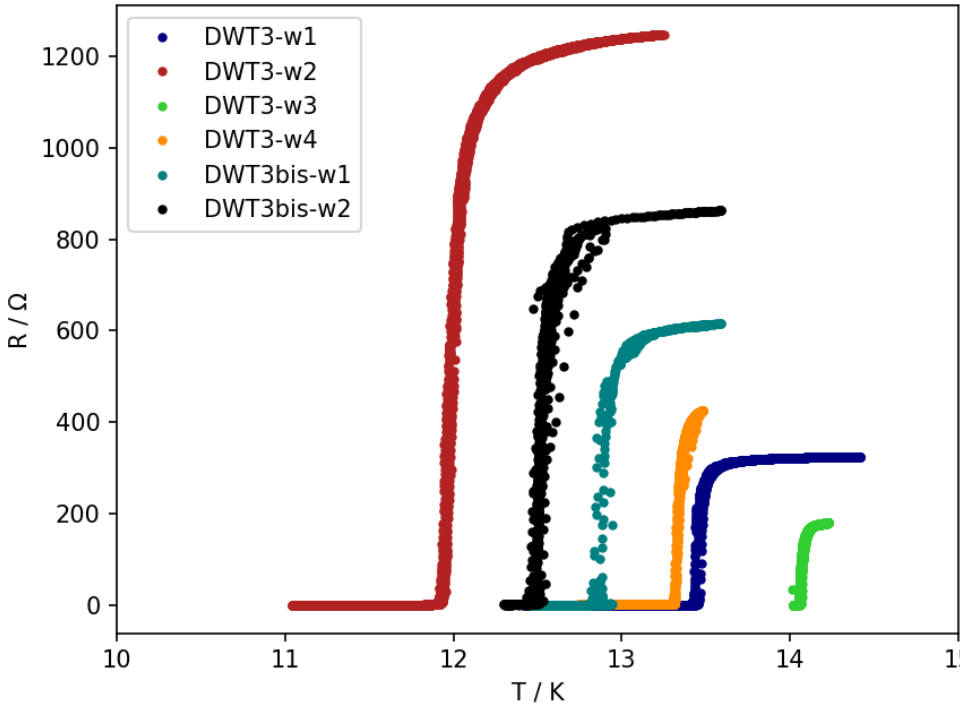
Total variation: 2.96 %
Variation excluding flat area: 2.96 %

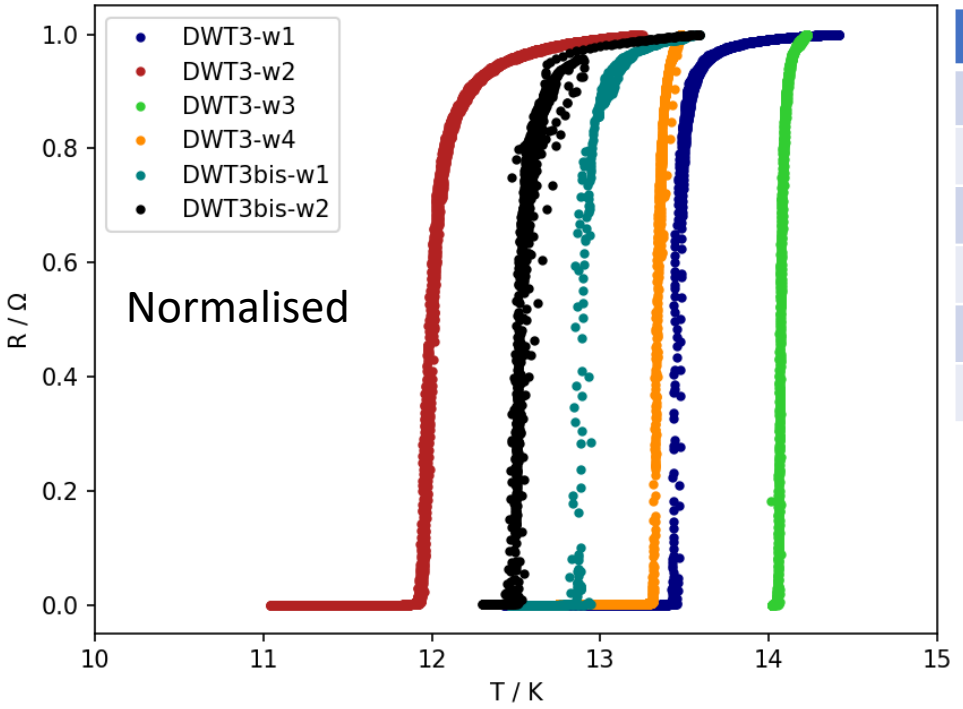
4 minutes



Total variation: 4.13 %
Variation excluding flat area: 4.13 %

Run DWT3: Plots

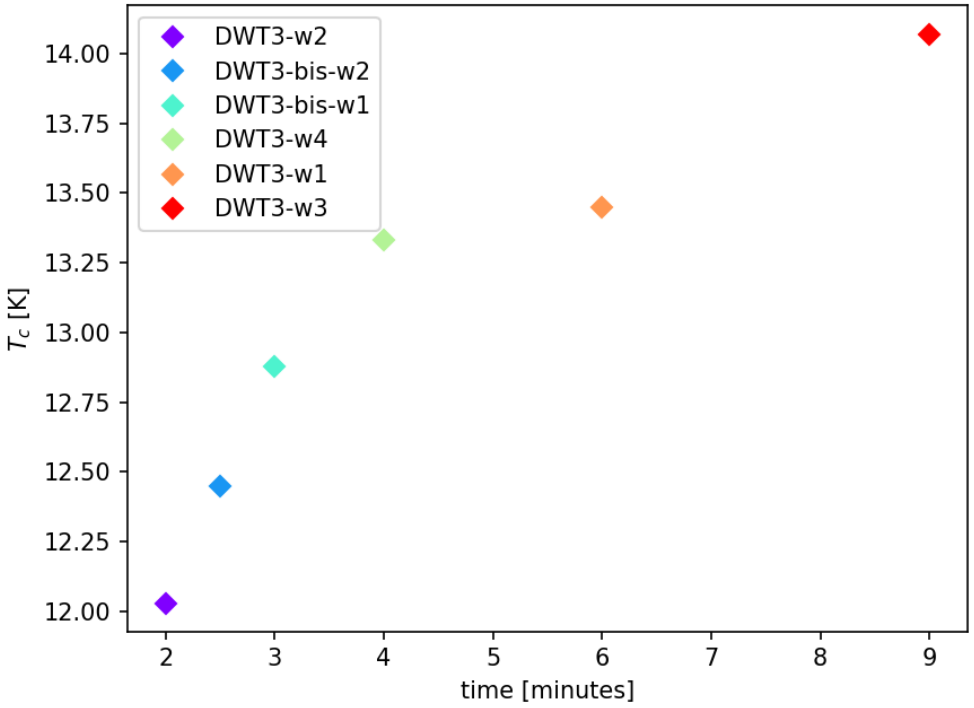


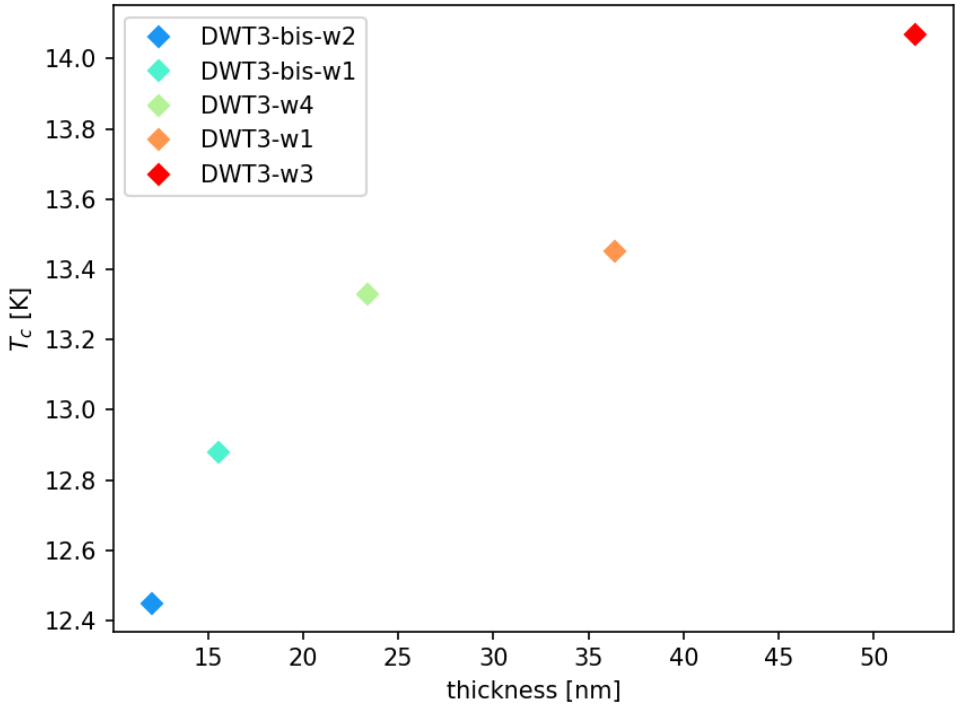


Wafer	t [min]	T [nm]
DWT3/w1	6	36.41
DWT3/w2	2	?
DWT3/w3	9	52.19
DWT3/w4	4	23.38
DWT3bis/w1	3	15.53
DWT3bis/w2	2.5	12.04

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Run DWT3: Plots Tc





Wafer	t [min]	T [nm]
DWT3/w1	6	36.41
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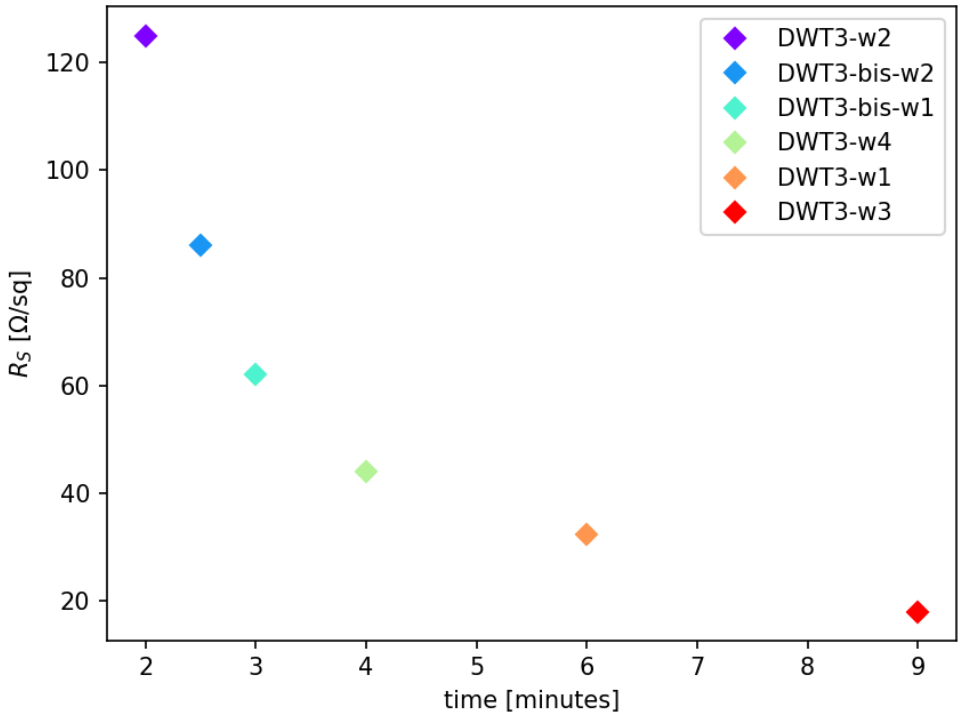
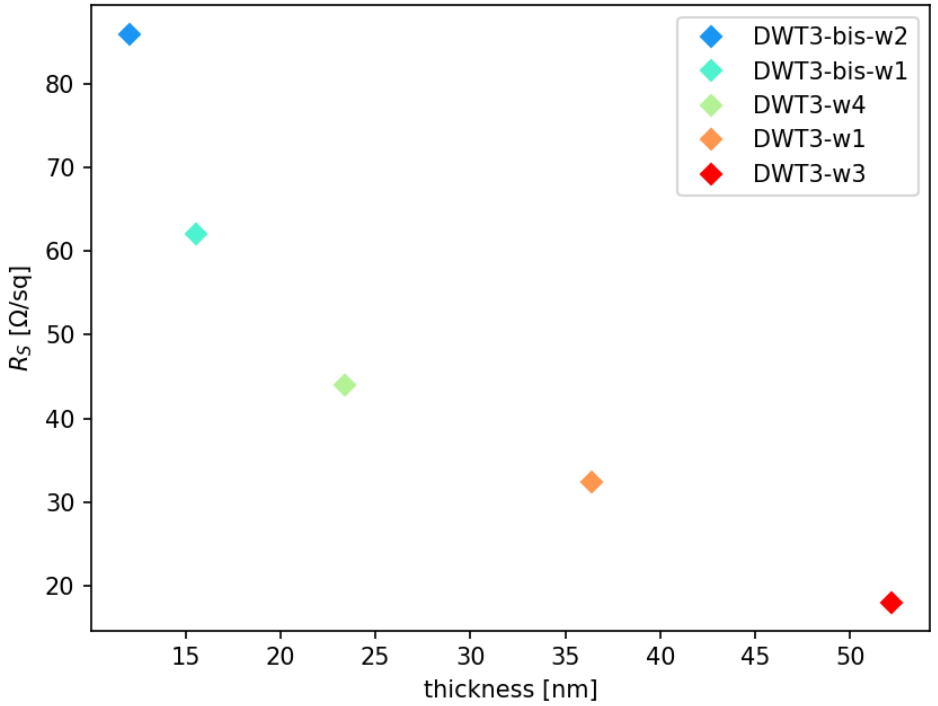
DWT3bis/w1	3	15.53
DWT3bis/w2	2.5	12.04

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Run DWT3: Plots Rs





Wafer	t [min]	T [nm]
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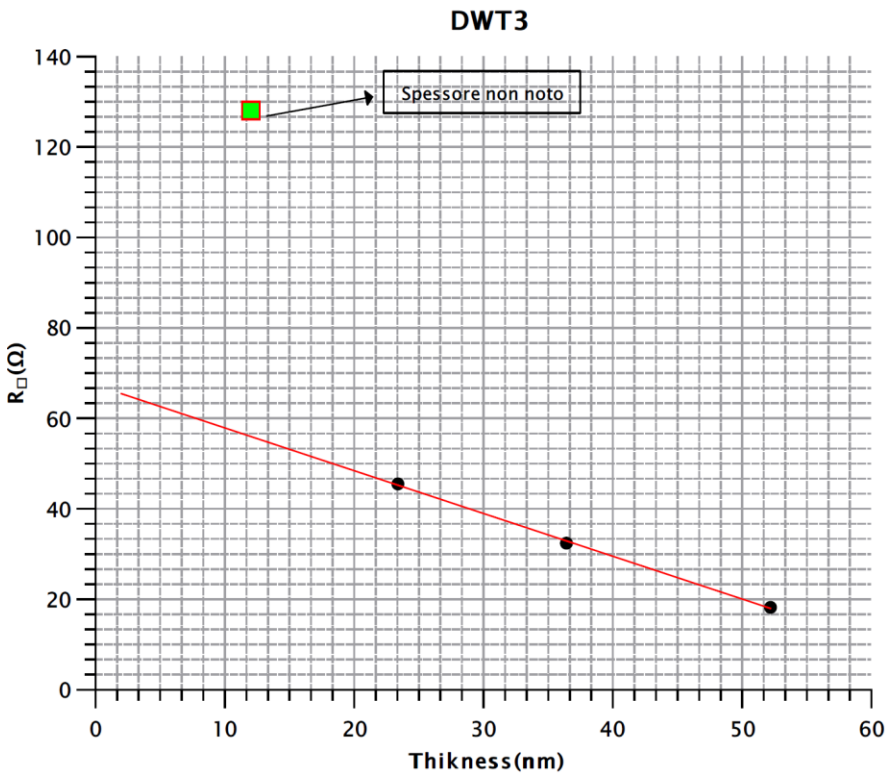
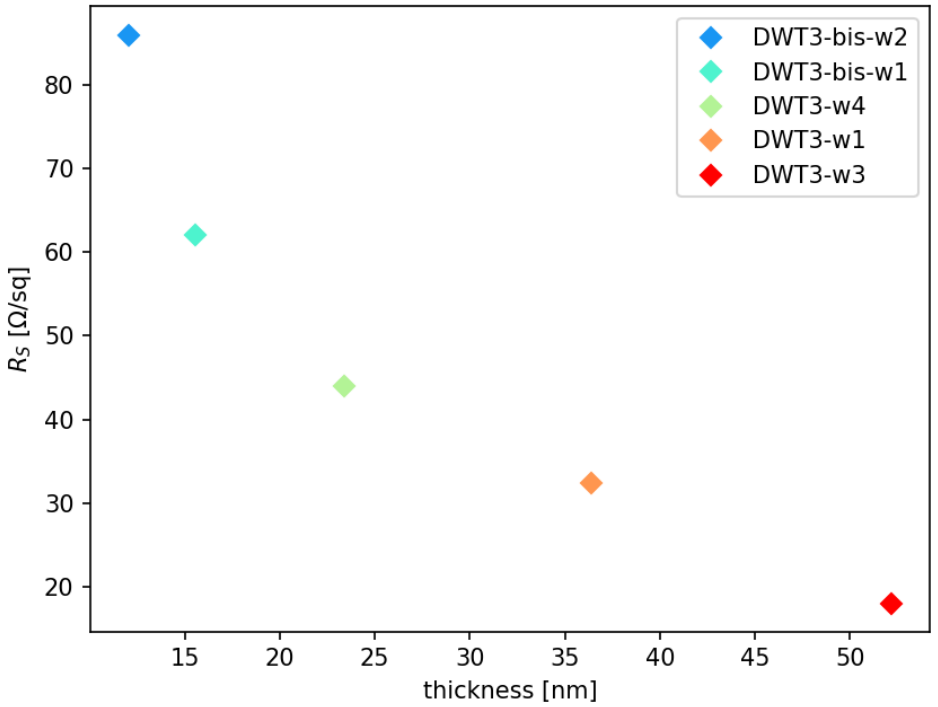
DWT3bis/w1	3	15.53
DWT3bis/w2	2.5	12.04

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Run DWT3: Plots Rs





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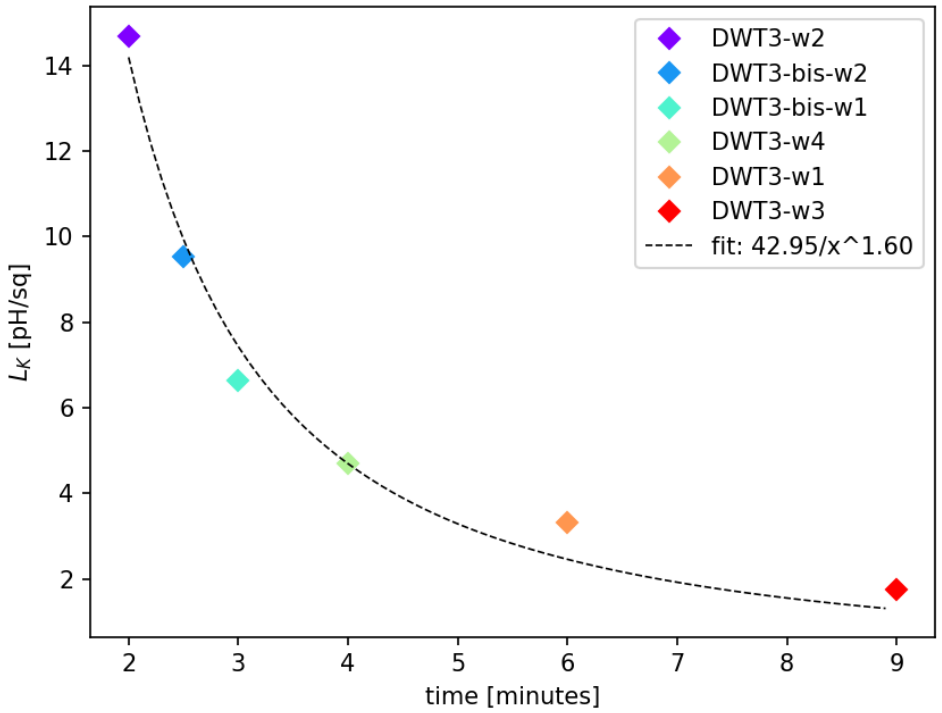
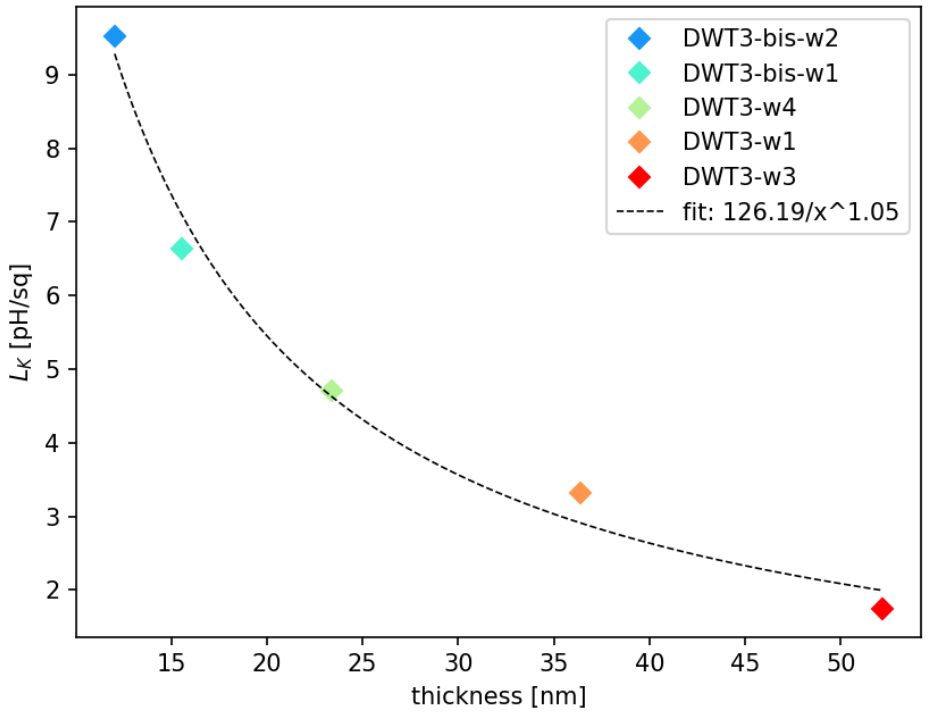
DWT3/w4	4	23.38
DWT3bis/w1	3	15.53
DWT3bis/w2	2.5	12.04

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Run DWT3: Plots Lk





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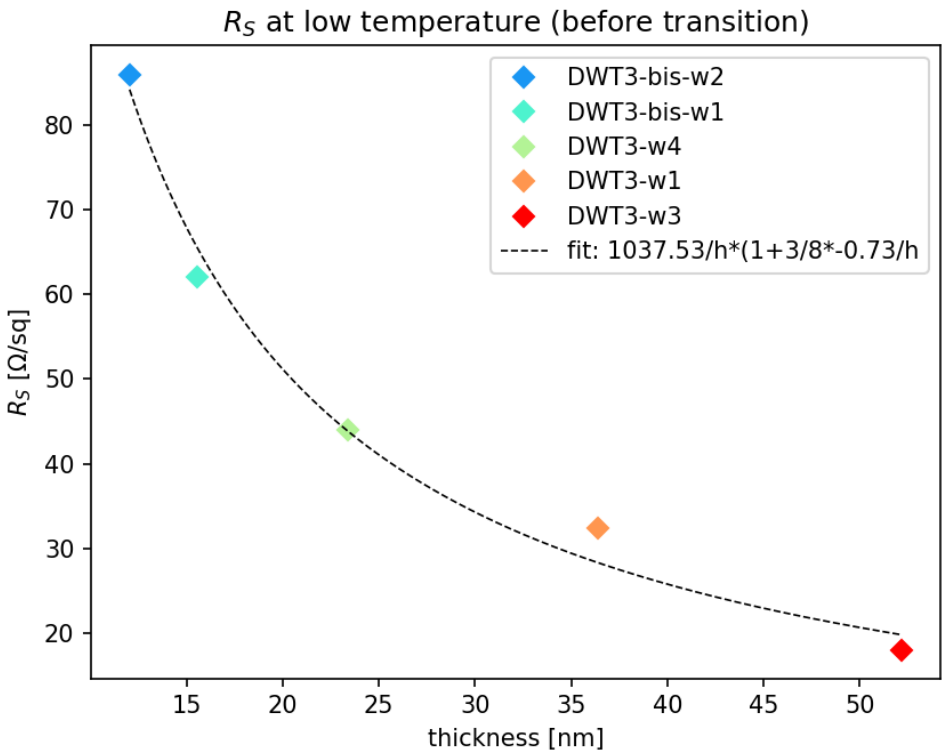
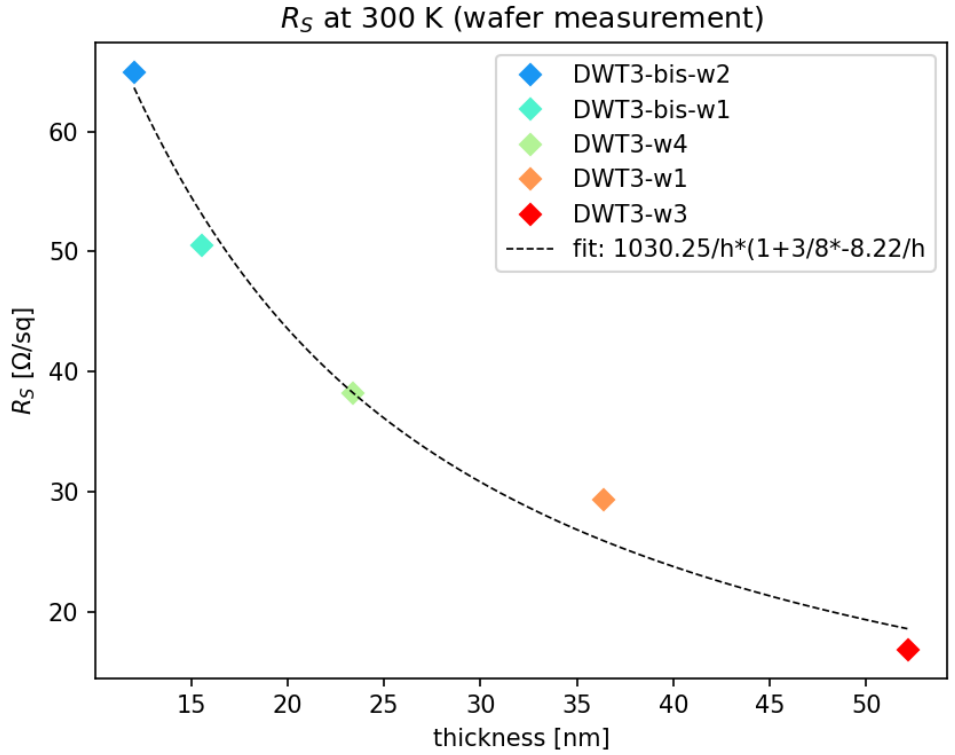
DWT3/w4	4	23.38
DWT3bis/w1	3	15.53
DWT3bis/w2	2.5	12.04

P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

$$L_K(0) = \frac{R_S \cdot \hbar}{\pi \cdot T_C \cdot k_B \cdot 1.762}$$

Run DWT3: Fits Rs vs thickness





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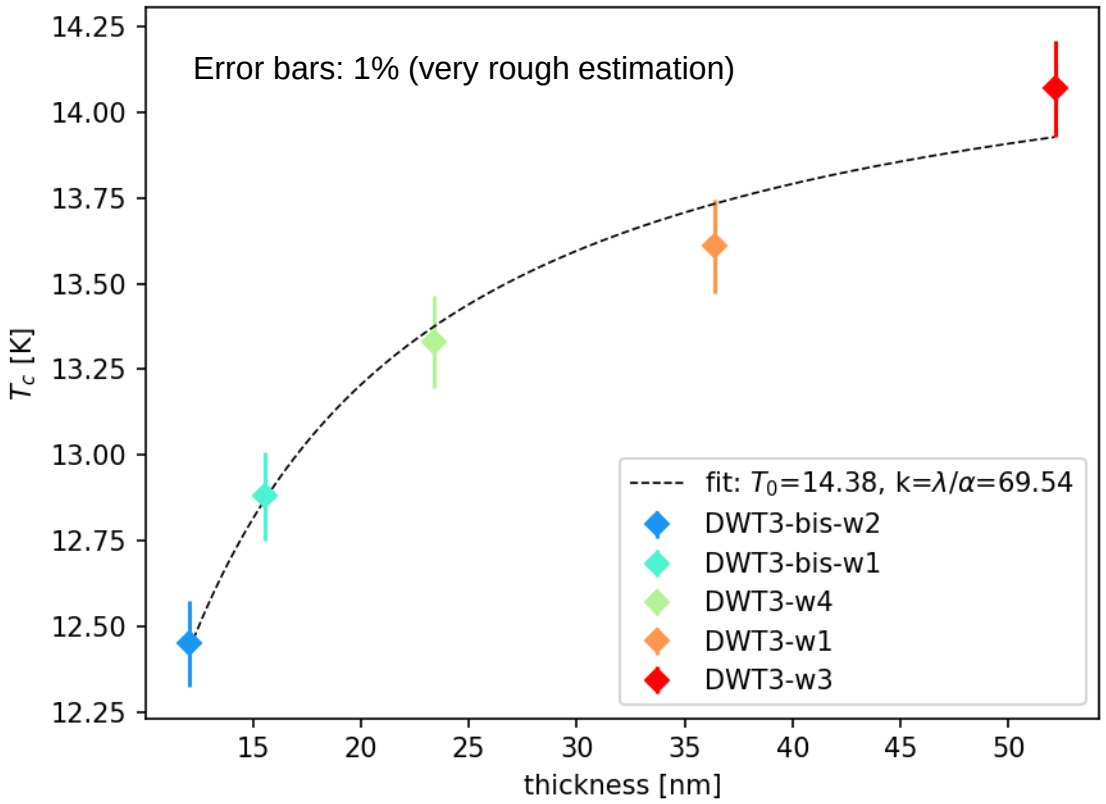
P = 600 W
p = 3e-3 mbar
Ar flux = 50 sccm
N2 flux = 7 sccm
T = 400 °C

Fuchs & Sondheimer model:

$$R_S(h) = \frac{\rho_0}{h} \cdot \left(1 + \frac{3}{8} \cdot \frac{l_b}{h}\right)$$

Run DWT3: Fits Tc vs thickness



Malbouisson model (*) :

$$T_C(h) = T_0 - \frac{3\gamma\lambda_\mu}{2\sqrt{2}\pi\alpha h}$$

$$= T_0 - \frac{3\gamma k}{2\sqrt{2}\pi h}$$

with $k = \lambda_\mu/\alpha$

(*) doi: 10.1103/PhysRevLett.14.949

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T = 400 °C