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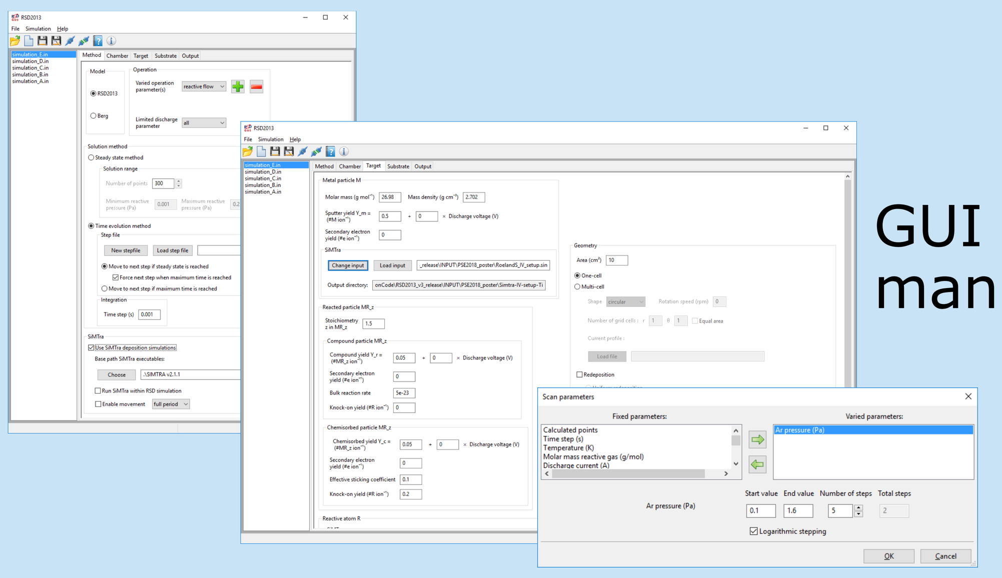
GHENT UNIVERSITY

FACULTY OF SCIENCES

The (in)stability of process control mechanisms in reactive DC sputtering deposition

Simulation software

RSD 2013 version 3 = balance equation model



GUI + manual

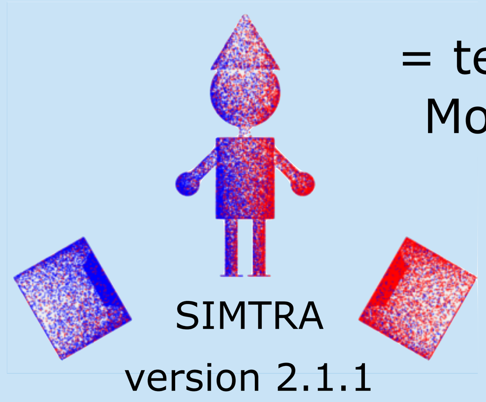
INPUT
operation and material parameters

OUTPUT
operation process curves (with hysteresis)

System observables:
- reactive gas pressure
- discharge current/voltage
- target/substrate state

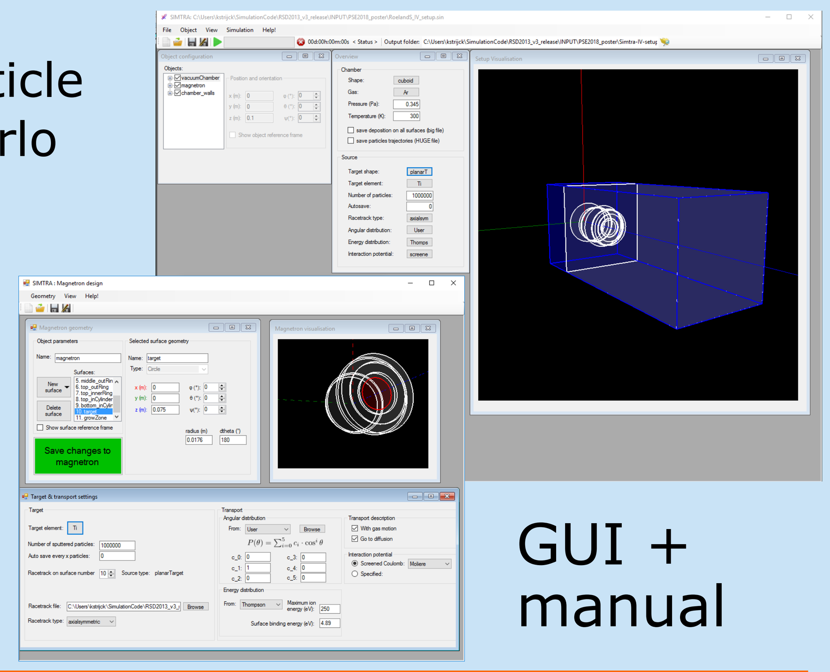
process curve O(S)

Operation parameters:
- reactive gas flow
- pumping speed NEW
- discharge current/voltage NEW



= test particle Monte Carlo model

SIMTRA version 2.1.1



GUI + manual

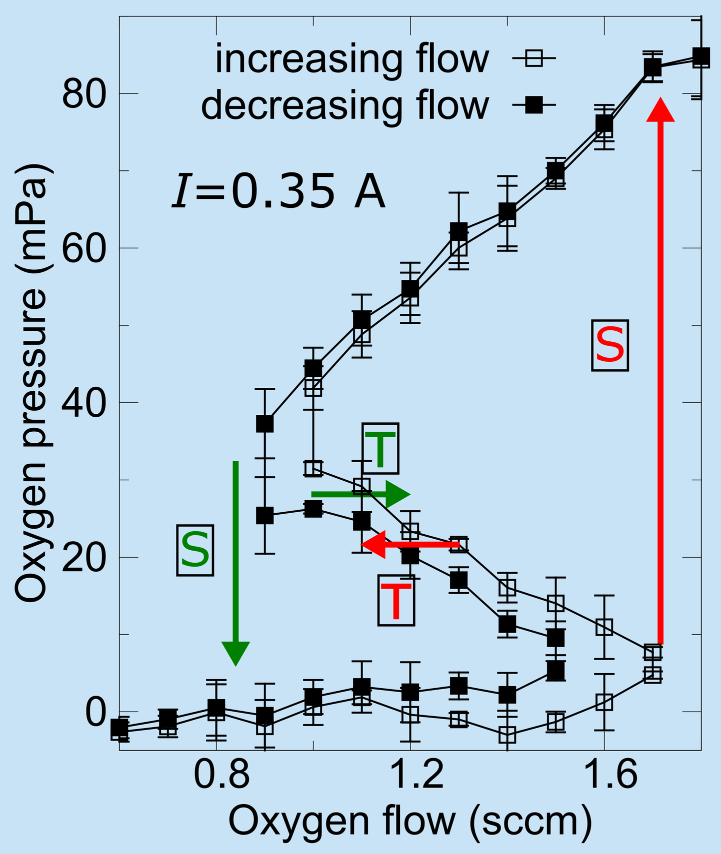
OUTPUT
deposition:
number densities
energy distribution
incidence direction

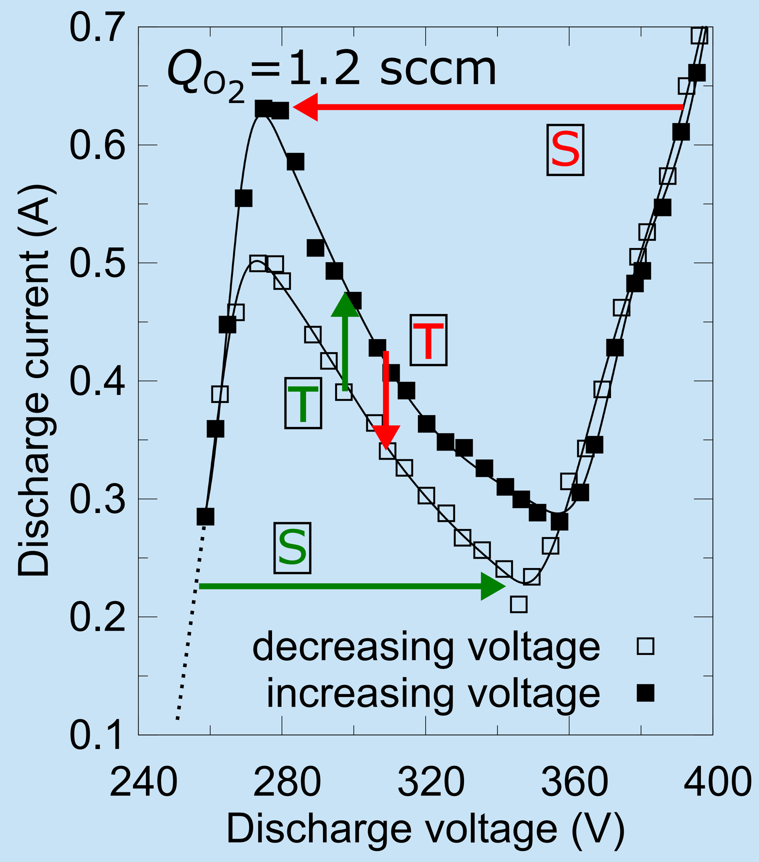
deposition rates
film composition
uniformity control

INPUT
3D representation setup
target racetrack
initial energy/angular distribution
sputter gas pressure/temperature
interaction potential

Problem : Criticality mechanisms during reactive deposition

Planar 2 inch Al DC sputtered in Ar/O_2 atmosphere



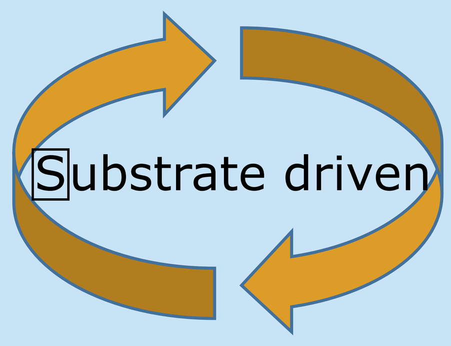


R. Schelfhout et al., Applied Physics Letters 109, 111605 (2016)

"traditional" hysteresis

higher/lower reactive gas pressure

more/less target reaction



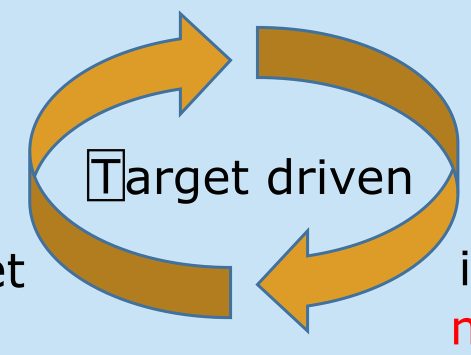
less/more reactive gas gettering by substrate

lower/higher deposition rate

"double" hysteresis

higher/lower compound fraction

lower/higher erosion speed



more/less target reaction

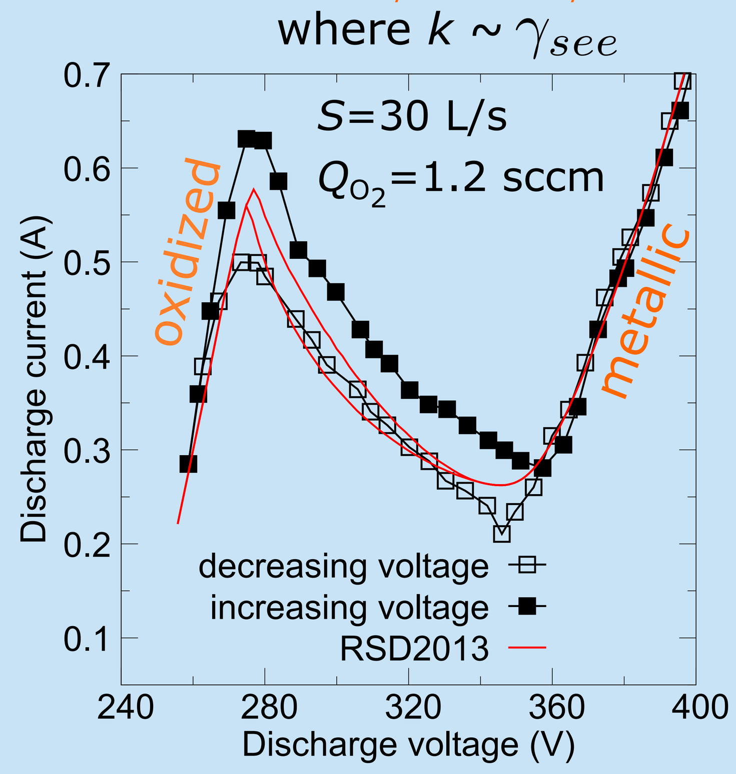
more/less implanted reactive gas
more/less time to react

Solution : Voltage control ?

stable — Al - Al_2O_3

$\gamma_{see,ox} > \gamma_{see,m}$

reactive IV-characteristic = superposition of metallic and oxidized $I=k_{m/ox}(V-V_{m/ox,0})^2$ where $k \sim \gamma_{see}$

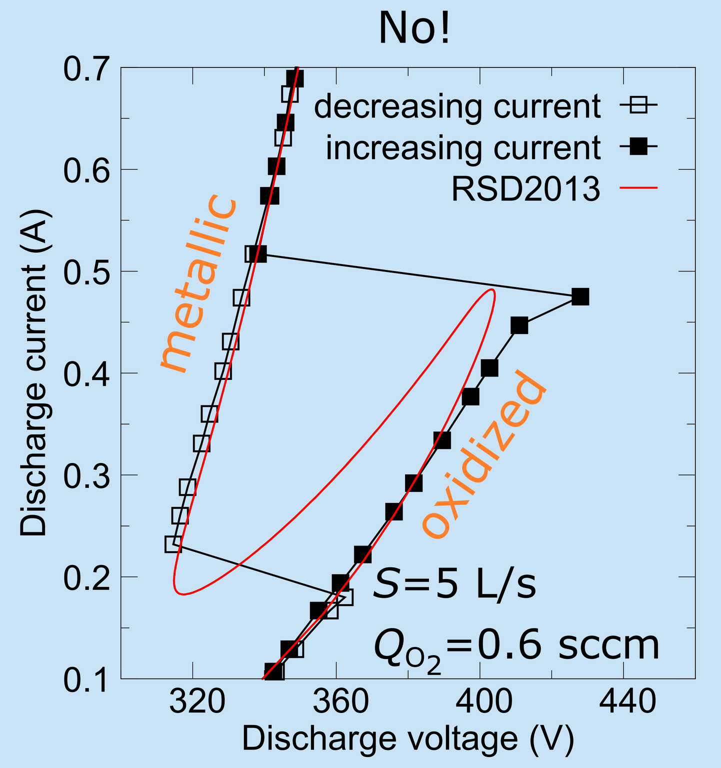


unstable — Ti - TiO_2 - ...

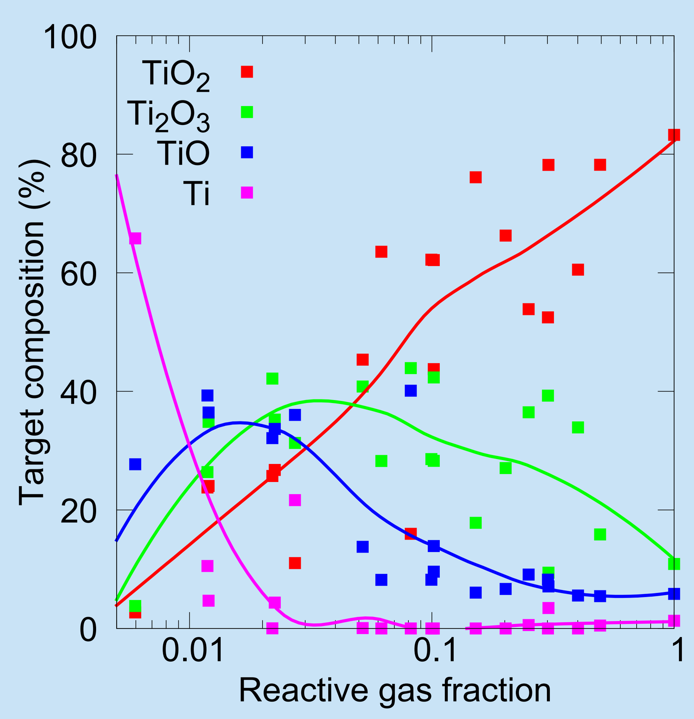
$\gamma_{see,ox} < \gamma_{see,m}$

reactive IV-characteristic = superposition of metallic and ONE oxidized *IV* ?

No!

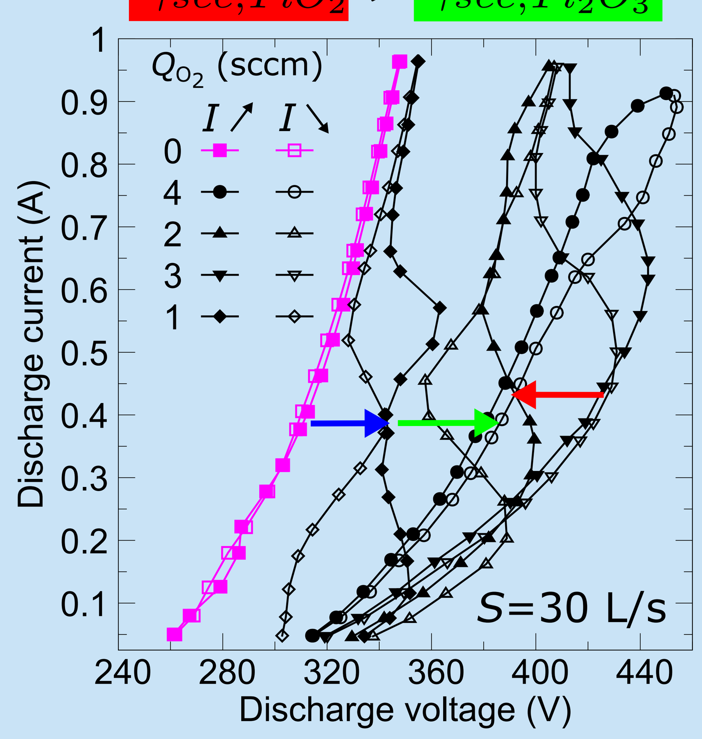


Different oxidation states?
In-vacuo XPS determination of target composition proves existence of two additional sub-oxides TiO and Ti_2O_3 along hysteresis.



Reactive IV-characteristic is in fact a mixture of four $I=k_i(V-V_{i,0})^2$ with i=Ti, TiO, Ti_2O_3, TiO_2 and $k_i \sim \gamma_{see,i}$ where

$\gamma_{see,Ti} > \gamma_{see,TiO} > \gamma_{see,TiO_2} > \gamma_{see,Ti_2O_3}$



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