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

**Simulation software**

- **GUI + manual**
- **INPUT**
  - operation and material parameters
- **OUTPUT**
  - operation process curves (with hysteresis)

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

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

**Problem:** Criticality mechanisms during reactive deposition

Planar 2 inch Al DC sputtered in Ar/O₂ atmosphere

- Increasing flow: **I = 0.35 A**
- Discharge current (A)
- Oxygen pressure (mPa)
- Discharge voltage (V)

**Solution:** Voltage control?

**Stable**

- **AI - Al₂O₃** (superposition of metallic and oxidized)
- Reactive IV-characteristic
- Q₀₂ = 1.2 sccm
- S = 30 L/s

**Unstable**

- **Ti - TiO₂ – – – –**
- Reactive IV-characteristic
- No!
- Q₀₂ = 1.2 sccm
- S = 30 L/s

Different oxidation states?

In-vacuo XPS determination of target composition proves existence of two additional sub-oxides TiO and Ti₂O₃ along hysteresis.

**Reactive IV-characteristic is in fact a mixture of four**

\[ I = k(V - V_{\text{bias}})^2 \]

with \( i = \text{Ti}, \text{TiO, Ti}_2\text{O}_3, \text{TiO}_2 \)

and \( k_i \propto \gamma_{\text{see}, i} \), where

\[ \gamma_{\text{see}, i} \propto \frac{1}{\Delta E_i} \]

**Different**

**Target composition**

- Reactive gas fraction
- Target reaction

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