Technology Metals I Advanced Ceramics

Highest capacitance at higher voltages: Pushing the limits of tantalum high voltage capacitors

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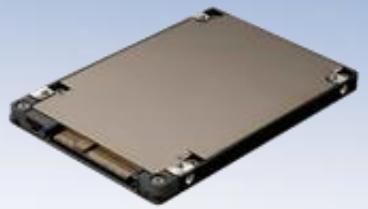
High Voltage Market Trends: Focus High Reliability

Increasing demand for HV applications!

Data Storage (SSD)



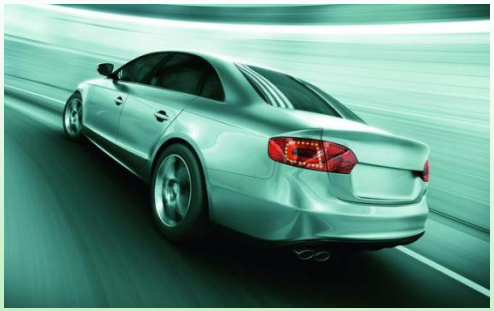
Medical Devices

Aviation

Aerospace

Transportation and Railroad

Automotive



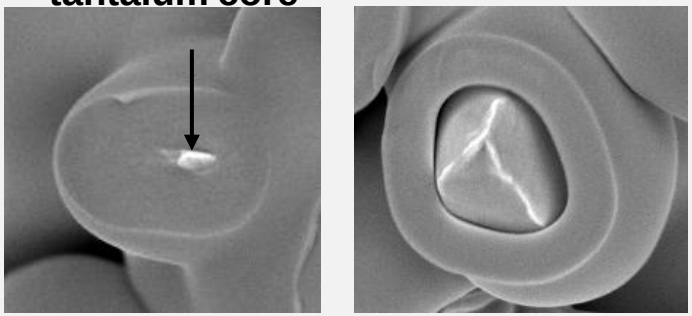
Defense

Source: Deutsch Bahn, Wikipedia

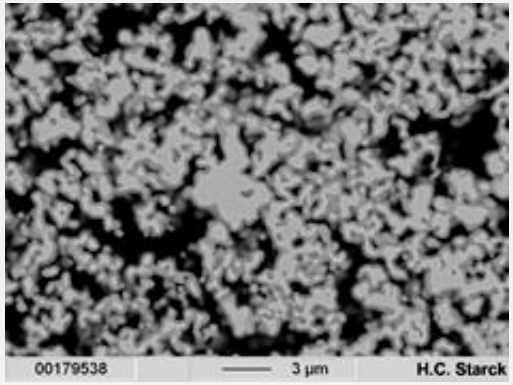
High Voltage Medium Capacitance - HVMC

- Main focus at H.C. Starck: New powders with formation voltages 50 - 350 V_f

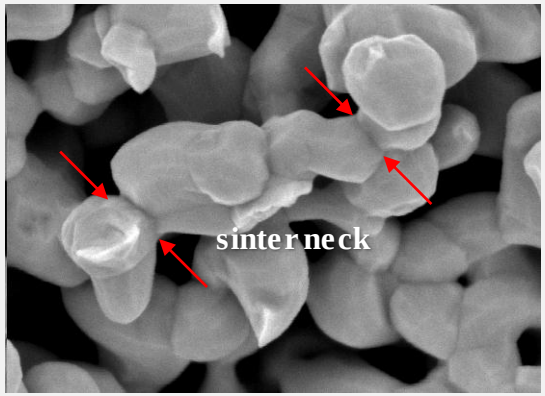
1. Suitable large primary particle size



3. Sufficiently large pore size diameter



2.Sufficiently strong (thick) sinter necks



4. Good homogeneity of 1-3

5. High Purity

New high voltage powder generation requires improved microstructure!

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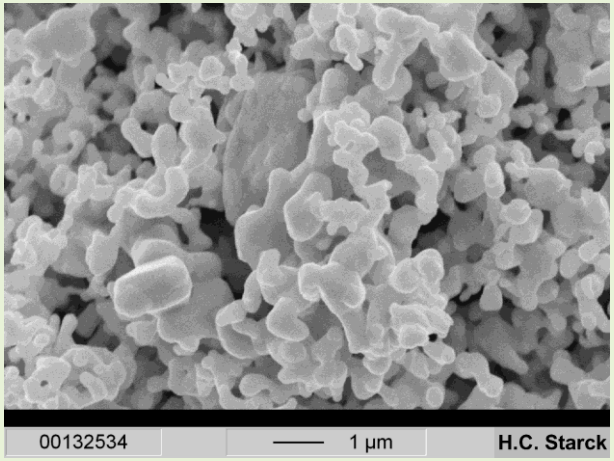
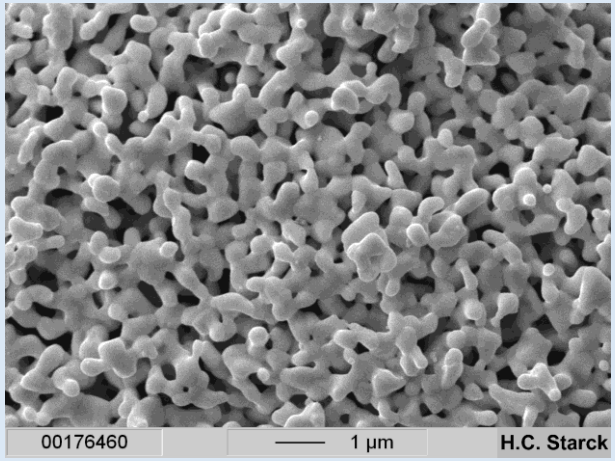
Capability of Different Tantalum Powder Processes

Powder Type	Na Reduced	Mg Reduced
+ Advantages	• Large pores • Large primary particles	• Very homogenous morphology • Higher purity
- Disadvantages	• Less homogenous powder	• Small pores (< 400 nm) • Too small primary particles
Main Focus (Past)	• Low CV / high voltage	• High CV / low voltage
Microstructure (showcase)		

➔ HVMC combining the advantages of both powder types!

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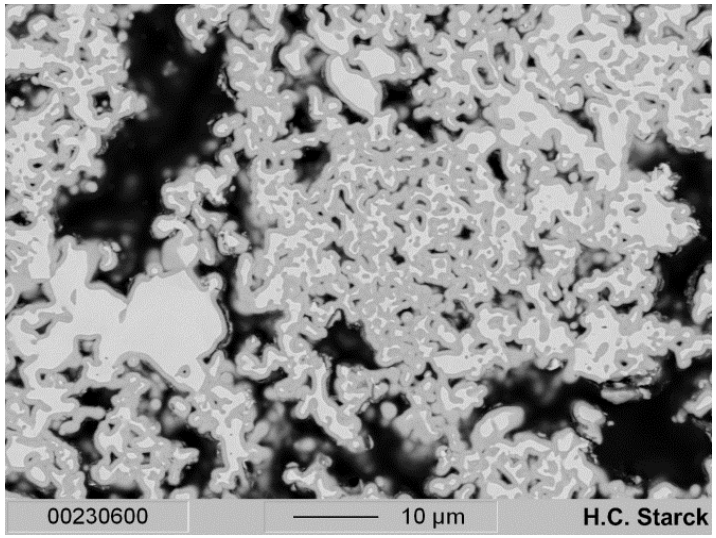
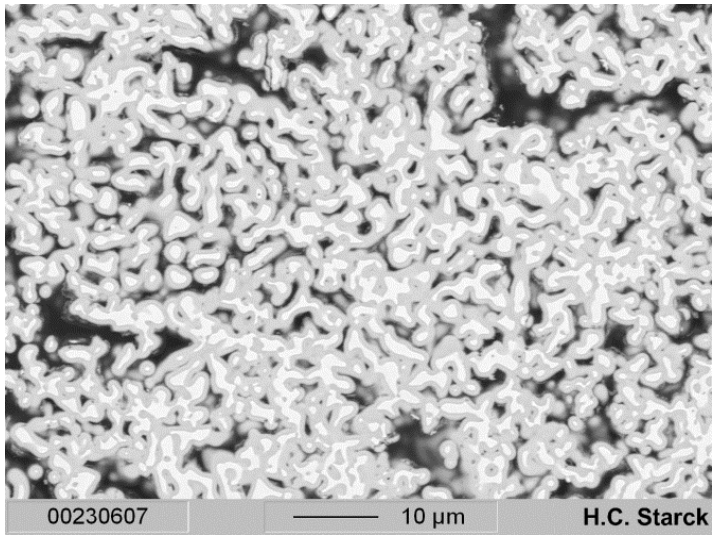
Comparing the Micro Structure: HV300 vs. Standard Anode

Cross Section of 300 V formed anodes

12k µFV/g Anode



HV300 Anode



- ○ Large variation of primary particle size
- ○ Large variation of pore size, wasted space

- ✓ Superior microstructural homogeneity
- ✓ More uniform pores and particles

Improved HVMC microstructure is responsible for highest cap!

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HVMC: Highest Capacitance for 100 – 350 V

Powder Naming

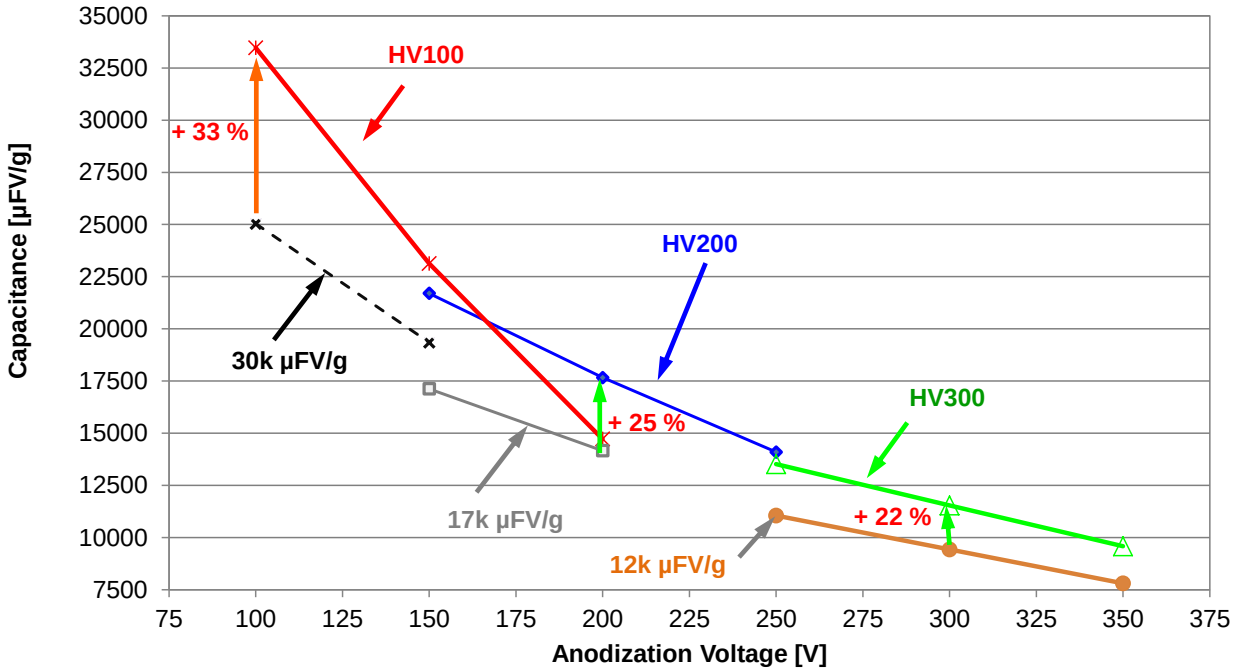
"High Voltage"

↓

HV 300

↑

target formation voltage



- HVMC give highest cap at each formation voltage!
- Superior microstructural homogeneity of pores and particles
  - High dielectric strength
  - High reliability
  - Highest energy density

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Finding the Optimum

Impact of pressing and sintering for 300 V_f

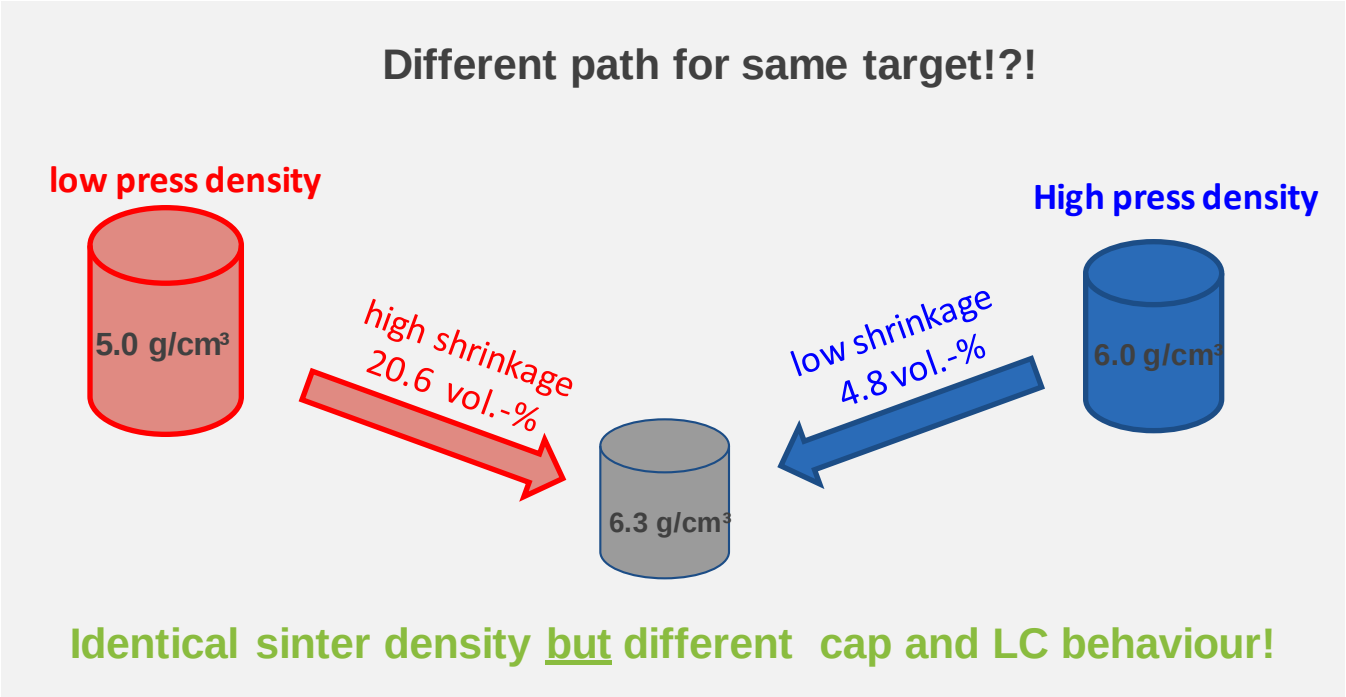
Highest Energy Density at 300 V_f: HV 300

- **Task** — Determination of optimum pressing and sintering condition for HV 300

  ➔ Finding maximum CV/cm³ and good leakage current/BDV behavior

- **Problem** — Best powder will failure when wrong conditions are applied!

  !! Each powder and anodization voltage has its own optimum!!



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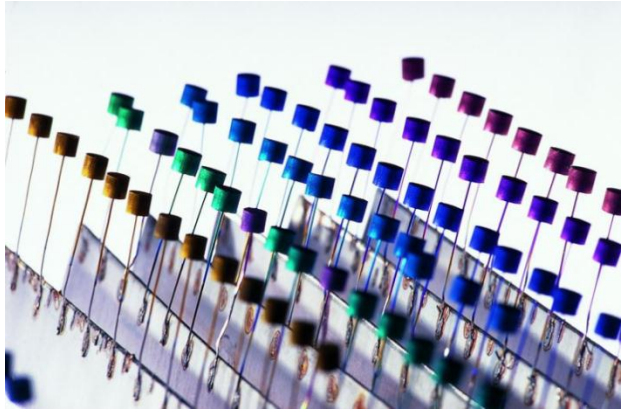
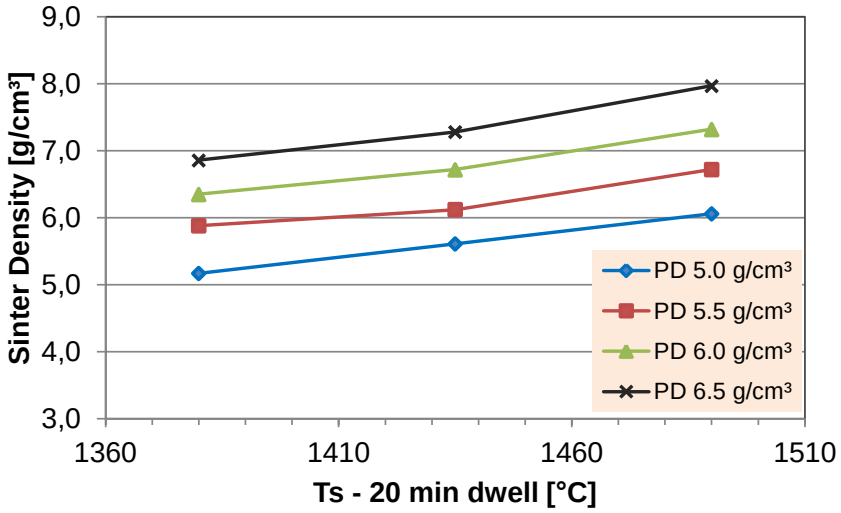
Experimental Part

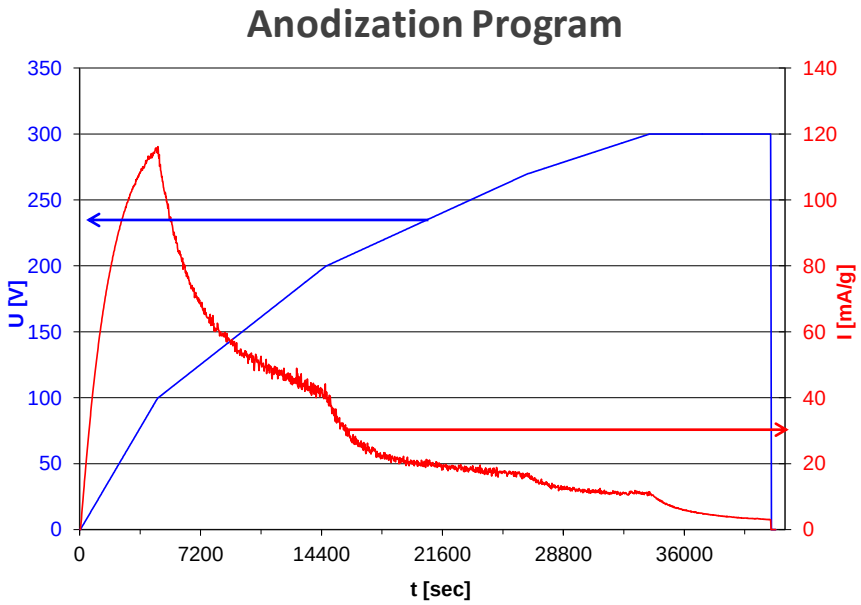


- Press density 5.0 – 6.5 g/cm³ (0.5 g/cm³ steps)
- Sintering 3 temperatures ➔ 5, 10, 16 vol.-% (±1 %)
- Diameter 3 mm

➢ Different anode sizes and anodization conditions have also an impact

➢ However, general tendencies are comparable!





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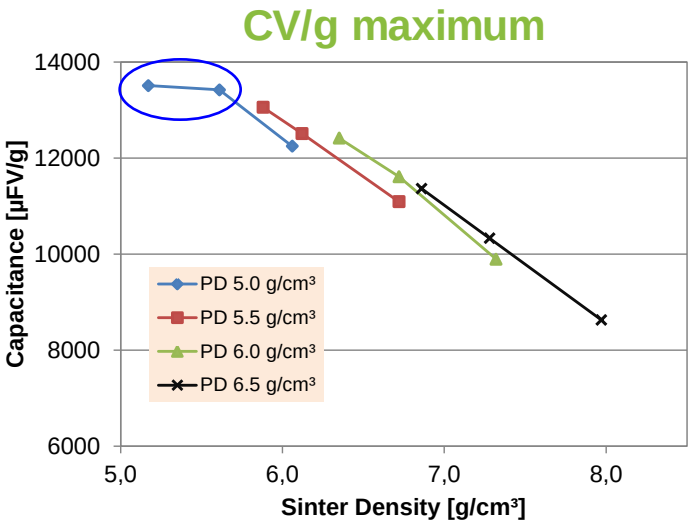
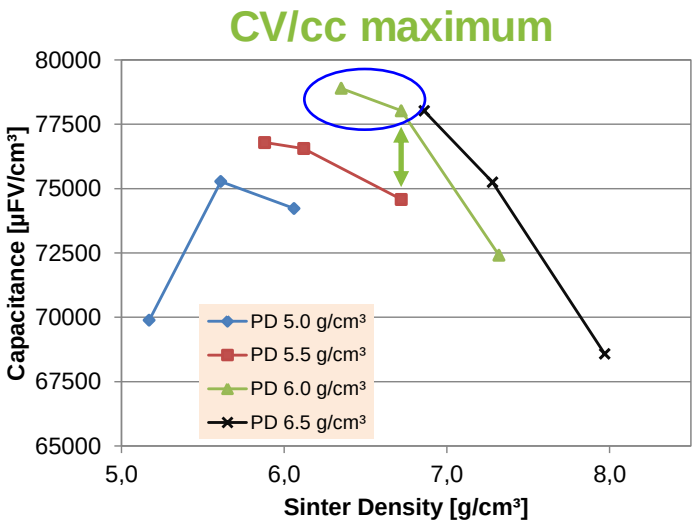
HV 300: Capacitance Data @ 300 V_f





- Powder has highest CV/g ➔ increased pressing and shrinkage reduces always CV/g
- But: Higher press density increases the powder amount per volume
- If pressing density is too high: pore closing effect will be higher and can not be compensated by more powder and causes bad impregnation behavior
- This optimum depends on
  a) Powder type
  b) Anodization Voltage

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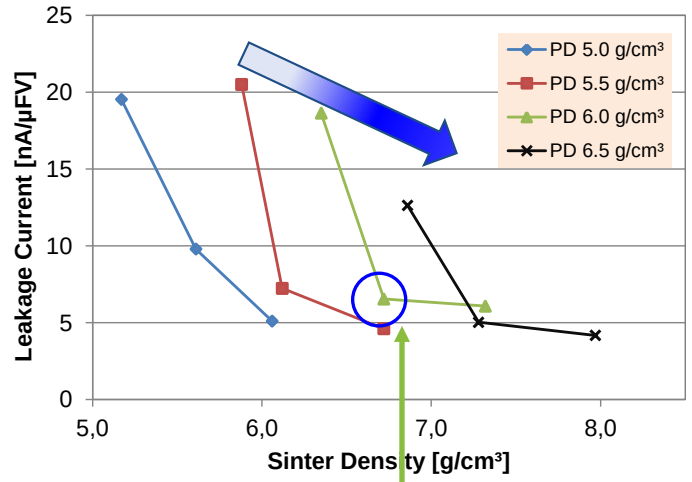
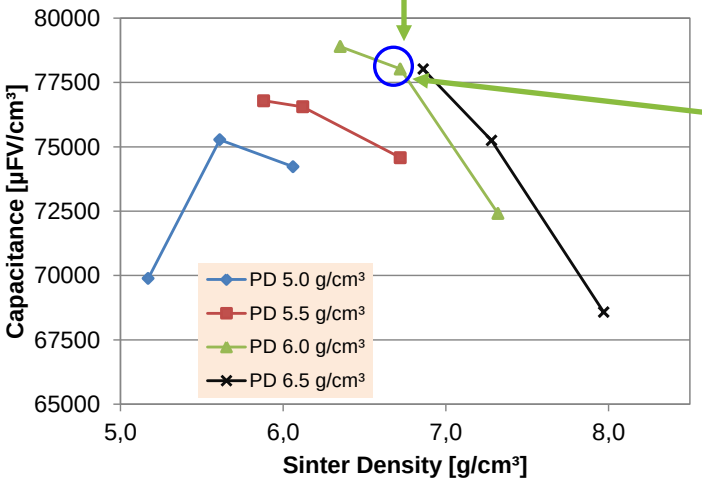
HV 300: Leakage Current @ 300 V_f





- Increased press density improves LC
- Increased shrinkage improves LC
- Significant improvement from 5 ➔ 10 % shrinkage

➔ Best conditions is compromise between LC and cap

Recommendation:

PD 6.0 g/cm³ and ~10 vol.-% for 300 V

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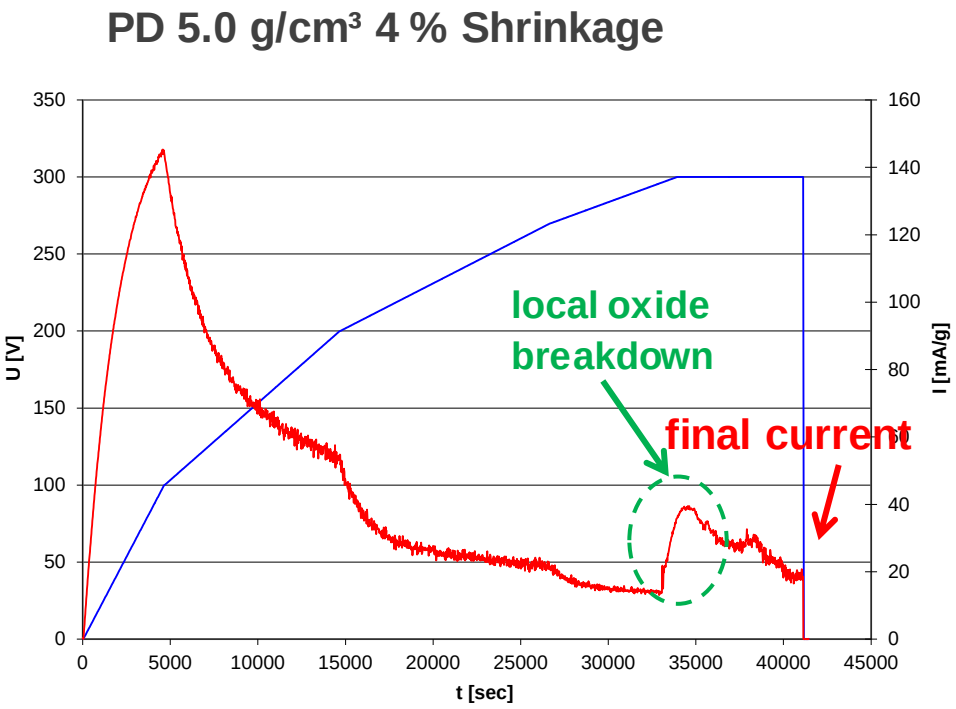
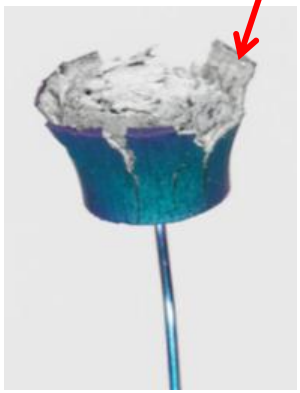
HV 300: Anode Breakdown



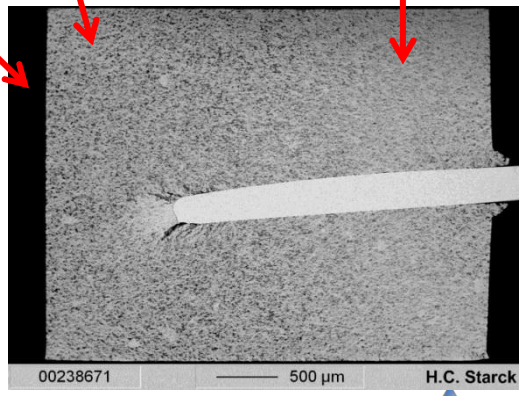
- Too weak anode strength causes anode breakdown and high LC!

Impact of pressing gradient

breakdown starts here



lower PD **higher PD**



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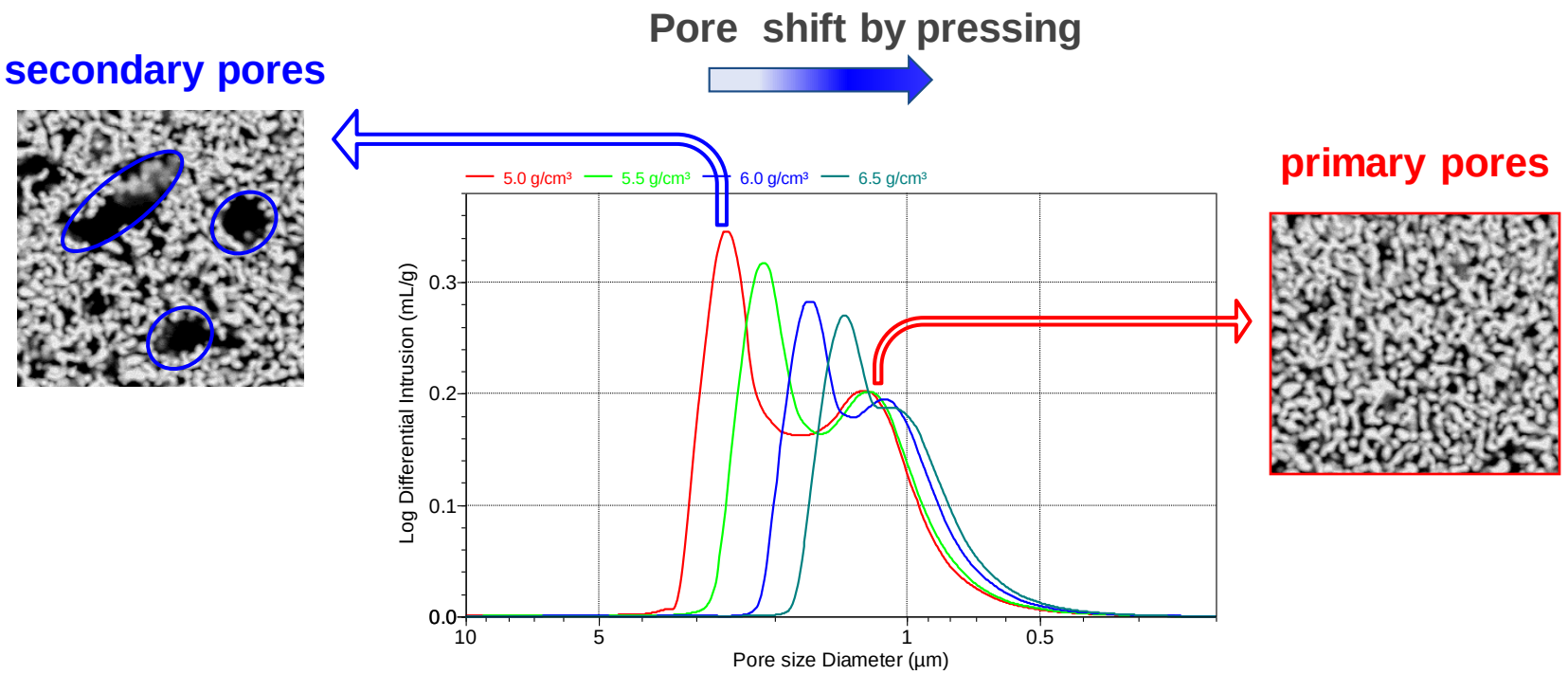
Anode Pores: Effect of Pressing



- Primary pores are responsible for capacitance (strong impact on anode surface)
- Secondary pores are beneficial for infiltration: space between adjacent agglomerates
- The higher the press density the lower the total pore volume ➔ pore shift to smaller values
- Increased press density increases also the contact area of adjacent agglomerates

Summary

- ✓ HVMC enable the production of new high voltage capacitor ➔ delivers more cap than Na standard powders
- ✓ Provide an increase in volumetric efficiency ➔ supporting the trend toward miniaturization.

- ✓ Pressing and sintering has a strong impact on capacitance and leakage current and breakdown behavior
- ✓ Best powder will fail if wrong conditions are applied
- ✓ Optimum condition for HV300: Press density of 6.0 g/cm³ and 10 vol.-% provides high CV/cm³ and good leakage current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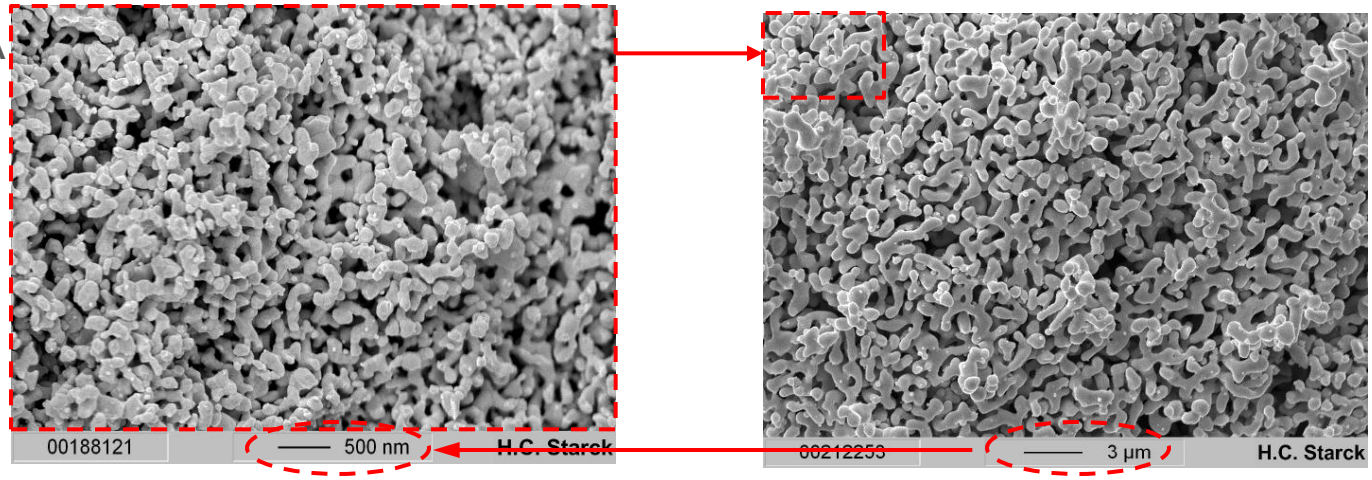
Microstructure of HVMC Anodes

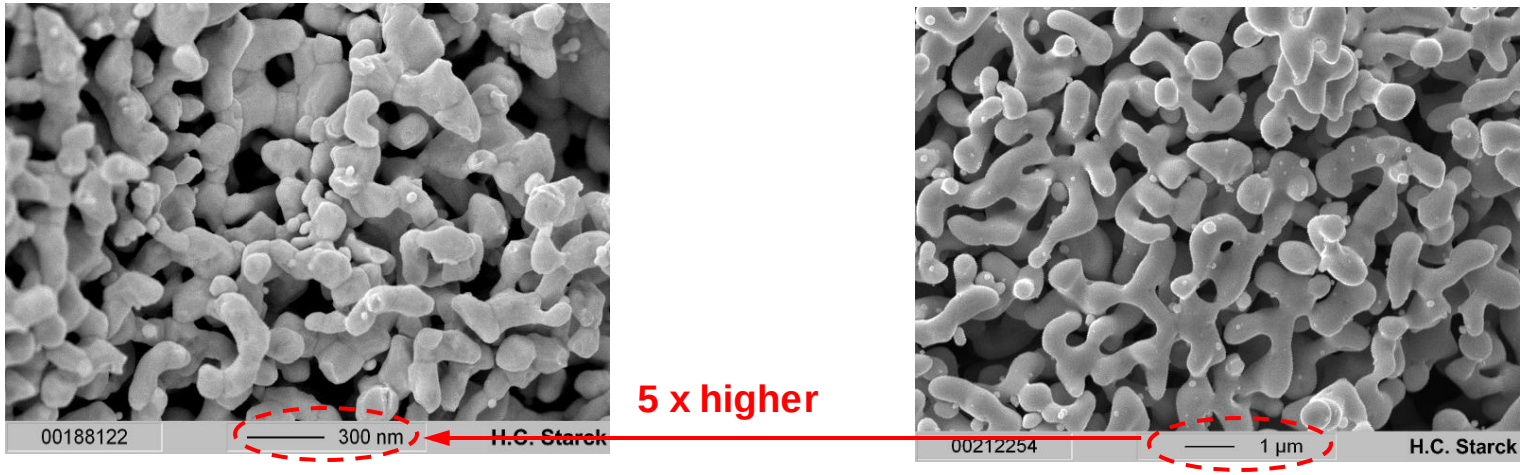
Increasing the dimensions but keep the structure homogeneous!

STA150KA
6 V-20 V



HV200
150 V-200 V

5 x higher magnification



5 x higher

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