Synchrotron-Tomographie und 3D-Bildanalyse zur Charakterisierung von Metallschäumen

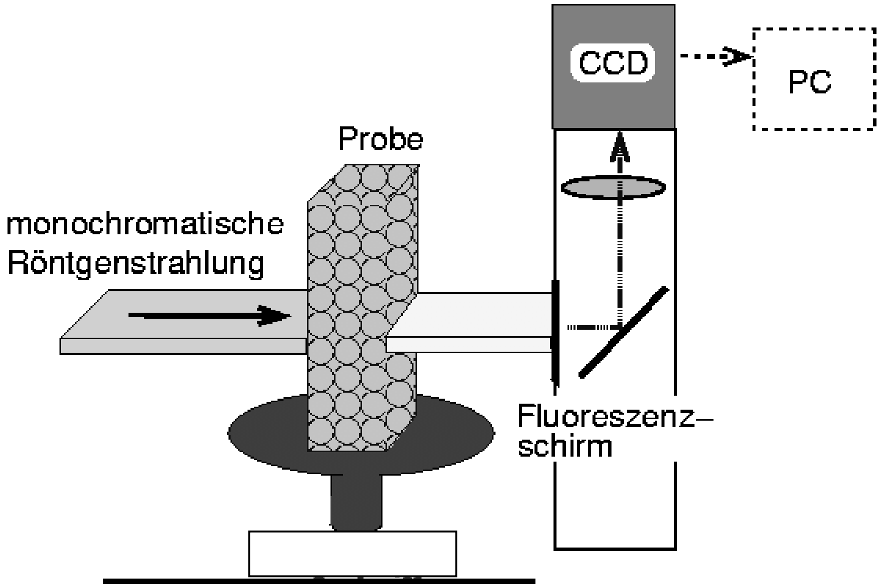
A. Rack, A. Haibel, B. Matijasevic, A. Bütow, J. Banhart

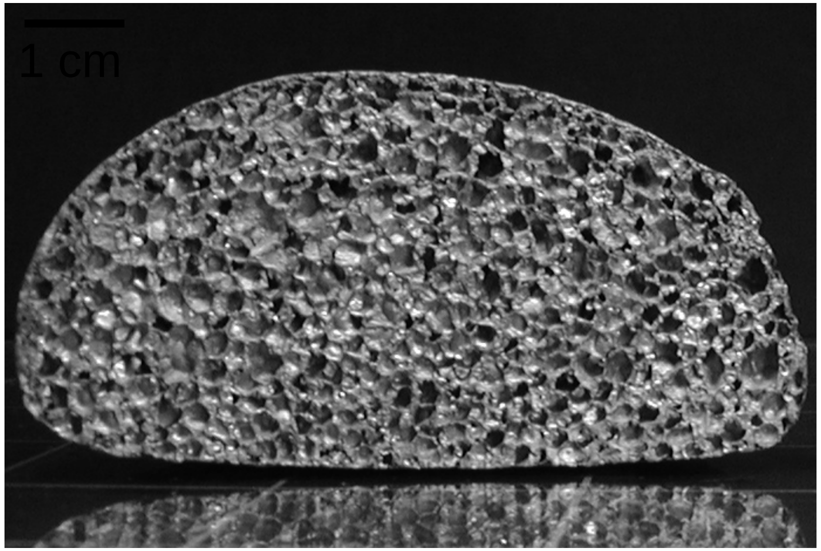
Bereich Strukturforschung (Werkstoffe), Hahn-Meitner-Institut Berlin

G. Weidemann, H. Riesemeier, J. Goebbels

Bundesanstalt für Materialforschung und -prüfung

Motivation

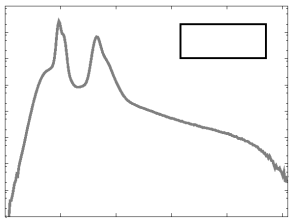




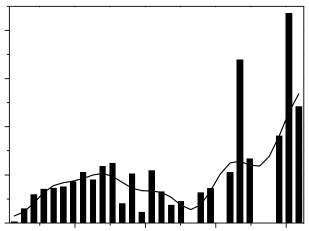
Tomographie

Metallschaum

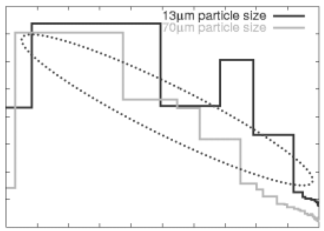
Quantitative Auswertung



Histogramm



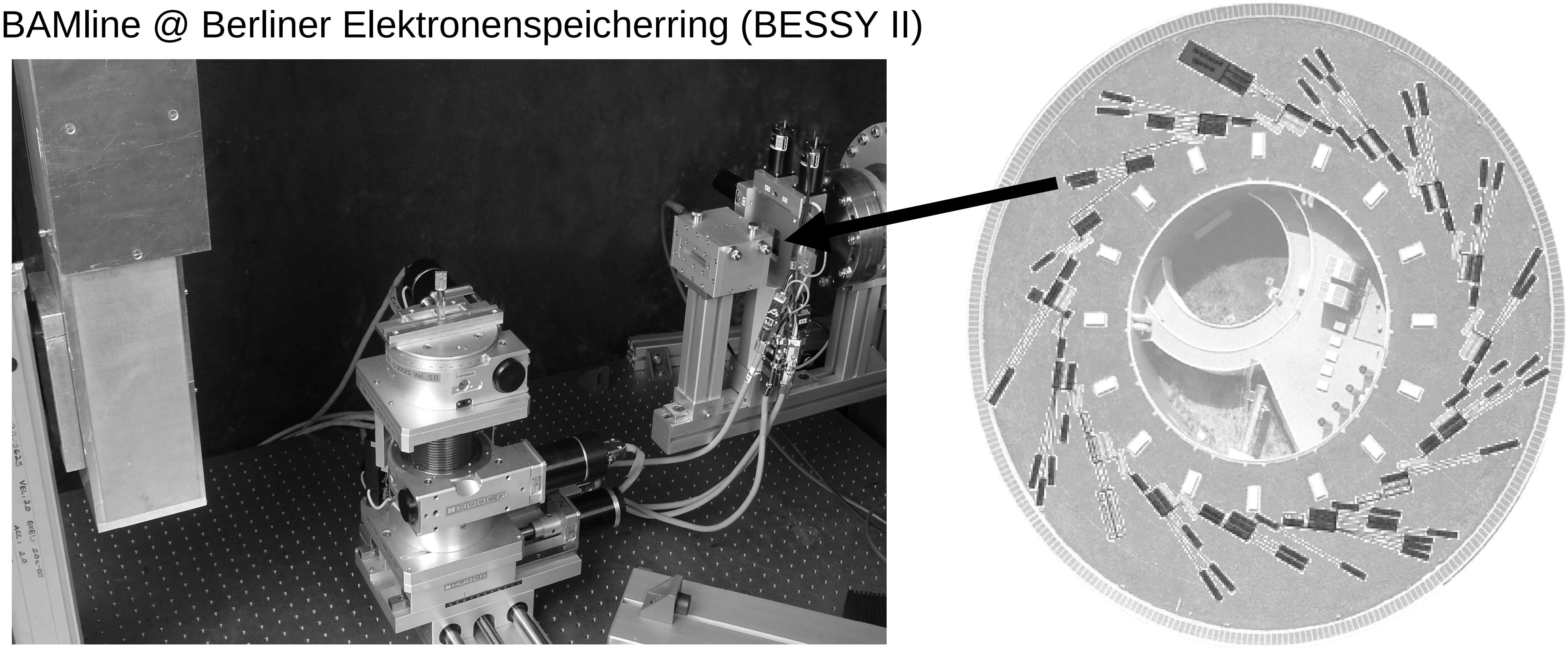
Statistik



Zusammenhänge

Synchrotron-Tomographie

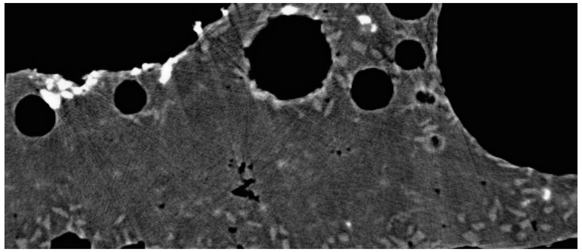
BAMline @ Berliner Elektronenspeicherring (BESSY II)



- Auflösung 3.5 µm, max. Probendimension: 7 mm Durchmesser
- 900 bis 1800 gemessenen (Winkel-)Projektionen
- Energien 6-60 keV (monochromatisch), Energieauflösung ca. 10^{-2}

Binarisierung - Beispiel

Al-Schaum

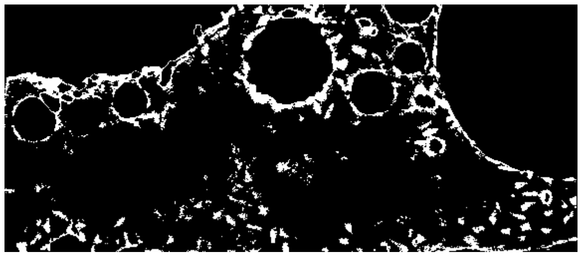


2 mm

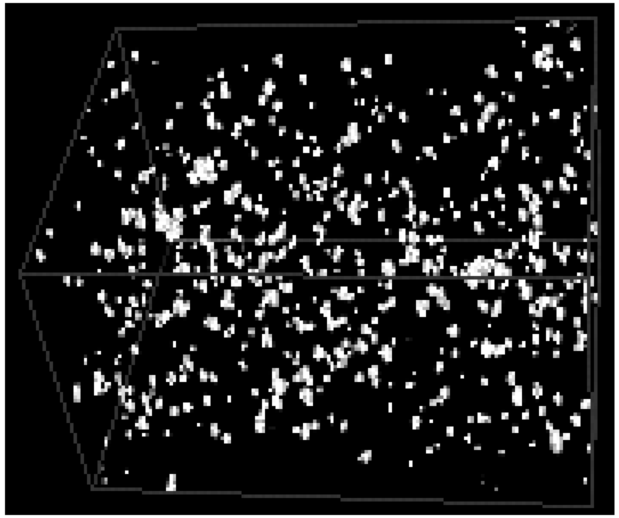
Poren

TiH_2

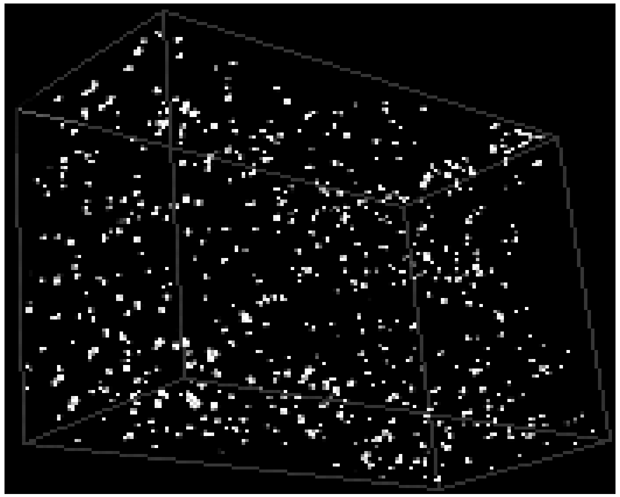
SiC



3D Verteilung TiH_2



Partikel >28 µm

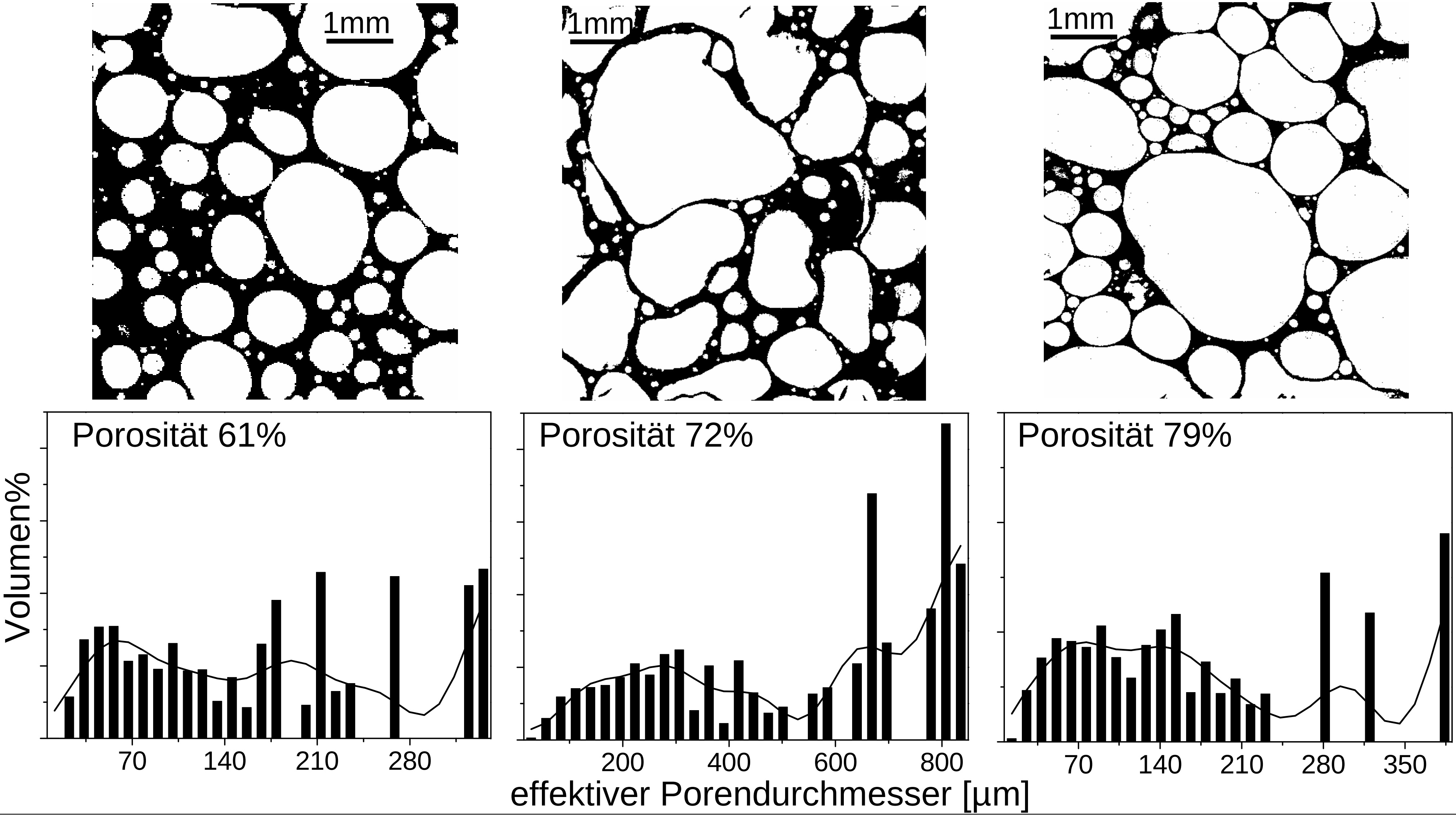


Partikel <28 µm

ca. 3x3x5 mm^3

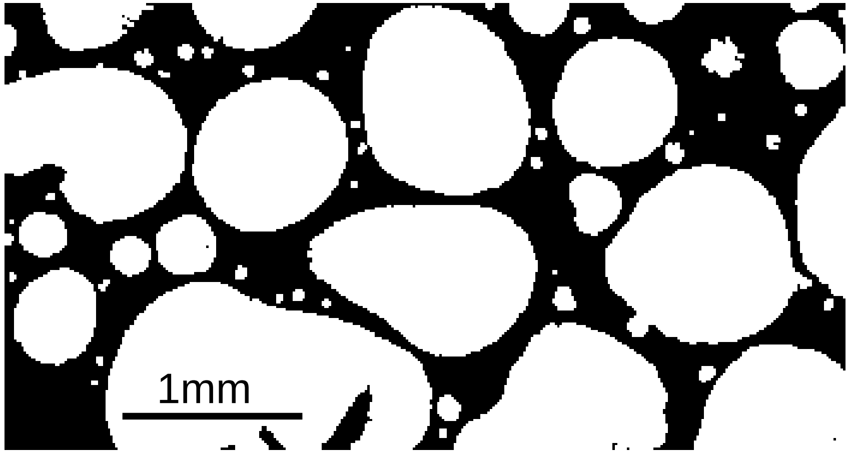
Statistik (a4iL C-Bibliothek) – Zn-Schaum

Labeling -> ObjectFeatures -> Zählen & Ausgeben

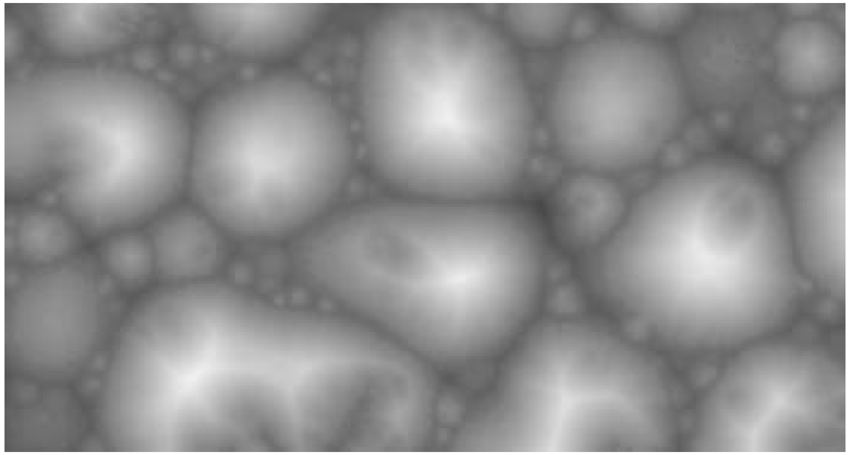


Euklidische Distanz-Transformation (EDT)

Binärbild Φ (Bool‘sches Bild)



edt[Φ]



Poren (Bool=1):

Vordergrund $\equiv \bigcup V_{x,y}$

Rest (Bool=0):

Hintergrund $\equiv \bigcup H_{x,y}$

$$\mathrm{edt}[\Phi] \equiv \bigcup \mathrm{edt}\left[H_{x,y}\right] \oplus \bigcup \mathrm{edt}\left[V_{x,y}\right]$$

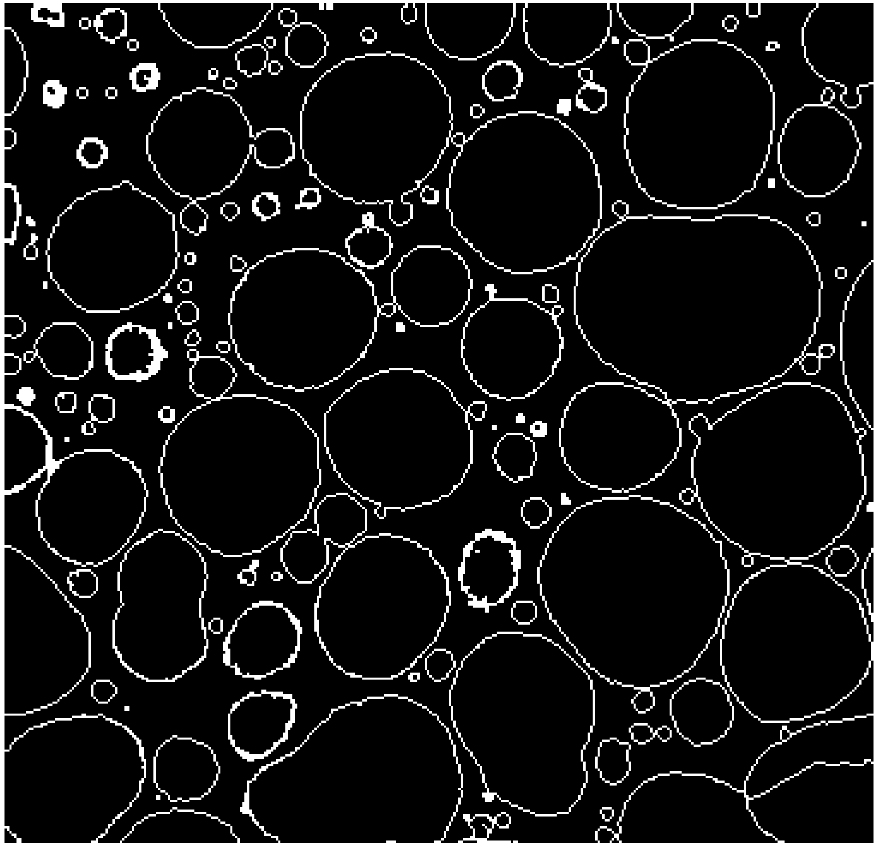
mit:

$$\mathrm{edt}\left[V_{x,y}\right] \equiv \min\left[\underset{i,j}{\mathrm{dist}}\left[V_{x,y}, H_{i,j}\right]\right]$$

$$\mathrm{edt}\left[H_{x,y}\right] \equiv -\min\left[\underset{i,j}{\mathrm{dist}}\left[H_{x,y}, V_{i,j}\right]\right]$$

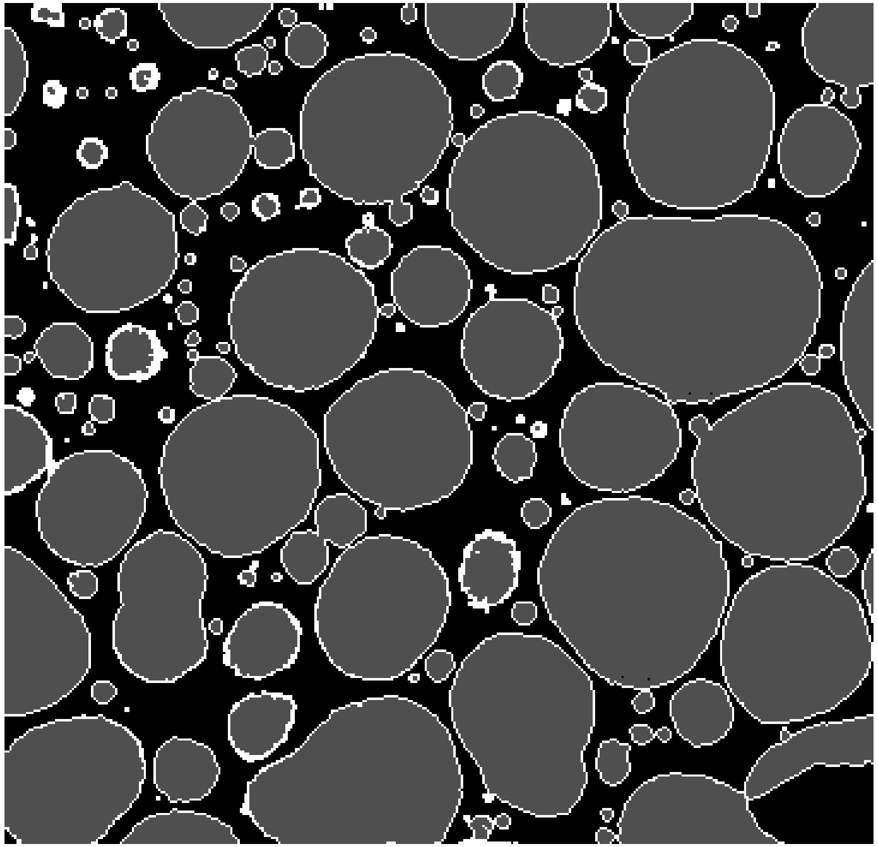
Euklidische Distanz-Transformation – Anwendungen

Poren und Porenumgebung



1. Porenumgebung:

$$\bigcup\left(EDT_{x,y} = \max\left[edt\left[H_{x,y}\right]\right]\right)$$



1. EDT-Dilatationsschritt:

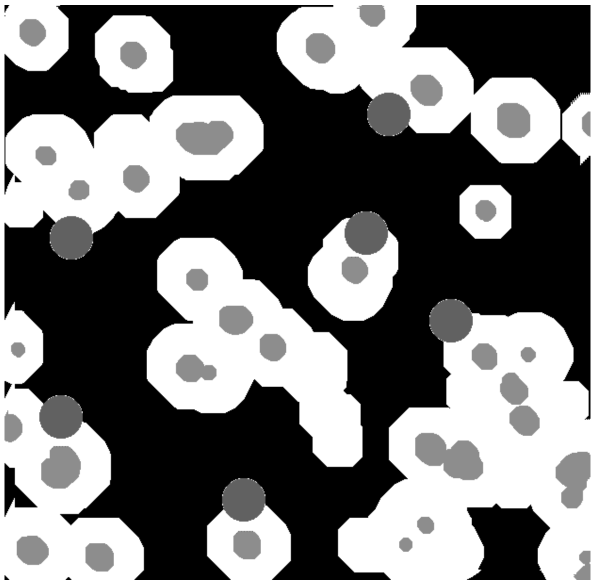
Poren $\oplus$ 1. Porenumgebung

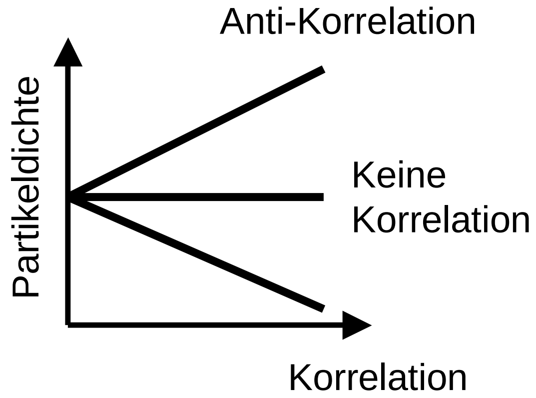
Anwendung - Bestimmung von Korrelationen

EDT-Dilatation der Poren ⊕ Messen der gesuchten Partikeldichte in jeder neuen Porenumgebung

Abnehmende/Zunehmende Partikeldichte

Korrelation/Anti-Korrelation

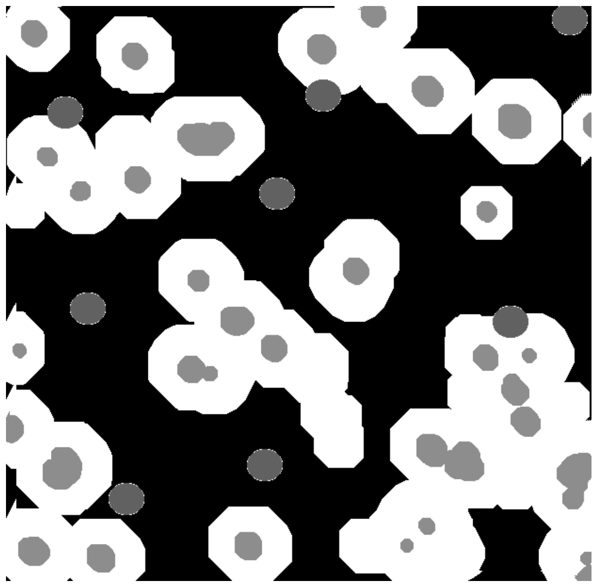




Ohser, Helfen et al.

Konstante Partikeldichte

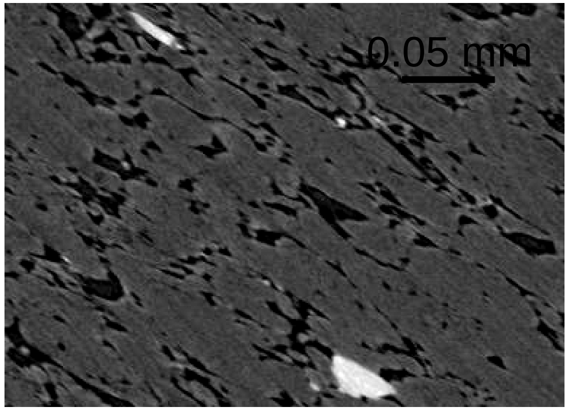
keine Korrelation



● Partikel ● Poren

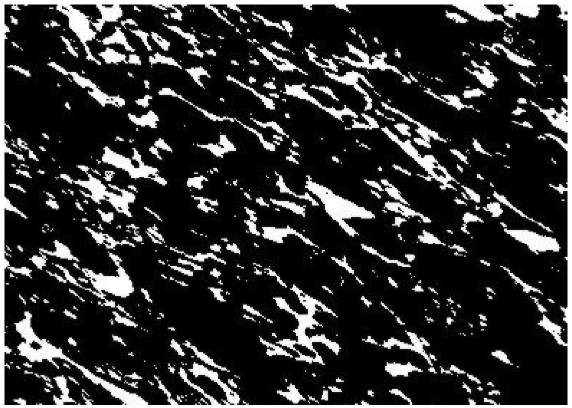
○ Porenumgebung

AlSi7 + 0.5 wt% TiH_2 – Poren-Treibmittel Korrelation

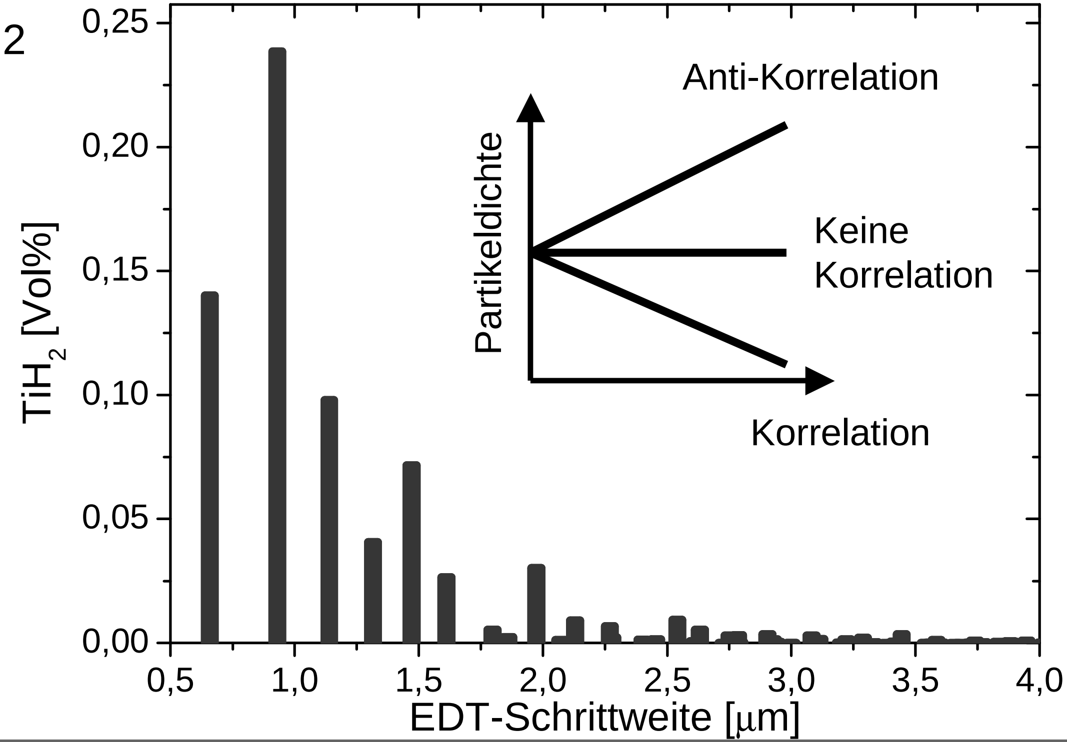


- heiß kompaktiert bei 200 ℃
- 90 s Schäumzeit
- 19% Porosität
- Poster *SYPF 5.1*

TiH_2

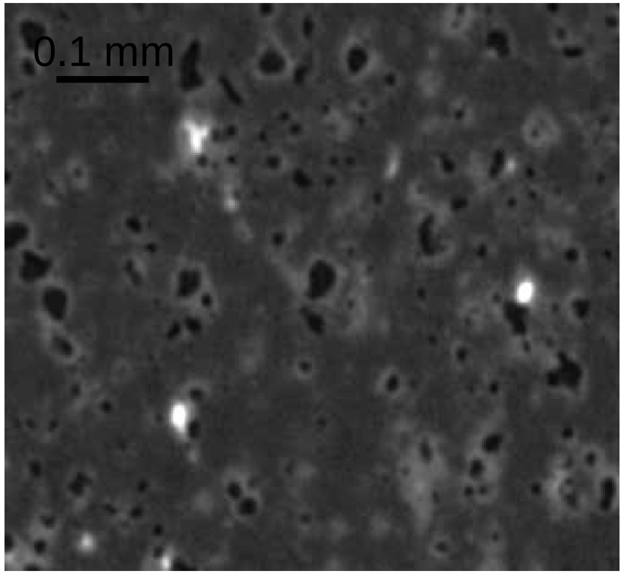


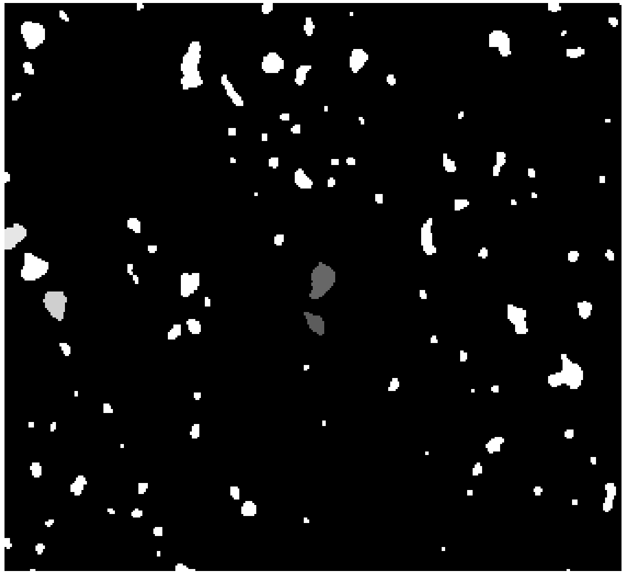
Poren



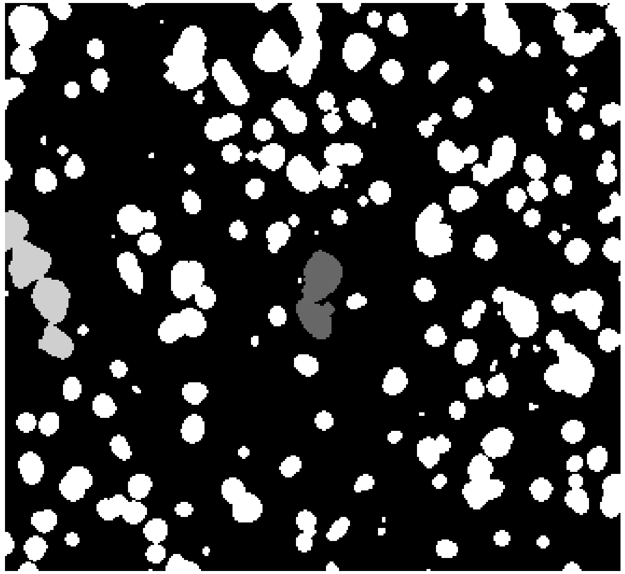
3D Bestimmung der minimalen Zellwandstärke

AlSiCu + 1.0 wt% TiH_2 , 5.0% Porosität (Poster *SYPF 5.2*)

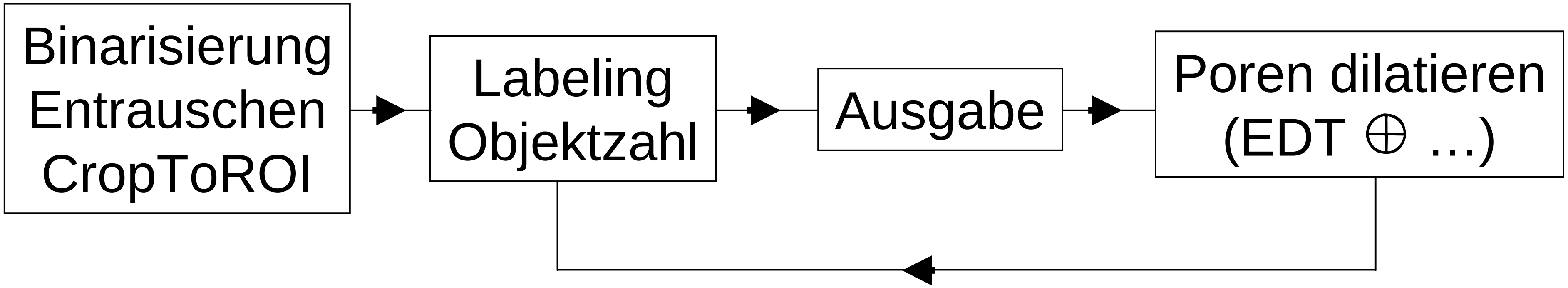




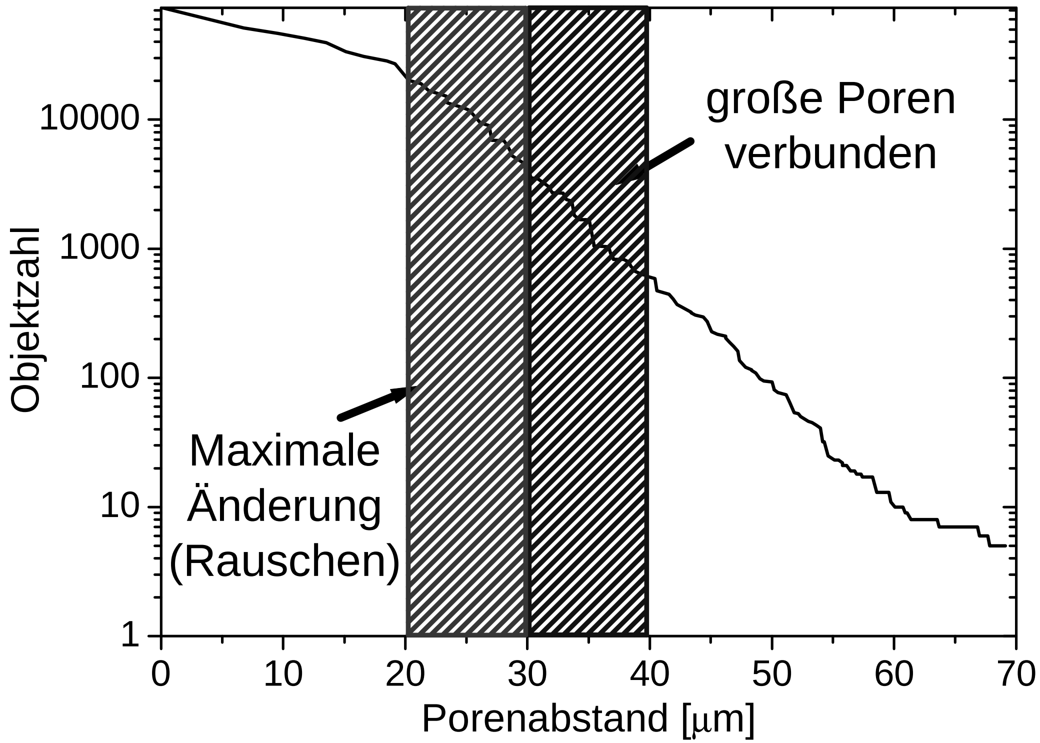
binäres Porenbild

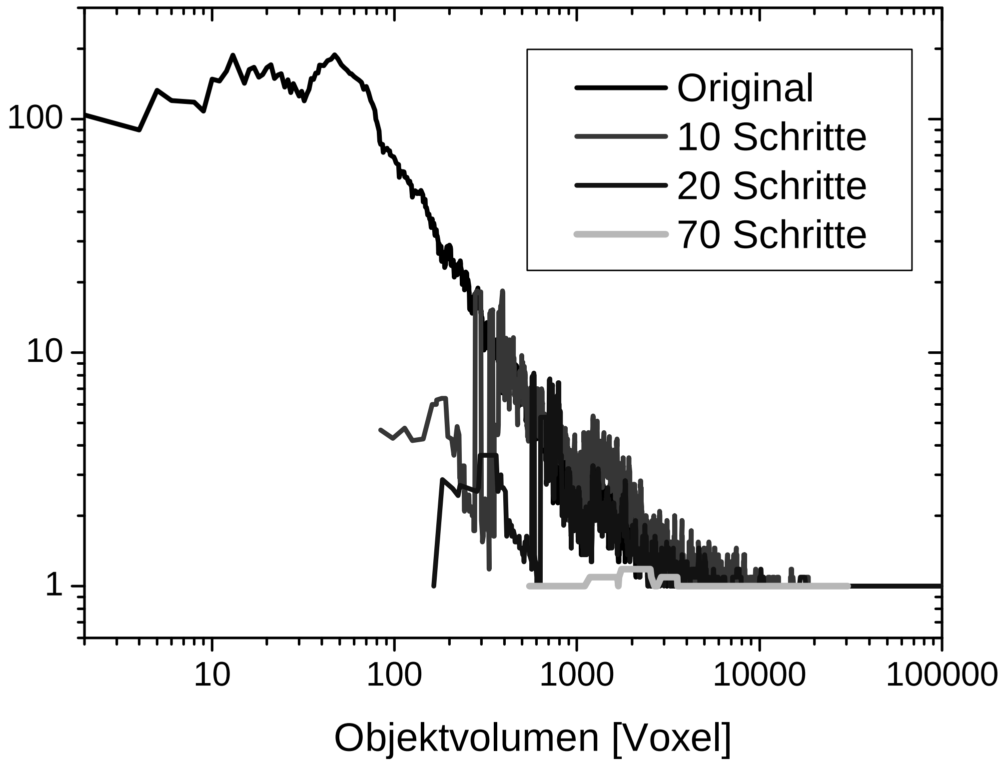


EDT-dilatierte Poren



3D Bestimmung der minimalen Zellwandstärke





min. Zellwandstärke 20 bis 50 µm bzw. <= 50 µm

Zusammenfassung

- Synchrotron-Tomographie verschiedener Metallschäume an der BAMline@BESSY
- Methoden der 3D-Bildanalyse
  - Binarisierung & Statistik
  - Morphologische Transformationen
  - Algorithmen zur Bestimmung von Korrelationen und minimaler Zell-wandstärke

Danksagung: Lukas Helfen ⊕ ID19 (ESRF), Prof. J. Ohser