Combining CO_2 streams from different emitters - a challenge for pipeline transportation

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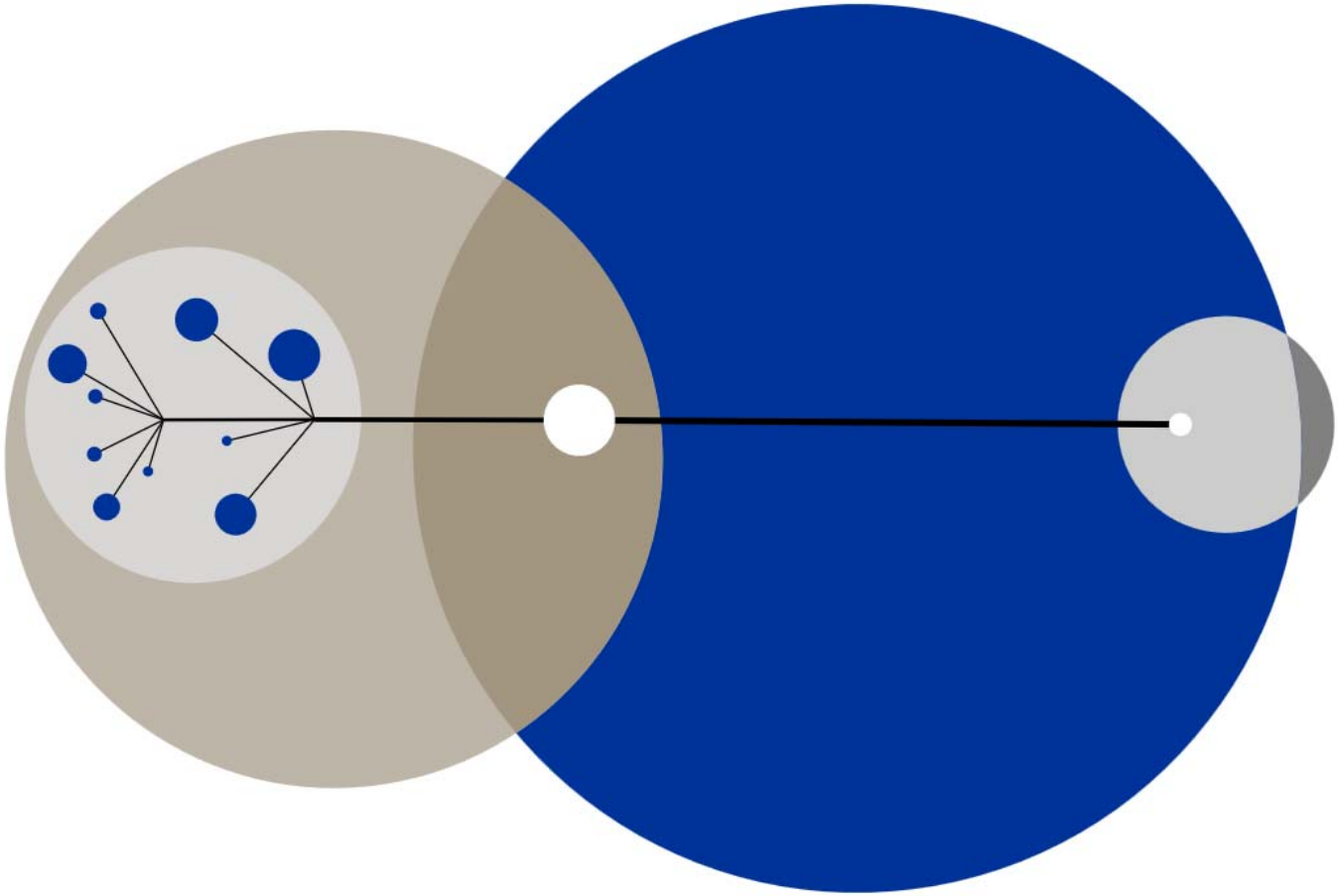
Cluster Scenario

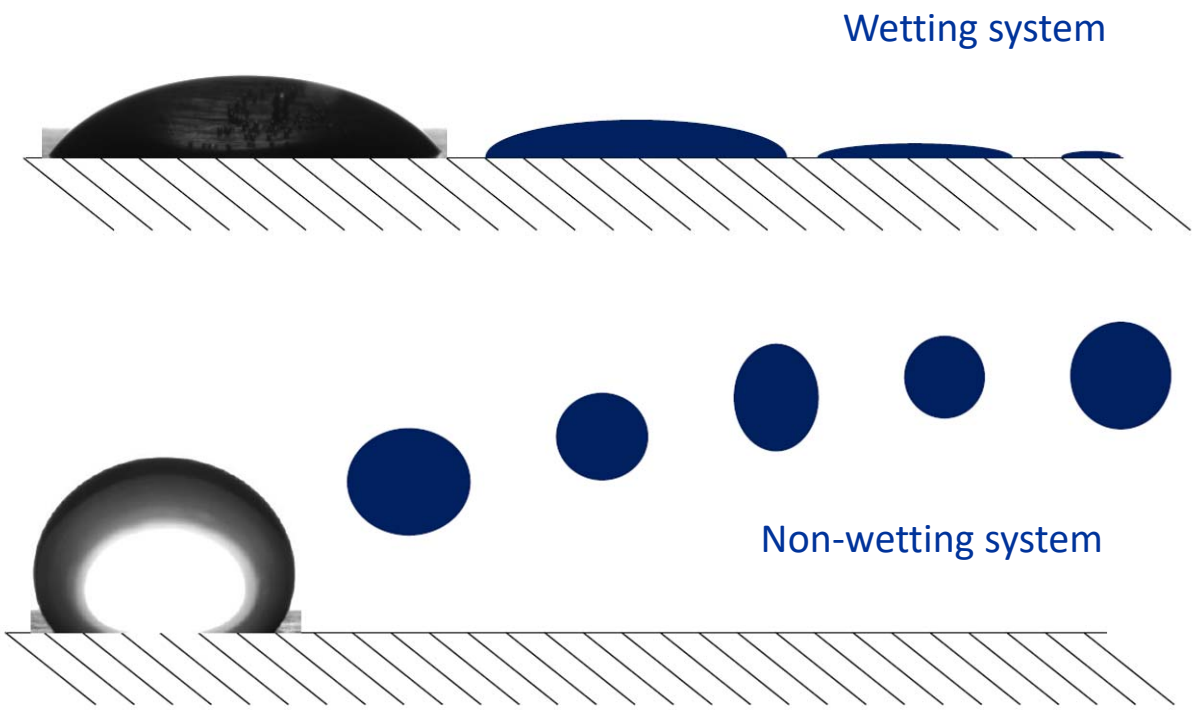


Not to scale

Project Homepage: www.bgr.bund.de/CLUSTER-EN

Reactions in CO_2 streams – acid formation and condensation

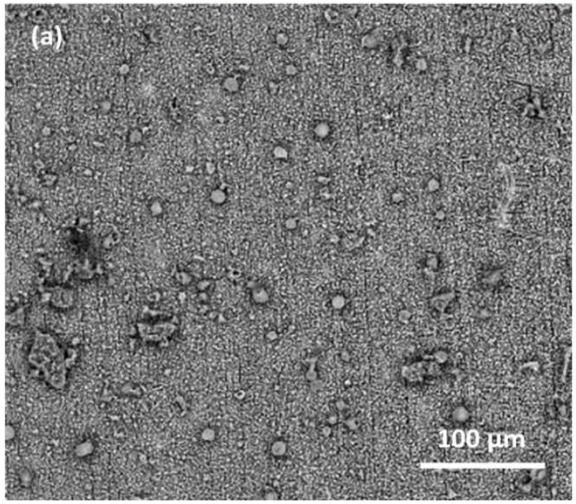
$SO_2 + NO_2 \rightarrow SO_3 + NO$
$2\ NO + O_2 \rightarrow 2NO_2$
$SO_3 + H_2O \rightarrow H_2SO_4$
$2\ NO_2 + H_2O \rightarrow HNO_3 + HNO_2$
$SO_2 + H_2O \rightarrow H_2SO_3$
$2\ H_2SO_3 + O_2 \rightarrow 2\ H_2SO_4$

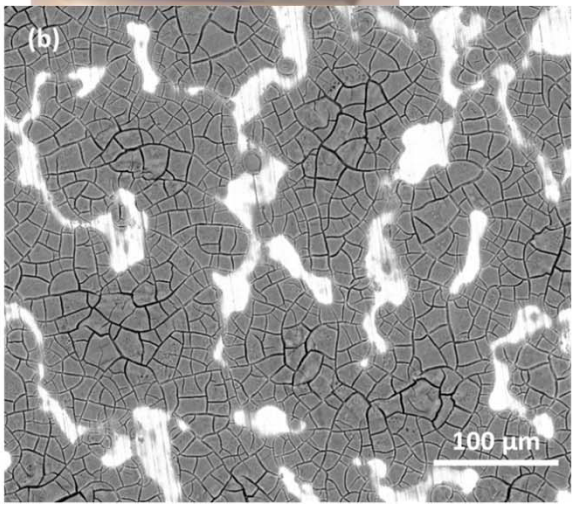


Condensation of water and/or acids: temperature effect

288 K

278 K





Backscattered electron imaging

X70 (L485MB)

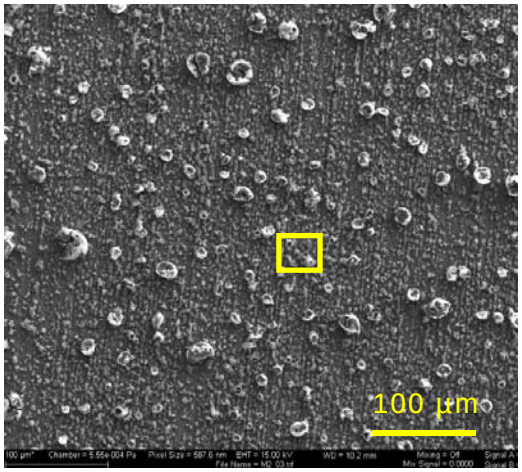
in CO_2 with
200 ppm_{mole} H_2O,
220 ppm_v SO_2,
6700 ppm_v O_2

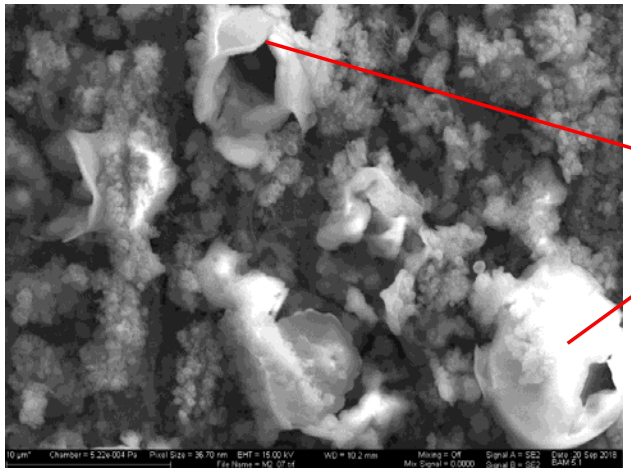
@ 5 MPa, 7 days

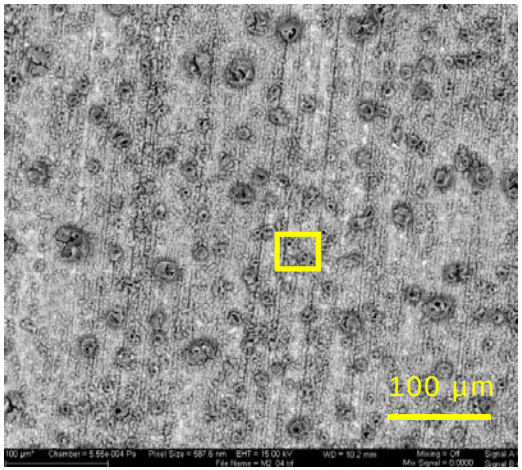
Cross-reactions – implications for corrosion (X70)

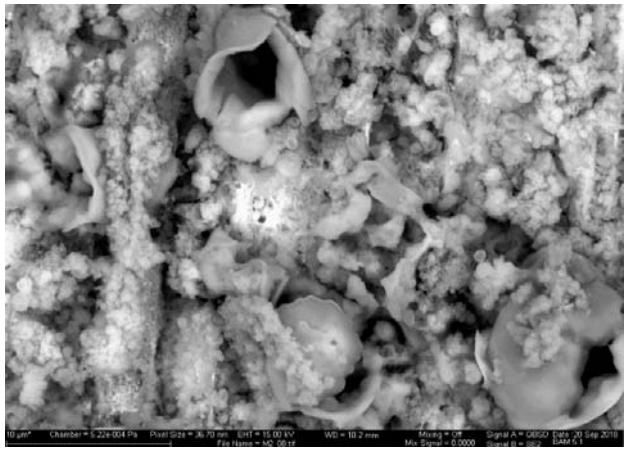
SEM imaging

Backscattered electron imaging









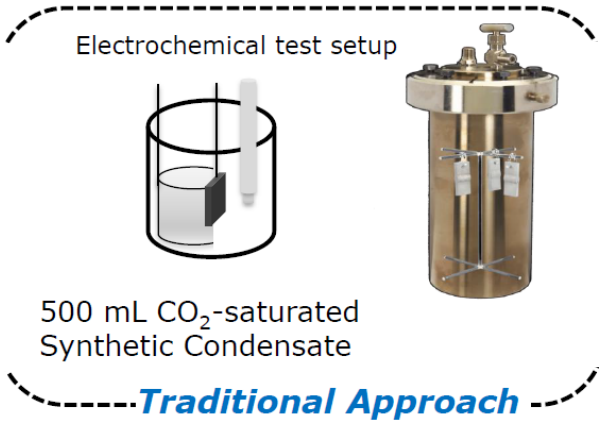
Ratio of O/S is higher cf. product formed without NO_2

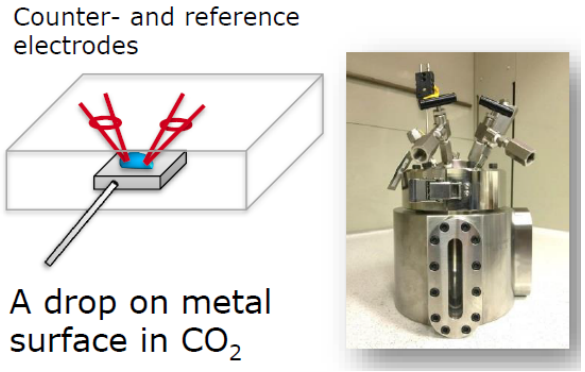
X70 (L485MB)

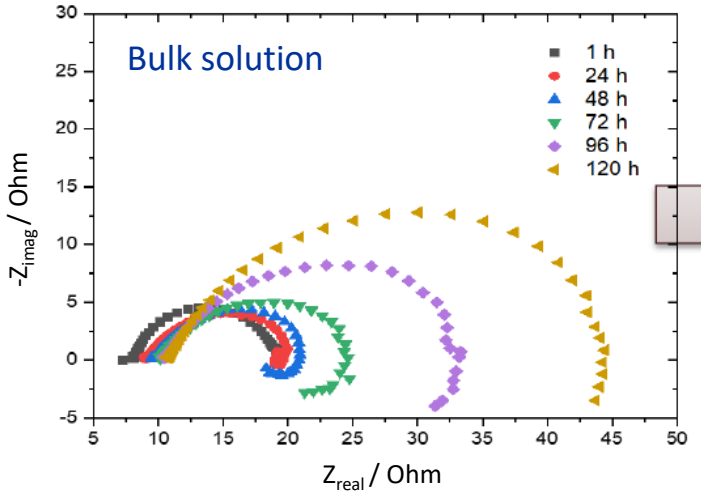
in CO_2 with
200 ppm_{mole} H_2O,
70 ppm_v SO_2,
100 ppm_v NO_2
and 6700 ppm_v O_2

after 7 days
@ 5 MPa, 278 K

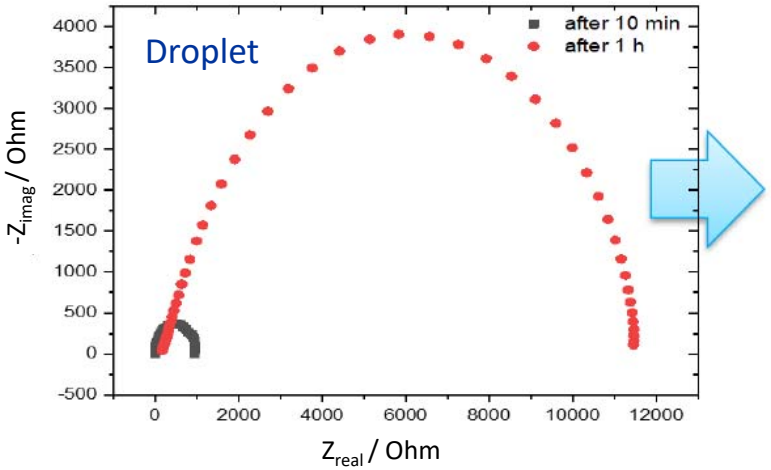
Approaches to study acid corrosion





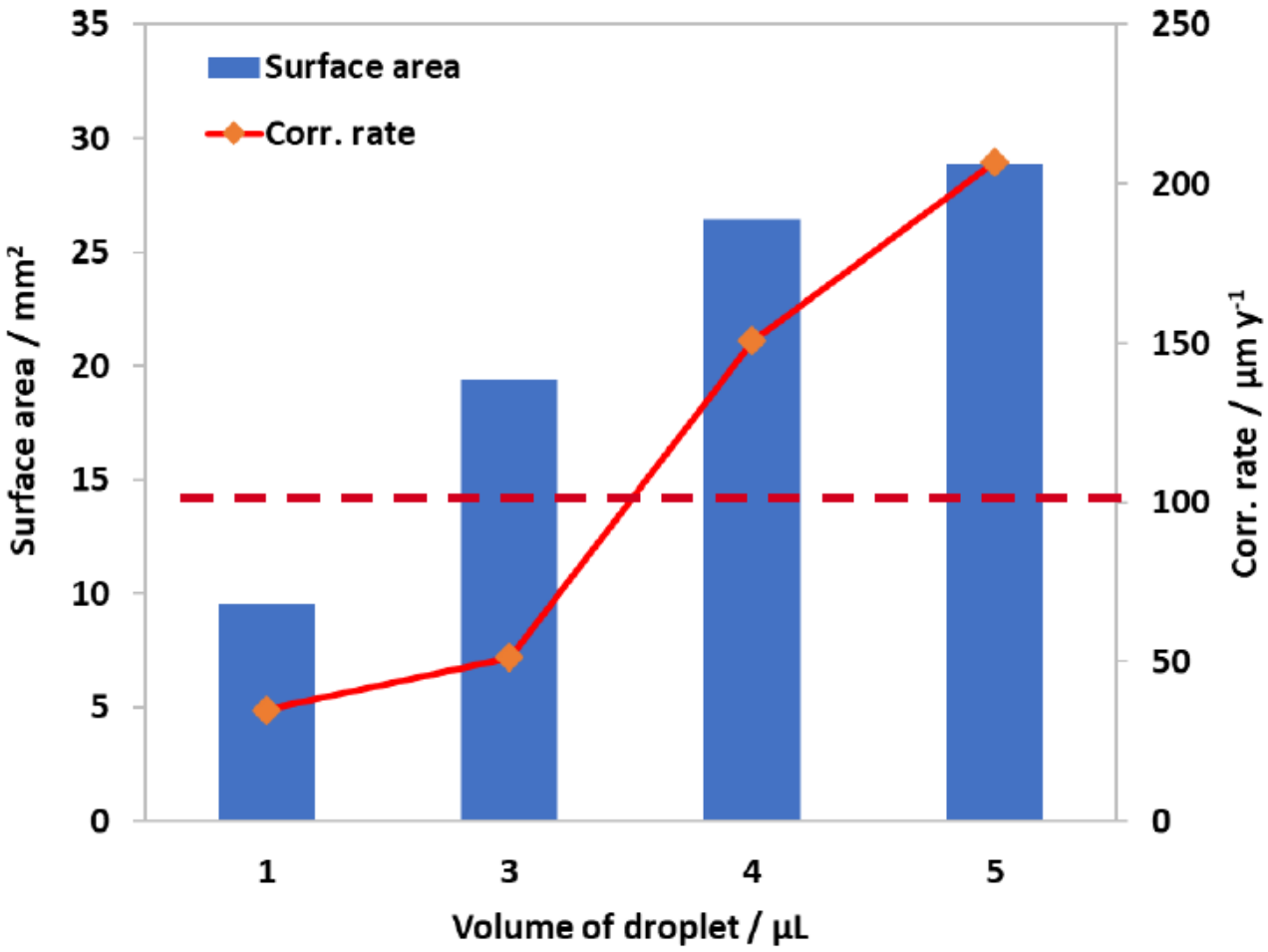


- dissolvable corrosion products
- high corrosion rate
- strong pitting



- thick, high-resistance corrosion products
- low corrosion rate

Effect of droplet size

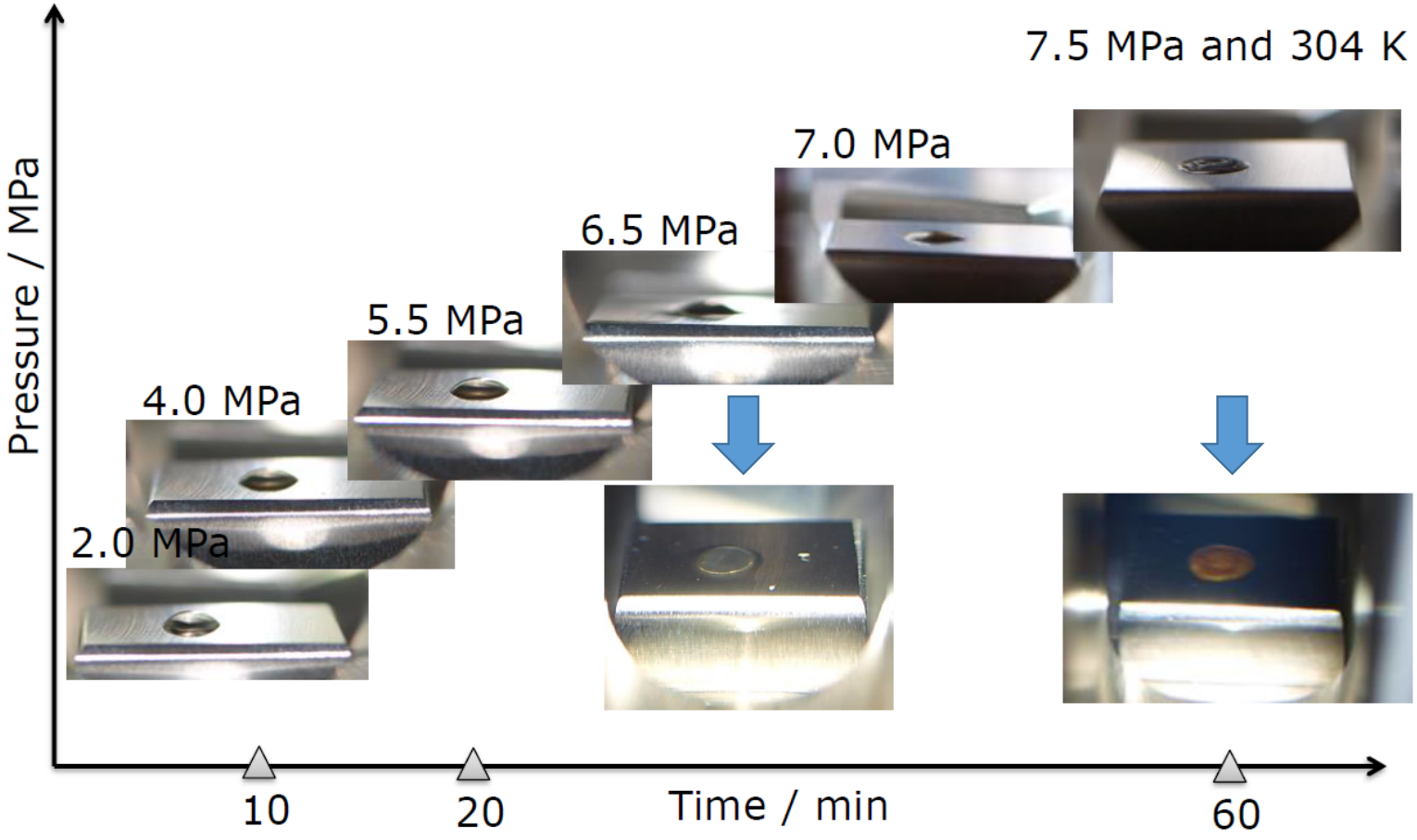


X70 (L485MB)

in CO_2 with
220 ppm_v SO_2 and
6700 ppm_v O_2

@ 278 K, 5 MPa,
7 days

Acid formation by impurity diffusion into CO_2-saturated water drop



X70 (L485MB)

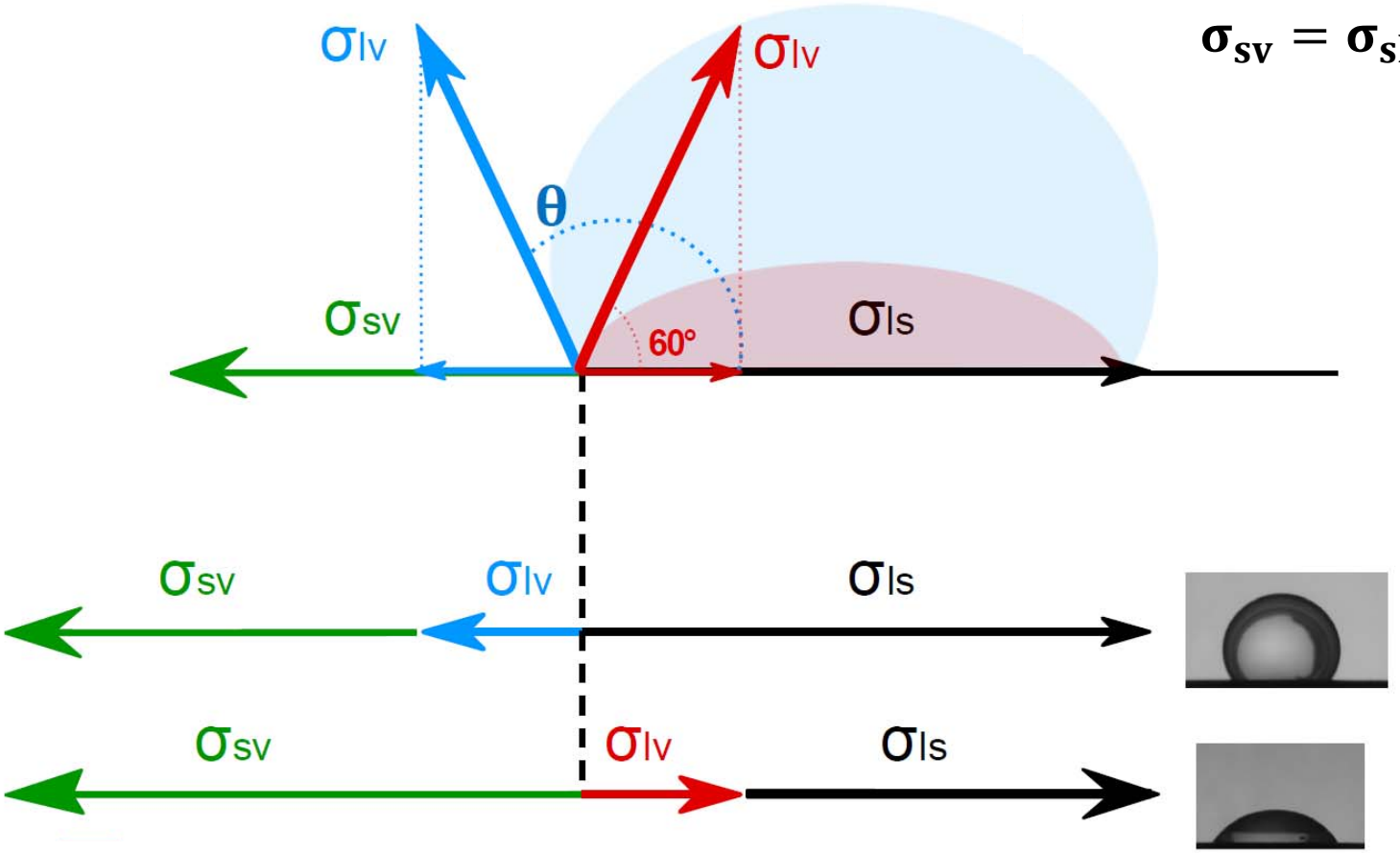
in CO_2 with
220 ppm_v SO_2 and
6700 ppm_v O_2

V_{drop} = 5 µL

Wettability: Contact angle

Young equation:

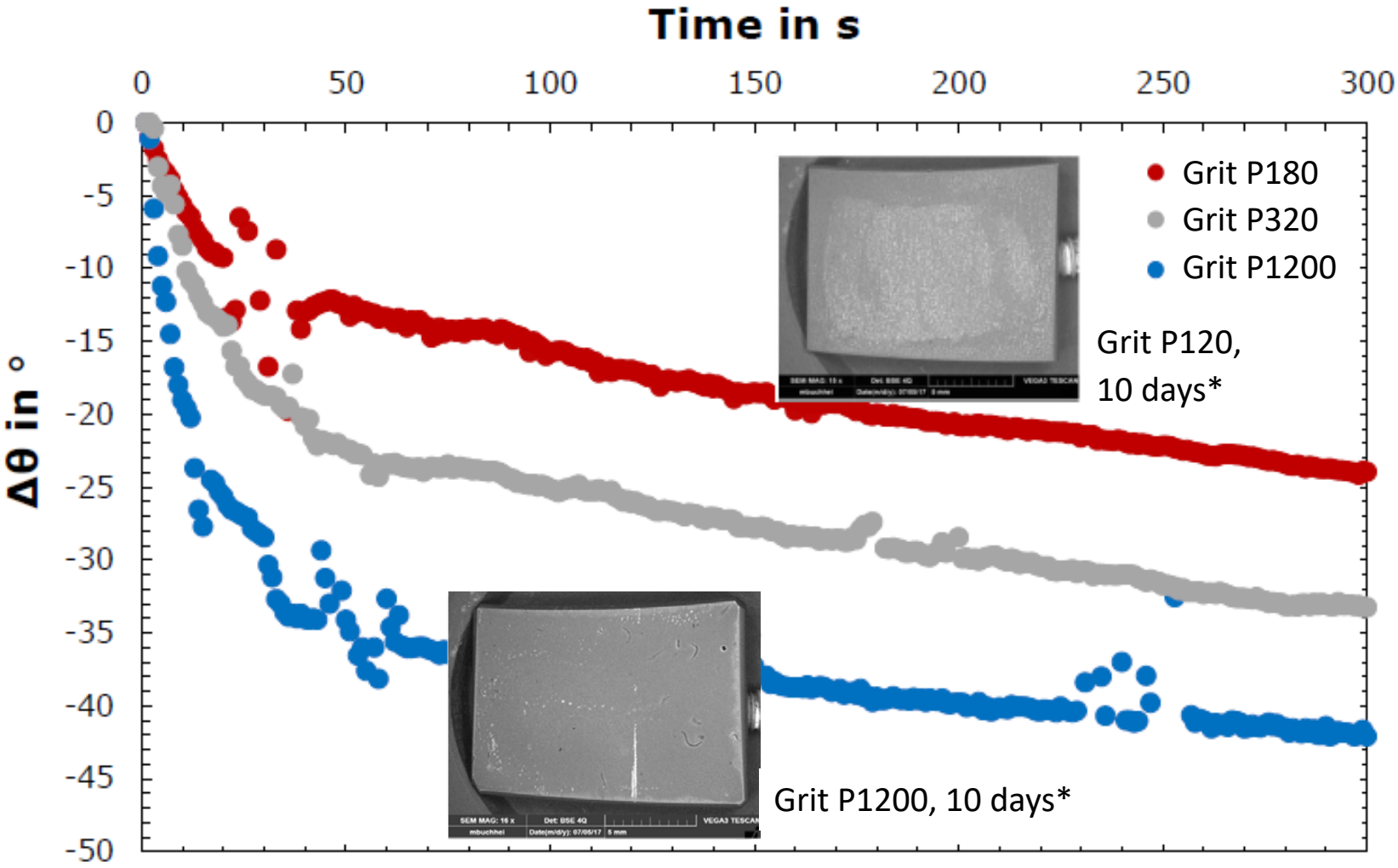
$$\boldsymbol{\sigma_{sv} = \sigma_{sl} + \sigma_{lv} \cdot \cos(\theta)}$$



θ > 90°
Non-wetting system

θ < 90°
Wetting system

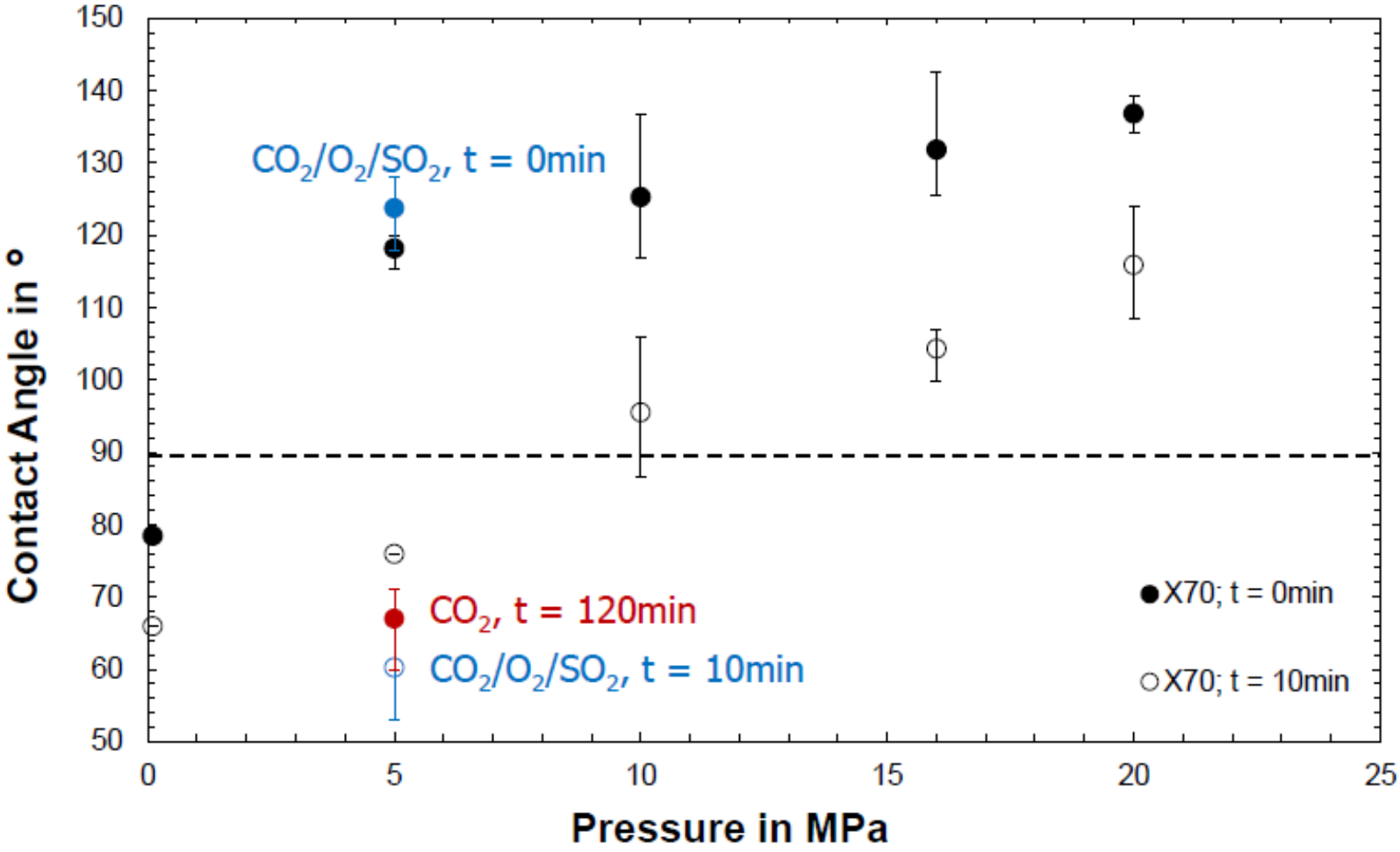
Contact angle difference ($\Delta\theta$) as f (surface roughness)



*: coupons – exposed to CO_2 for 10 days at 278 K, 5 MPa with SO_2 (220 ppm_v), O_2 (6700 ppm_v), H2O (200 ppm_{mole})

X70 (L485MB)
in CO_2
@ 278 K,
5 MPa

Contact Angle as f (p, impurities)



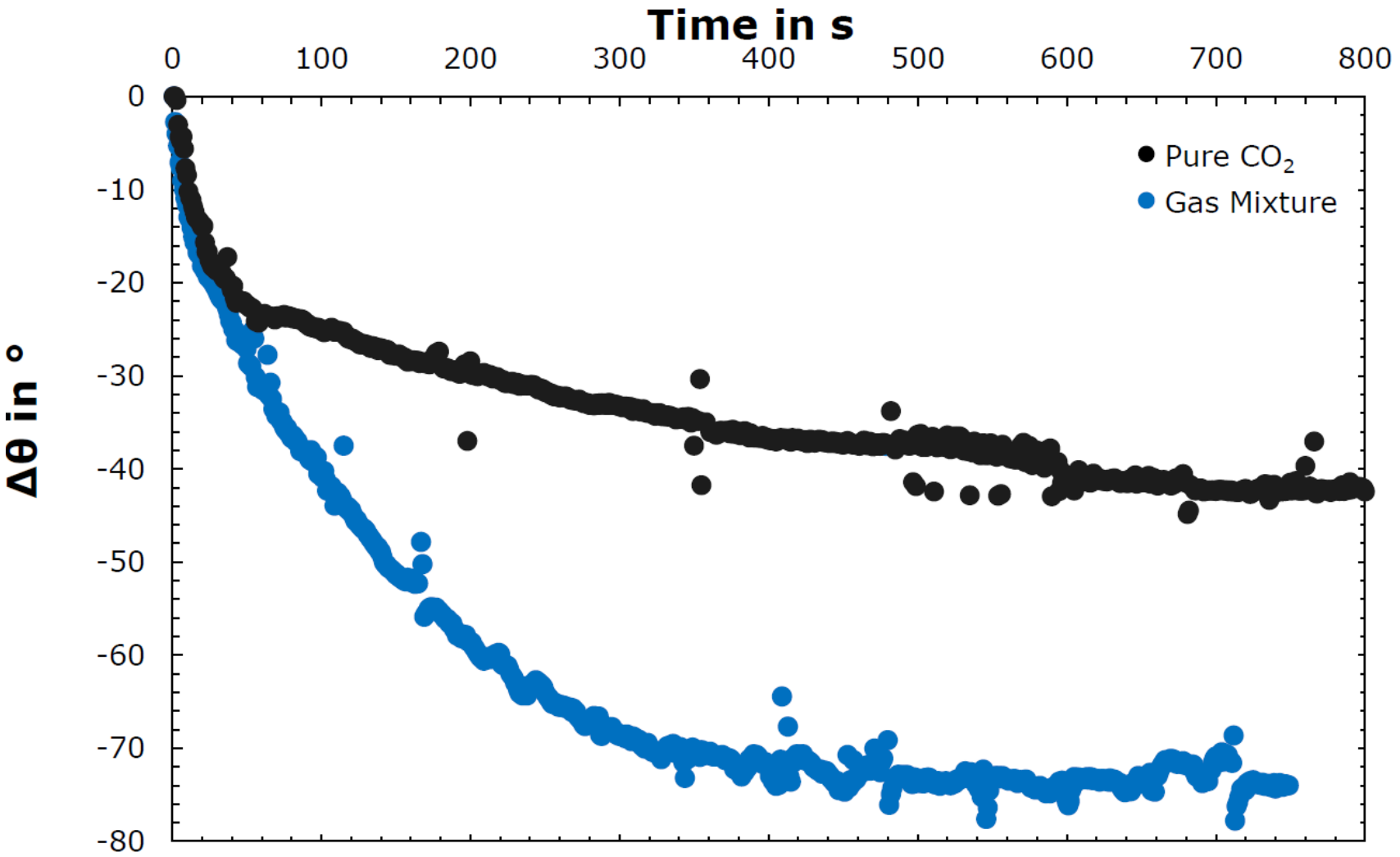
X70 (L485MB)

in CO_2
with
220 ppm_v SO_2 /
6700 ppm_v O_2

@278 K

(Grit P320)

Contact angle changes – reactive wetting (X70)



X70 (L485MB)
in CO_2 (with
220 ppm_v SO_2,
6700 ppm_v O_2)

@ 278 K, 5 MPa

(Grit P320)

In summary

Contact angle decreases

….with decreasing pressure,
….with time due to formation of corrosion products,
….faster on smoother surfaces,
….faster in case of higher corrosion rate
(e.g. in presence of O_2, SO_2)

resulting in better wetting and thus potentially in …

……larger contact area droplet/steel,
……droplet mobilization being less likely,
….. droplet accumulation being more likely,
….. potentially more severe corrosion.

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