ID N° 18753 - Contact Angle Measurement - M4$^{d+'}$

v2-Test HDPE dyn. - AutoInc (A11)

- **HDPE / Wasser** : (25,1°C, 0,65', 12mm, 0,605mm/s - dynamic)

$\Theta_{M,d}$ = 86,4$_{\pm 0,58°}$ CAH 17,8°, **$^{a}\bar{E}_d$ = 3,67$_{\pm 0,68}$ mN/m** $^{a}H_d$ -22,24mN/m, **$\bar{B}_{\%,d}$= 5,1%**

Report

1. ===== Introduction ======

Principle: The M4 contact angle measurement using the *modified Wilhelmy method* is based on force measurements on a cuboid or cylindrical solid body brought into contact with a liquid surface. The contact line between the solid, the liquid surface, and the gas phase is called the three-phase boundary line (triple line), and the angle at which the liquid surface meets the three-phase boundary line is the contact angle Θ (theta). The relative position of the three-phase boundary line-above, on, or below the surrounding liquid level-reflects the surface energy characteristics and is indicated by the resulting curvature of the meniscus. The weight of this meniscus curvature is determined gravimetrically, taking buoyancy and kinetic forces into account, and is related to the length of the three-phase boundary line. With perfect wetting (Θ=0°), this specific force reaches a maximum value, which corresponds to the surface tension of the liquid; with poor wettability (Θ>90°), however, this wetting force becomes negative. Energetic interactions between the solid and liquid phases are thus made visible through the contact angle. When the solid body is immersed, the *triple line scans the solid surface*, yielding the advancing contact angle (Θ_A), and when it is withdrawn, the receding contact angle (Θ_R) is obtained - measured by force of wetting. The difference 'Θ_A-Θ_R' is called the contact angle hysteresis (CAH).

Physically: The Wilhelmy equation $\cos\Theta_{(A|R)} = {}^{a}F / (p \cdot \gamma)$ describes the relationship between the contact angle Θ, the perimeter of the solid p, the wetting force ^{a}F, and the surface tension of the liquid γ. Adhesion tension ^{a}E is defined according $^{a}E_{A,R} = m_{meniscus} \cdot g/p = {}^{a}F/p = \gamma \cdot \cos\Theta = \gamma_s - \gamma_{sl}$

Practically: In this measurement, after the position of contact of liquid and solid has been determined, the *'HDPE'* test specimen is moved into and out of the *Wasser* liquid at a constant speed attended by ***'CLT'***(*Constant-Level-Technic*). This allows the determination of *most accurate dynamic contact angles*. While for each of the selected 172 measurements, the respective contact angle $\Theta_{A,d}$ or $\Theta_{R,d}$ is calculated independently.

Information: The IMETER M4 method description, available at *'https://imeter.de/?view=article&id=46'*, provides information on procedures and calculations.

2. ===== Collection of Measurements in this Series ^{HDPE}/$_{Wasser}$ ======

Tabelle 1.2: Conditions and Results

N°	IDN° ...erData36	ϑ [°C]	$\Delta\tau$ [min]	$\bar{v}_z$ [mm/s]	$\bar{C}a$ [1]	$t_{eq.}$ [s]	Θ_M [°]	CAH [°]	^{a}H [mN/m]	$^{a}\bar{E}$ [mN/m]	$\pm\sigma$ [mN/m]	$\bar{S}$ [mJ/m²]	$\bar{B}_{\%,Wasser...}$ [%]
1.	18742_0	25,039	-44,9	0,250	3,09E-6	*2,0*	86	21	-26,0	5,3	±1,2	-66,7	7,4%
2.	18743_1	25,047	-34,7	0,250	3,09E-6	*2,1*	85,3	20,2	-25,05	5,82	±0,87	-66,2	8,1%
3.	18744_2	25,044	-32,6	0,250	3,09E-6	*2,2*	86	21	-26,42	5,46	±0,76	-66,5	7,6%
4.	18745_3	25,035	-30,3	0,250	3,09E-6	*0,4*	85,8	21,5	-26,81	5,08	±0,92	-66,9	7,1%
5.	18746_4	25,01	-27,4	0,250	3,09E-6	*2,0*	86,4	21,5	-26,81	4,42	±0,84	-67,6	6,1%
6.	18747_5	25,058	-22,0	0,250	3,09E-6	*2,0*	87,6	21,3	-26,58	3,01	±0,83	-69,0	4,2%
7.	18748_6	25,061	-13,7	0,135	1,67E-6	*4,1*	86,7	23,8	-29,62	4,09	±0,80	-67,9	5,7%
8.	18749_7	25,075	-7,52	0,182	2,25E-6	*3,5*	87	23	-29,01	4,15	±0,90	-67,8	5,8%
9.	18750_8	25,062	-4,92	0,246	3,03E-6	*0,4*	86,8	22,6	-28,15	3,94	±0,92	-68,0	5,5%
10.	18751_9	25,071	-2,90	0,332	4,09E-6	*0,3*	86,7	22,0	-27,32	4,06	±0,50	-67,9	5,6%
11.	18752_{10}	25,077	-1,25	0,448	5,53E-6	*1,6*	86,9	20,0	-25,01	3,84	±0,79	-68,1	5,3%
12.	**18753_{11}**	**25,091**	****0****	**0,605**	**7,46E-06**	***1,3***	**87,0**	**17,8**	**-22,24**	**3,67**	**±0,68**	**-68,3**	**5,1%**
13.	18754_{12}	25,09	+1,08	0,817	1,01E-5	*1,4*	84,0	21,4	-26,51	7,37	±0,81	-64,6	10,2%
14.	18755_{13}	25,06	+2,00	1,10	1,36E-5	*1,3*	87,3	28,2	-35,00	3,29	±0,60	-68,7	4,6%
15.	18756_{14}	25,06	+2,77	1,49	1,84E-5	*1,3*	87,3	28,7	-35,71	3,34	±0,59	-68,6	4,6%
16.	18757_{15}	25,07	+3,43	2,01	2,48E-5	*1,5*	87,3	29,5	-36,66	3,35	±0,49	-68,6	4,7%
17.	18758_{16}	25,09	+4,02	2,71	3,35E-5	*1,3*	87,5	29,8	-36,98	3,08	±0,88	-68,9	4,3%
18.	18759_{17}	25,09	+4,52	3,66	4,52E-5	*1,2*	87,6	30,1	-37,31	3,0	±1,0	-69,0	4,2%
19.	18760_{18}	25,06	+5,00	4,95	6,11E-5	*1,2*	87,9	30,5	-37,75	2,5	±1,3	-69,5	3,5%
20.	18761_{19}	25,06	+5,43	6,68	8,25E-5	*1,3*	88	32	-39,6	2,5	±1,4	-69,5	3,5%
21.	18762_{20}	25,05	+5,93	9,01	1,11E-4	*1,1*	88	31	-38,6	2,8	±2,3	-69,2	3,9%

*This table provides an overview of the measurements in this series. Each seperate M4 measurement is referenced by IDN°. The highlighted row indicates the data set of the measurement documented below. The column labeled ϑ shows the measurement temperature, $\Delta\tau$ the time interval to previous/following measurements, $\bar{v}_z$ the movement speed - where additional symbols clarify: »**n**« indicates static measurements, <**n**> represents distance-accelerated movement of the triple line, '*' stands for continous acceleration and a number without any symbol indicates a constant movement speed, $\bar{C}a$ is the capillary number, $t_{eq.}$ is the equilibration time before turnaround - but for static measurements the number denotes the average equilibration time as a levelling time between the measurement points, Θ_M is the mean of the advancing and receding contact angle, contact angle hysteresis is given in degrees (**CAH**) and in energy units (^{a}H), $^{a}\bar{E}$ is the mean adhesion energy, and $\pm\sigma$ is the corresponding standard deviation, $\bar{S}$ is the mean of the spreading parameter, and $\bar{B}_{\%,Wasser...}$ indicates the relative wettability ($B_{\%,lq|sl|md...} = 100\% \cdot {}^{a}E/\gamma$).*

Tabelle 2.2: Summary of sample weights in the individual measurements (initial weight W_0 = 8,0464 g)

N°	W_A [g]	ΔW_{A-0} [mg]	W_E [g]	ΔW_{E-0} [mg]	V_{E-0} [µL]	ΔV_{E-A} [µL]
1.	8,0464	0,0	8,0596	13,2	13,3	13
2.	8,0470	0,6	8,0582	11,8	11,8	-1,4
3.	8,0566	10,2	8,0572	10,8	10,8	-1,0
4.	8,0553	8,9	8,0566	10,2	10,2	-0,60
5.	8,0550	8,6	8,0567	10,3	10,3	0,10
6.	8,0551	8,7	8,0566	10,2	10,2	-0,10
7.	8,0547	8,3	8,0563	9,9	9,9	-0,30
8.	8,0554	9,0	8,0565	10,1	10,1	0,20
9.	8,0551	8,7	8,0568	10,4	10,4	0,30
10.	8,0547	8,3	8,0565	10,1	10,1	-0,30
11.	8,0549	8,5	8,0566	10,2	10,2	0,10
12.	**8,0546**	**8,2**	**8,0562**	**9,8**	**9,8**	**-0,40**
13.	8,0544	8,0	8,0562	9,8	9,8	~0
14.	8,0544	8,0	8,0561	9,7	9,7	-0,10
15.	8,0543	7,9	8,0561	9,7	9,7	~0
16.	8,0540	7,6	8,0560	9,6	9,6	-0,10
17.	8,0542	7,8	8,0559	9,5	9,5	-0,10
18.	8,0542	7,8	8,0560	9,6	9,6	0,10
19.	8,0539	7,5	8,0558	9,4	9,4	-0,20
20.	8,0543	7,9	8,0560	9,6	9,6	0,20
21.	8,0545	8,1	8,0559	9,5	9,5	-0,10

Symbols: W_A: Total weight before each measurement, ΔW_{0-A}: Change in weight from the initial weight W_0 at the start of the series, W_E: Total weight after the measurement (possibly including the weight of any adherent fluid), ΔW_{E-0}: Change in weight from the initial weight W_0 at the start of the series, V_{E-0}: Weight change interpreted as fluid volume, ΔV_{E-A}: Fluid volume change calculated as the difference between W_E and W_A. (Automated weighings without contact to the surface of the fluid).

3. ===== Measurement IDN°18753: *Dynamic* Contact Angle ======

HDPE, cylindric Ø8,3mm

	12mm HDPE\Wasser, γ =71,97mN/m		ϑ=25,1°C
Contact Angle, CA $\Theta_{M,d}$	**87,0 ±0,58°**	$\Theta_{C,d}$ = 86,4°	
Contact Angle Hysteresis, CAH_d	17,8°		
	Advancing $\Theta_{A,d}$	**Receding $\Theta_{R,d}$**	Transition 0,441 mm
Contact Angles, Θ_d	**95,9°**	**78,1°**	99,9°$_{adv.}$ ⇒ 92,6°$_{rec.}$
Standard deviation σ_Θ	±0,3°	±0,5°	±0,9°
Rated measurements n mm-range	82 2,569 - 11,618mm	90 10,065 - 0,107mm	5 11,586 - 11,145mm
Linear regression, slope [°/mm]	-0,0178	0,0738	16,9
Correlation coefficient r^2	0,03	0,16	0,920
Triple line speed $\bar{v}_z$ [mm/s]	**0,605** ±2,99E-05	**-0,605** ±2,89E-05	
Capillary number Ca	7,46E-06	-7,46E-06	

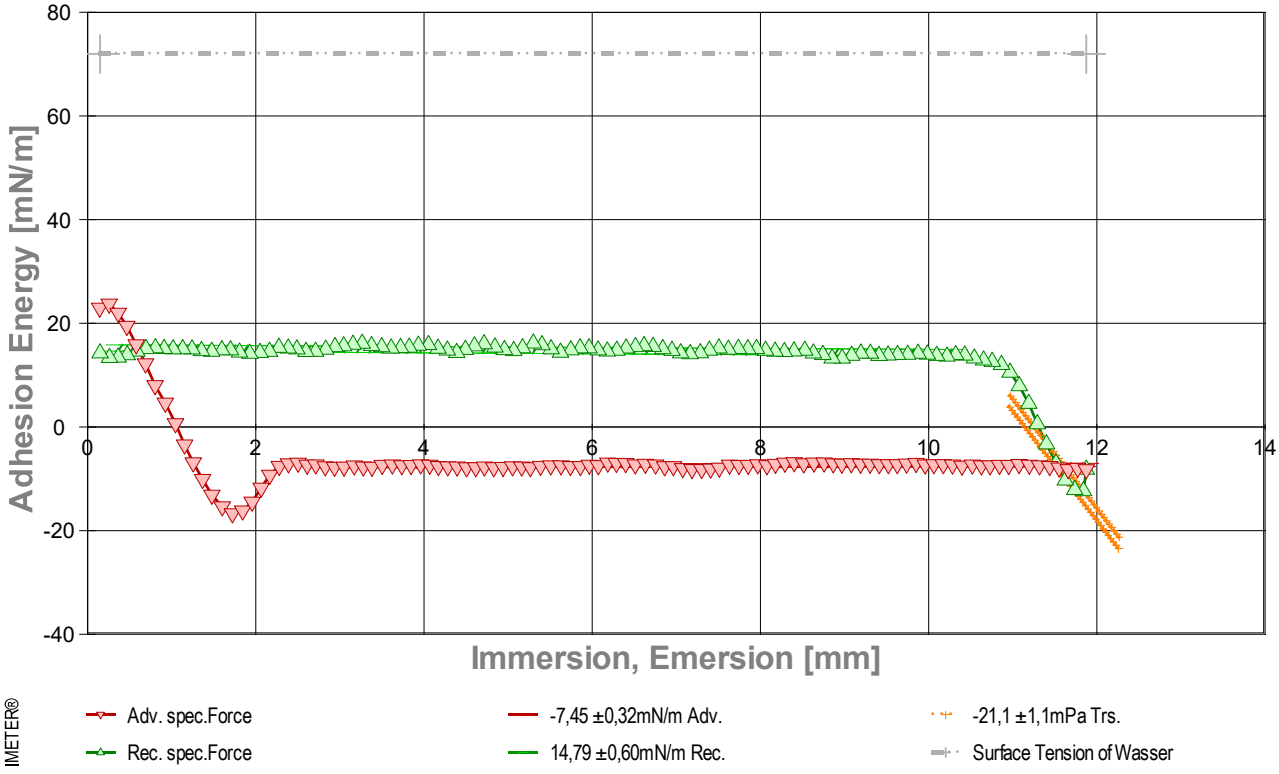
Dynamic Contact Angle Measurement: The Contact Angle Θ_C is calculated from advancing and receding values according to the formula of Tadmore/Chibowski; the average value of advancing and receding Contact Angle is given by Θ_M. (Derjaguin's Law: e~0,0074mm deposit layer). The change of the direction from advancing to receding - where the triple line may be pinned and only the angle is changing from advancing to receding - is analyzed within the column 'Transition'.(CA-Diagramm available)

Adhesion Force of the dynamic Triple Line

Energy of Adhesion, $^a\bar{E}_d=(^aE_A+^aE_R)/2$	**3,67 ±0,68 mN/m**
Hysteresis, $^aH_d = {}^aE_A - {}^aE_R$	-22,24 mN/m
Parameter of spreading, $\bar{S}_d = {}^a\bar{E} - \gamma$	-68,30 mJ/m²
relative wettability, $\bar{B}_{\%,d}=100\cdot{}^a\bar{E}/\gamma$	5,1% with Wasser

	Advancing $^aE_{A,d}$	Receding $^aE_{R,d}$	Transition 0,441 mm
Energy of Adhesion, ^aE_d [mN/m]	**-7,45**	**14,79**	-12,36$_{<adv.>}$ ⇒ -3,31 rec.
Standard deviation $^a\sigma$ [mN/m]	±0,32	±0,60	±1,1
Linear regression, slope [mPa]	0,02	-0,09	-21,1
correlation coefficient r^2	0,03	0,16	0,920
Relative wettability, $B_{\%,d}$	-10%	21%	

¬ *Diagramm 1.3: 'Triple-line Force²' dynamic forces at the triple line, $\bar{v}_z$=0,61 mm/s*



- Das Diagramm zeigt den Verlauf der Adhäsionsenergie ^aE entlang der Probenoberfläche. Die roten ∇-Markierungen stehen für adv.-Messwerte (Eintauchen; von links nach rechts aufgezeichnet), grüne Δ-Markierungen gehören zu rec.-Werten (Rückzugsbewegung; von rechts nach links laufend). Die Oberflächenspannung von Wasser ist als grau gestrichelte Horizontale bei 71,97 mN/m eingezeichnet; sie gibt die *maximale Zugfestigkeit* an, die eine flüssige Wasser-Oberfläche aushalten kann. Die Adhäsionsenergie ^aE auf der Probenoberfläche ist kleiner als die Oberflächenspannung und verursacht Kontaktwinkel und je kleiner die Adhäsionsenergie ist, umso größer ist der Kontaktwinkel. Die orangefarben markierte Gerade misst die Steilheit der Adhäsionsenergie-Hysterese, die mit der Umkehr der Bewegungsrichtung adv.↔rec. einher geht. Das dortige Pinning der Triple Line bedeutet, dass eine Bewegung von 0.1 mm eine Adhäsionsenergie-Änderung von 2,1 mN/m bzw. eine Kontaktwinkeländerung von 1,7° bewirkt.

4. ===== Details on the Measurement and Setup ======

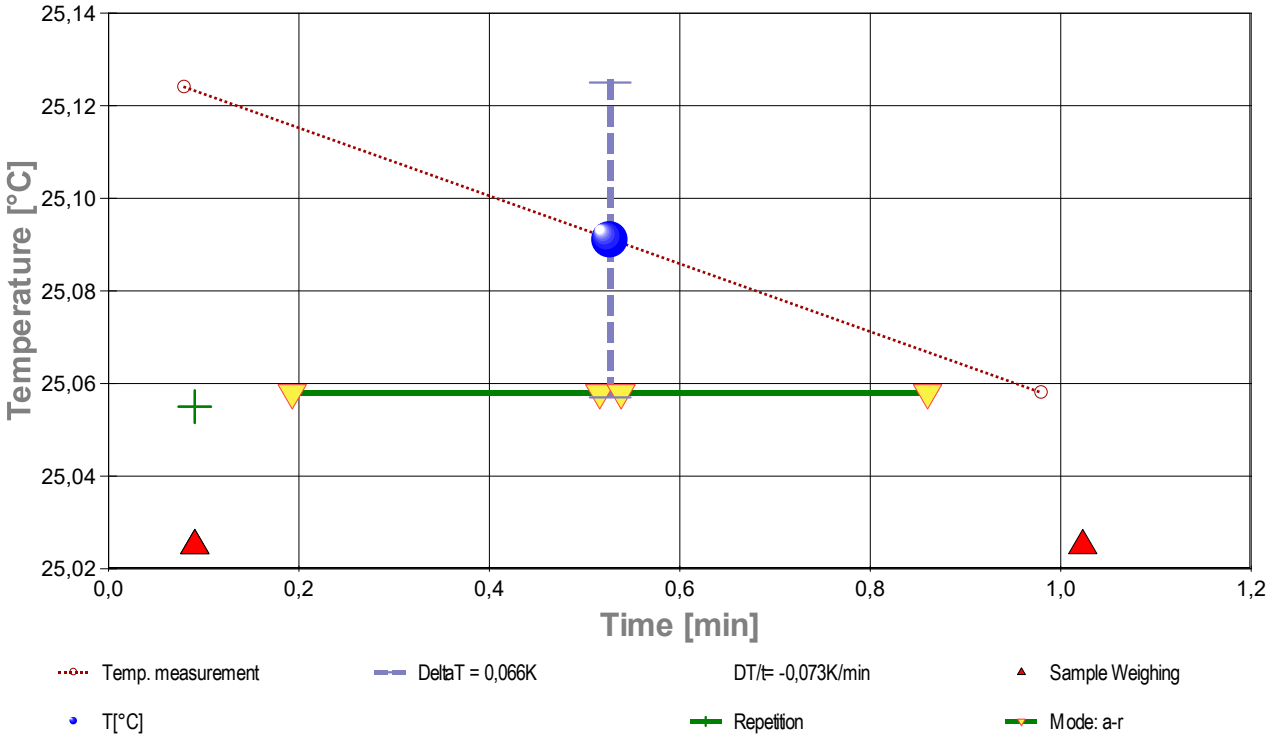
This document is reporting the **11. Repetition of the Measurement IDN°18742**

- Details of the setup, data on liquid and sample of this IDN°18753 are declared in the first measurement that is IDN°18742 of this series.

Weight at Start: 8,0546 g; alteration to reference 0,0082 g.

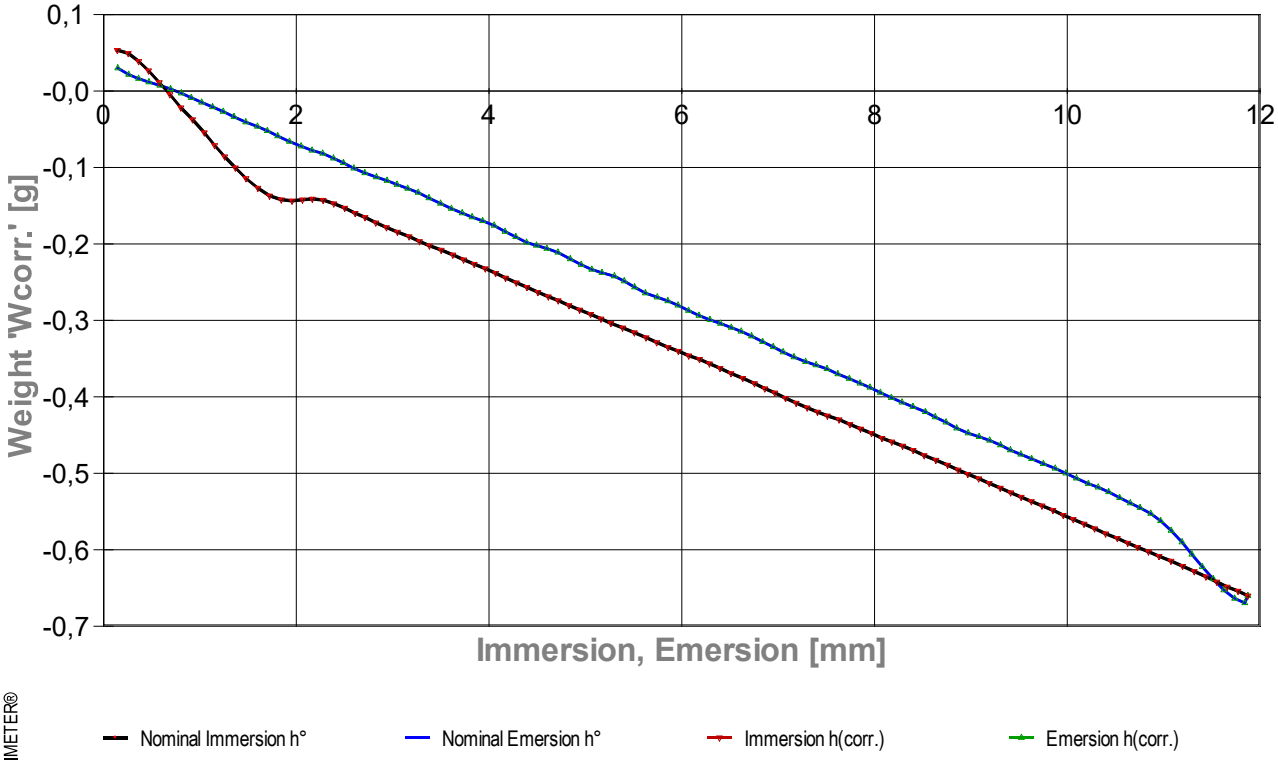
Measurement algorithm: dynamic CA-measurement, acquisition during constant movement. Maximum immersion of 11,874 mm and force equilibration at the inflection point for 1,3 s. Duration for immersion 19 s, for emersion 20 s. The *CLT* was used. - *The 'CLT' Constant-Level-Technic prevents rising/falling of the Wasser-level in the vessel (surface 1452mm²) through immersion/emersion of the sample volume in the vessel by appropriate pumping of Wasser.*

Time & Temperature: Messdauer eine Minute; Temperaturabnahme von 25,12 auf 25,06°C. ¬ *Diagramm 2.4: 'Temperature & Events²' -- Survey on Temperature and Time*



- Das Diagramm "Temperature & Events²" dokumentiert neben der Flüssigkeitstemperatur der Messfluids (Wasser) die zeitliche Abfolge der Verfahrensschritte. Die Temperaturmesswerte sind als kleine Kreise abgebildet; die kugelförmige Marke gibt die der Messung insgesamt zugeordnete Temperatur an (25,091°C). Weitere gelbe Dreiecke auf der grünen Horizontalen bezeichnen die Schaltung jweiliger Messmodi ('a-r' bedeutet *Advancing*- - und *Receding*-Bewegung). Die roten Dreiecke, unten im Diagramm, markieren die Zeitpunkte der Probenwägung von HDPE (ohne Kontakt zur Fluidoberfläche).

¬ *Diagramm 3.4: 'RawData²' -- Acquired weights during immersion and emersion (raw data and immersion corrected lengths)*



- Im Diagramm "RawData²" werden die Wägewerte zur dynamischen Kontaktwinkelmessung gegen die Eintauchtiefe der Probe abgebildet. Von den Roh-Wägewerten W_{RAW} wurden Proben- und Aufhängungsgewichte subtrahiert, so dass hier die *Gewichte* der Benetzungs- und Auftriebskräfte abgebildet werden ($W_{corr.}$). Die Kurvenverläufe fallen mit der Eintauchtiefe *h* (*immersion depth*) ab, indes der Volumenauftrieb des eintauchenden Probekörpers zunimmt. Im Diagramm sind Wägewerte für die advancing- und receding-Bewegung eingetragen, sowohl für nominelle (h_0) und für korrigierte Eintauchtiefen ($h_{corr.}$). Die roten Dreiecke bezeichnen die Messwerte bei $h_{corr.}$ bei der Vorwärtsbewegung (adv.), die grünen Dreiecke gehören zu Auszugsbewegungen (rec.). Durch 'CLT' (die *Constant-Level-Technic*) wird die Pegelveränderung besonders durch das ein- und austauchendes Probenvolumen simultan kompensiert, sodass die nominelle Eintauchtief mit der tatsächlichen identisch ist; die Kurven sind deshalb praktisch deckungsgleich.

5. ===== Table of raw data and results ======

The table below provides the data for each contact angle measuring position in this run (n=212). - Within a row the column ***t*** lists the time of the CA-measurement. $\boldsymbol{W_{RAW}}$ is the original weighing data. The nominal distance between the sample bottom flatface and the liquid surface is given by $\boldsymbol{h_0}$, whilst $\boldsymbol{h}_{corr.}$ shows the corrected immersion depth- *due to CLT the values are the same*. The sum of calculated dynamic forces are taken into account by $\boldsymbol{F}_{dyn.}$. The $\boldsymbol{W}_{corr.}$-values* are the original raw weighing values when the weight of the sample and its holder (W_0=8,0464g) is subtracted. After buoyancy- correction, $^{a}\boldsymbol{F}$ is the force excerted on the triple line. The Energy of Adhesion $^{a}\boldsymbol{E}_{A,R} = {}^{a}F/p$ is the force of adhesion per meter of the circumference (p) of the sample. $\boldsymbol{\Theta}$ is the Contact Angle. The last column indicates by **chr** the **a**dvancing resp. **r**eceding state.

(Resolving dynamic force of wetting) $^{a}F = (W_{Raw}\text{-}W_0\text{-}W_{Buoy.})\cdot g + F_{Buoy.air} - F_{visc.} - F_{kinet.} - F_{work} = (W_{corr.}\text{-}W_{Buoy.})\cdot g - F_{dyn.}$

Tabelle 3.5: Data table

N°	t [sec]	W_{RAW} [g]	h_0 [mm]	$h_{corr.}$ [mm]	$F_{dyn.}$ [mN]	$W_{corr.}$ [g]	^{a}F [mN]	$^{a}E_{A,R}$ [mN/m]	Θ [°deg]	chr --
1.	**0,00**	**8,0998**	**0,142**	**0,142**	**0**	**0,0534**	**0,5988**	**22,96**	**71,39**	**a**
2.	0,19	8,0958	0,256	0,256	1,81E-05	0,0494	0,6195	23,76	70,72	a
3.	0,37	8,0853	0,364	0,364	1,86E-05	0,0389	0,5734	21,99	72,21	a
4.	0,54	8,0731	0,466	0,466	1,91E-05	0,0267	0,5077	19,47	74,30	a
5.	0,72	8,0576	0,578	0,578	1,97E-05	0,0112	0,4147	15,90	77,23	a
6.	0,90	8,0419	0,688	0,688	2,02E-05	-0,0045	0,3188	12,23	80,22	a
7.	1,09	8,0246	0,802	0,802	2,07E-05	-0,0218	0,2092	8,02	83,60	a
8.	1,29	8,0091	0,923	0,923	2,13E-05	-0,0373	0,1210	4,64	86,30	a
9.	1,49	7,9920	1,045	1,045	2,19E-05	-0,0544	0,0175	0,67	89,47	a
10.	1,67	7,9753	1,153	1,153	2,24E-05	-0,0711	-0,0895	-3,43	92,73	a
11.	1,84	7,9606	1,256	1,256	2,28E-05	-0,0858	-0,1793	-6,88	95,48	a
12.	2,02	7,9461	1,367	1,367	2,34E-05	-0,1003	-0,2628	-10,08	98,05	a
13.	2,21	7,9321	1,477	1,477	2,39E-05	-0,1143	-0,3420	-13,12	100,50	a
14.	2,41	7,9195	1,601	1,601	2,45E-05	-0,1269	-0,4005	-15,36	102,32	a
15.	2,61	7,9094	1,722	1,722	2,50E-05	-0,1370	-0,4357	-16,71	103,42	a
16.	2,81	7,9043	1,844	1,844	2,56E-05	-0,1421	-0,4215	-16,17	102,98	a
17.	3,00	7,9028	1,956	1,956	2,61E-05	-0,1436	-0,3772	-14,47	101,59	a
18.	3,17	7,9042	2,064	2,064	2,66E-05	-0,1422	-0,3066	-11,76	99,40	a
19.	3,34	7,9053	2,166	2,166	2,71E-05	-0,1411	-0,2416	-9,26	97,40	a
20.	3,53	7,9038	2,278	2,278	2,77E-05	-0,1426	-0,1972	-7,56	96,03	a
21.	3,71	7,8992	2,389	2,389	2,82E-05	-0,1472	-0,1842	-7,07	95,63	a
22.	3,90	7,8934	2,503	2,503	2,87E-05	-0,1530	-0,1811	-6,94	95,54	a
23.	4,08	7,8866	2,610	2,610	2,92E-05	-0,1598	-0,1910	-7,32	95,84	a
24.	4,25	7,8812	2,713	2,713	2,97E-05	-0,1652	-0,1896	-7,27	95,80	a
25.	4,43	7,8742	2,825	2,825	3,02E-05	-0,1722	-0,1992	-7,64	96,09	a
26.	4,61	7,8680	2,935	2,935	3,07E-05	-0,1784	-0,2019	-7,74	96,18	a
27.	4,80	7,8620	3,049	3,049	3,13E-05	-0,1844	-0,2007	-7,70	96,14	a
28.	5,00	7,8561	3,170	3,170	3,19E-05	-0,1903	-0,1948	-7,47	95,96	a
29.	5,18	7,8497	3,279	3,279	3,24E-05	-0,1967	-0,2004	-7,68	96,13	a
30.	5,35	7,8441	3,381	3,381	3,28E-05	-0,2023	-0,2013	-7,72	96,16	a
31.	5,55	7,8385	3,503	3,503	3,34E-05	-0,2079	-0,1921	-7,37	95,88	a
32.	5,75	7,8322	3,624	3,624	3,40E-05	-0,2142	-0,1900	-7,29	95,81	a
33.	5,94	7,8258	3,736	3,736	3,45E-05	-0,2206	-0,1937	-7,43	95,93	a
34.	6,12	7,8200	3,846	3,846	3,50E-05	-0,2264	-0,1925	-7,38	95,89	a
35.	6,31	7,8142	3,960	3,960	3,56E-05	-0,2322	-0,1893	-7,26	95,79	a
36.	6,48	7,8082	4,068	4,068	3,61E-05	-0,2382	-0,1911	-7,33	95,84	a
37.	6,65	7,8020	4,171	4,171	3,66E-05	-0,2444	-0,1979	-7,59	96,05	a
38.	6,84	7,7958	4,283	4,283	3,71E-05	-0,2506	-0,1997	-7,66	96,11	a
39.	7,02	7,7898	4,393	4,393	3,76E-05	-0,2566	-0,2004	-7,69	96,13	a
40.	7,21	7,7833	4,507	4,507	3,81E-05	-0,2631	-0,2041	-7,83	96,24	a
41.	7,39	7,7775	4,615	4,615	3,87E-05	-0,2689	-0,2039	-7,82	96,24	a
42.	7,56	7,7724	4,717	4,717	3,91E-05	-0,2740	-0,1999	-7,67	96,12	a
43.	7,74	7,7660	4,829	4,829	3,97E-05	-0,2804	-0,2037	-7,81	96,23	a
44.	7,92	7,7602	4,940	4,940	4,02E-05	-0,2862	-0,2024	-7,76	96,19	a
45.	8,11	7,7544	5,053	5,053	4,07E-05	-0,2920	-0,1993	-7,64	96,10	a
46.	8,29	7,7485	5,161	5,161	4,12E-05	-0,2979	-0,2003	-7,68	96,13	a
47.	8,46	7,7426	5,264	5,264	4,17E-05	-0,3038	-0,2039	-7,82	96,24	a
48.	8,66	7,7368	5,385	5,385	4,23E-05	-0,3096	-0,1969	-7,55	96,02	a
49.	8,86	7,7305	5,507	5,507	4,29E-05	-0,3159	-0,1945	-7,46	95,95	a
50.	9,06	7,7240	5,629	5,629	4,34E-05	-0,3224	-0,1941	-7,44	95,94	a
51.	9,25	7,7176	5,741	5,741	4,40E-05	-0,3288	-0,1978	-7,59	96,05	a
52.	9,44	7,7112	5,859	5,859	4,45E-05	-0,3352	-0,1983	-7,61	96,07	a
53.	9,62	7,7062	5,965	5,965	4,50E-05	-0,3402	-0,1915	-7,34	95,86	a
54.	9,79	7,7002	6,072	6,072	4,55E-05	-0,3462	-0,1935	-7,42	95,92	a
55.	9,98	7,6955	6,184	6,184	4,60E-05	-0,3509	-0,1806	-6,92	95,52	a
56.	10,15	7,6898	6,287	6,287	4,65E-05	-0,3566	-0,1822	-6,99	95,57	a
57.	10,33	7,6838	6,398	6,398	4,70E-05	-0,3626	-0,1829	-7,01	95,59	a
58.	10,52	7,6770	6,511	6,511	4,76E-05	-0,3694	-0,1896	-7,27	95,80	a
59.	10,72	7,6708	6,633	6,633	4,82E-05	-0,3756	-0,1865	-7,15	95,70	a
60.	10,92	7,6639	6,754	6,754	4,87E-05	-0,3825	-0,1900	-7,29	95,81	a
61.	11,10	7,6572	6,862	6,862	4,92E-05	-0,3892	-0,1989	-7,63	96,08	a
62.	11,27	7,6517	6,965	6,965	4,97E-05	-0,3947	-0,1986	-7,62	96,07	a
63.	11,45	7,6447	7,077	7,077	5,02E-05	-0,4017	-0,2082	-7,98	96,37	a
64.	11,64	7,6383	7,187	7,187	5,08E-05	-0,4081	-0,2128	-8,16	96,51	a
65.	11,82	7,6322	7,301	7,301	5,13E-05	-0,4142	-0,2127	-8,16	96,51	a
66.	12,00	7,6266	7,409	7,409	5,18E-05	-0,4198	-0,2108	-8,08	96,45	a
67.	12,17	7,6216	7,511	7,511	5,23E-05	-0,4248	-0,2058	-7,89	96,30	a
68.	12,37	7,6166	7,633	7,633	5,29E-05	-0,4298	-0,1907	-7,31	95,83	a
69.	12,56	7,6104	7,745	7,745	5,34E-05	-0,4360	-0,1924	-7,38	95,89	a
70.	12,74	7,6045	7,855	7,855	5,39E-05	-0,4419	-0,1922	-7,37	95,88	a
71.	12,93	7,5987	7,969	7,969	5,44E-05	-0,4477	-0,1891	-7,25	95,78	a
72.	13,11	7,5924	8,077	8,077	5,50E-05	-0,4540	-0,1937	-7,43	95,92	a
73.	13,27	7,5876	8,180	8,180	5,54E-05	-0,4588	-0,1868	-7,16	95,71	a
74.	13,46	7,5822	8,292	8,292	5,60E-05	-0,4642	-0,1807	-6,93	95,53	a
75.	13,64	7,5765	8,402	8,402	5,65E-05	-0,4699	-0,1785	-6,85	95,46	a
76.	13,83	7,5698	8,516	8,516	5,70E-05	-0,4766	-0,1842	-7,07	95,63	a
77.	14,03	7,5637	8,637	8,637	5,76E-05	-0,4827	-0,1802	-6,91	95,51	a
78.	14,23	7,5572	8,758	8,758	5,82E-05	-0,4892	-0,1798	-6,89	95,50	a
79.	14,41	7,5509	8,866	8,866	5,87E-05	-0,4955	-0,1847	-7,08	95,65	a
80.	14,58	7,5453	8,969	8,969	5,91E-05	-0,5011	-0,1856	-7,12	95,68	a
81.	14,76	7,5395	9,081	9,081	5,97E-05	-0,5069	-0,1835	-7,04	95,61	a
82.	14,94	7,5333	9,191	9,191	6,02E-05	-0,5131	-0,1862	-7,14	95,69	a
83.	15,13	7,5272	9,305	9,305	6,07E-05	-0,5192	-0,1860	-7,13	95,69	a
84.	15,31	7,5211	9,413	9,413	6,12E-05	-0,5253	-0,1887	-7,24	95,77	a
85.	15,49	7,5153	9,521	9,521	6,17E-05	-0,5311	-0,1884	-7,23	95,76	a
86.	15,67	7,5096	9,627	9,627	6,22E-05	-0,5368	-0,1885	-7,23	95,76	a

87.	15,85	7,5040	9,737	9,737	6,28E-05	-0,5424	-0,1853	-7,11	95,67	a
88.	16,04	7,4982	9,851	9,851	6,33E-05	-0,5482	-0,1822	-6,99	95,57	a
89.	16,21	7,4916	9,959	9,959	6,38E-05	-0,5548	-0,1900	-7,29	95,81	a
90.	16,38	7,4862	10,062	10,062	6,43E-05	-0,5602	-0,1887	-7,24	95,77	a
91.	16,57	7,4802	10,174	10,174	6,48E-05	-0,5662	-0,1885	-7,23	95,76	a
92.	16,75	7,4741	10,284	10,284	6,53E-05	-0,5723	-0,1902	-7,29	95,82	a
93.	16,94	7,4674	10,398	10,398	6,59E-05	-0,5790	-0,1959	-7,51	95,99	a
94.	17,14	7,4614	10,520	10,520	6,64E-05	-0,5850	-0,1906	-7,31	95,83	a
95.	17,32	7,4552	10,628	10,628	6,70E-05	-0,5912	-0,1945	-7,46	95,95	a
96.	17,49	7,4497	10,730	10,730	6,74E-05	-0,5967	-0,1942	-7,45	95,94	a
97.	17,67	7,4439	10,842	10,842	6,80E-05	-0,6025	-0,1921	-7,37	95,87	a
98.	17,85	7,4379	10,953	10,953	6,85E-05	-0,6085	-0,1928	-7,39	95,90	a
99.	18,06	7,4318	11,076	11,076	6,91E-05	-0,6146	-0,1878	-7,20	95,74	a
100.	18,26	7,4249	11,197	11,197	6,96E-05	-0,6215	-0,1913	-7,34	95,85	a
101.	18,46	7,4181	11,318	11,318	7,02E-05	-0,6283	-0,1942	-7,45	95,94	a
102.	18,66	7,4112	11,439	11,439	7,08E-05	-0,6352	-0,1980	-7,59	96,06	a
103.	18,84	7,4044	11,552	11,552	7,13E-05	-0,6420	-0,2056	-7,88	96,29	a
104.	19,02	7,3978	11,660	11,660	7,18E-05	-0,6486	-0,2132	-8,18	96,52	a
105.	19,21	7,3924	11,772	11,772	7,23E-05	-0,6540	-0,2070	-7,94	96,33	a
106.	19,38	7,3862	11,874	11,874	7,28E-05	-0,6602	-0,2139	-8,20	96,55	a
107.	***20,72***	***7,3769***	***11,842***	***11,842***	***0***	***-0,6695***	***-0,3222***	***-12,36***	***99,89***	***r***
108.	20,90	7,3827	11,737	11,737	-0,00450	-0,6637	-0,3161	-12,12	99,70	r
109.	21,08	7,3936	11,625	11,625	-0,00445	-0,6528	-0,2683	-10,29	98,22	r
110.	21,26	7,4082	11,515	11,515	-0,00441	-0,6382	-0,1832	-7,03	95,60	r
111.	21,45	7,4242	11,401	11,401	-0,00437	-0,6222	-0,0864	-3,31	92,64	r
112.	21,63	7,4403	11,293	11,293	-0,00433	-0,6061	0,0146	0,56	89,55	r
113.	21,80	7,4563	11,191	11,191	-0,00429	-0,5901	0,1176	4,51	86,41	r
114.	21,99	7,4714	11,078	11,078	-0,00425	-0,5750	0,2062	7,91	83,69	r
115.	22,17	7,4842	10,969	10,969	-0,00420	-0,5622	0,2740	10,51	81,61	r
116.	22,34	7,4937	10,866	10,866	-0,00416	-0,5527	0,3131	12,01	80,39	r
117.	22,52	7,5012	10,756	10,756	-0,00412	-0,5452	0,3286	12,60	79,92	r
118.	22,69	7,5074	10,654	10,654	-0,00408	-0,5390	0,3354	12,86	79,71	r
119.	22,87	7,5144	10,544	10,544	-0,00404	-0,5320	0,3459	13,26	79,38	r
120.	23,06	7,5220	10,430	10,430	-0,00400	-0,5244	0,3603	13,82	78,93	r
121.	23,24	7,5281	10,321	10,321	-0,00396	-0,5183	0,3629	13,92	78,85	r
122.	23,40	7,5328	10,219	10,219	-0,00392	-0,5136	0,3551	13,62	79,09	r
123.	23,61	7,5398	10,096	10,096	-0,00387	-0,5066	0,3589	13,76	78,98	r
124.	23,79	7,5464	9,985	9,985	-0,00383	-0,5000	0,3651	14,00	78,78	r
125.	23,97	7,5528	9,875	9,875	-0,00379	-0,4936	0,3697	14,18	78,64	r
126.	24,18	7,5589	9,752	9,752	-0,00374	-0,4875	0,3647	13,99	78,79	r
127.	24,38	7,5653	9,630	9,630	-0,00369	-0,4811	0,3633	13,93	78,84	r
128.	24,56	7,5711	9,518	9,518	-0,00365	-0,4753	0,3611	13,85	78,91	r
129.	24,74	7,5767	9,410	9,410	-0,00361	-0,4697	0,3588	13,76	78,98	r
130.	24,91	7,5833	9,308	9,308	-0,00357	-0,4631	0,3695	14,17	78,64	r
131.	25,09	7,5894	9,196	9,196	-0,00353	-0,4570	0,3702	14,20	78,62	r
132.	25,28	7,5942	9,085	9,085	-0,00348	-0,4522	0,3591	13,77	78,97	r
133.	25,46	7,5989	8,972	8,972	-0,00344	-0,4475	0,3452	13,24	79,40	r
134.	25,66	7,6053	8,853	8,853	-0,00340	-0,4411	0,3453	13,24	79,40	r
135.	25,84	7,6131	8,742	8,742	-0,00335	-0,4333	0,3633	13,93	78,84	r
136.	26,03	7,6199	8,630	8,630	-0,00331	-0,4265	0,3709	14,23	78,60	r
137.	26,20	7,6268	8,528	8,528	-0,00327	-0,4196	0,3846	14,75	78,17	r
138.	26,41	7,6334	8,399	8,399	-0,00322	-0,4130	0,3813	14,62	78,28	r
139.	26,60	7,6392	8,285	8,285	-0,00318	-0,4072	0,3781	14,50	78,38	r
140.	26,78	7,6453	8,175	8,175	-0,00314	-0,4011	0,3798	14,57	78,32	r
141.	26,97	7,6519	8,061	8,061	-0,00309	-0,3945	0,3845	14,75	78,18	r
142.	27,15	7,6586	7,953	7,953	-0,00305	-0,3878	0,3933	15,08	77,90	r
143.	27,32	7,6640	7,850	7,850	-0,00301	-0,3824	0,3919	15,03	77,95	r
144.	27,50	7,6702	7,739	7,739	-0,00297	-0,3762	0,3939	15,11	77,88	r
145.	27,70	7,6762	7,620	7,620	-0,00293	-0,3702	0,3899	14,95	78,01	r
146.	27,88	7,6829	7,507	7,507	-0,00288	-0,3635	0,3961	15,19	77,81	r
147.	28,07	7,6879	7,393	7,393	-0,00284	-0,3585	0,3851	14,77	78,16	r
148.	28,25	7,6924	7,285	7,285	-0,00280	-0,3540	0,3721	14,27	78,56	r
149.	28,45	7,6984	7,164	7,164	-0,00275	-0,3480	0,3673	14,09	78,71	r
150.	28,64	7,7049	7,052	7,052	-0,00271	-0,3415	0,3717	14,25	78,58	r
151.	28,81	7,7117	6,949	6,949	-0,00267	-0,3347	0,3840	14,73	78,19	r
152.	28,99	7,7185	6,839	6,839	-0,00263	-0,3279	0,3926	15,06	77,92	r
153.	29,18	7,7258	6,725	6,725	-0,00258	-0,3206	0,4041	15,50	77,57	r
154.	29,35	7,7320	6,617	6,617	-0,00254	-0,3144	0,4081	15,65	77,44	r
155.	29,52	7,7370	6,515	6,515	-0,00250	-0,3094	0,4031	15,46	77,60	r
156.	29,71	7,7423	6,403	6,403	-0,00246	-0,3041	0,3959	15,18	77,82	r
157.	29,89	7,7471	6,292	6,292	-0,00242	-0,2993	0,3849	14,76	78,17	r
158.	30,08	7,7528	6,179	6,179	-0,00238	-0,2936	0,3807	14,60	78,29	r
159.	30,26	7,7592	6,070	6,070	-0,00233	-0,2872	0,3863	14,81	78,12	r
160.	30,44	7,7661	5,962	5,962	-0,00229	-0,2803	0,3968	15,22	77,79	r
161.	30,61	7,7718	5,856	5,856	-0,00225	-0,2746	0,3968	15,22	77,79	r
162.	30,79	7,7767	5,746	5,746	-0,00221	-0,2697	0,3867	14,83	78,11	r
163.	31,00	7,7821	5,622	5,622	-0,00216	-0,2643	0,3745	14,36	78,49	r
164.	31,18	7,7899	5,510	5,510	-0,00212	-0,2565	0,3918	15,03	77,95	r
165.	31,36	7,7978	5,402	5,402	-0,00208	-0,2486	0,4125	15,82	77,30	r
166.	31,53	7,8042	5,300	5,300	-0,00204	-0,2422	0,4212	16,15	77,03	r
167.	31,74	7,8087	5,171	5,171	-0,00199	-0,2377	0,3973	15,24	77,78	r
168.	31,91	7,8129	5,066	5,066	-0,00195	-0,2335	0,3832	14,70	78,22	r
169.	32,10	7,8193	4,956	4,956	-0,00191	-0,2271	0,3879	14,87	78,07	r
170.	32,28	7,8267	4,843	4,843	-0,00187	-0,2197	0,4007	15,37	77,67	r
171.	32,50	7,8353	4,714	4,714	-0,00182	-0,2111	0,4173	16,00	77,15	r
172.	32,69	7,8404	4,599	4,599	-0,00177	-0,2060	0,4066	15,59	77,49	r
173.	32,86	7,8444	4,492	4,492	-0,00173	-0,2020	0,3890	14,92	78,04	r
174.	33,03	7,8483	4,389	4,389	-0,00169	-0,1981	0,3732	14,31	78,53	r
175.	33,22	7,8556	4,277	4,277	-0,00165	-0,1908	0,3857	14,79	78,14	r
176.	33,40	7,8625	4,167	4,167	-0,00161	-0,1839	0,3949	15,15	77,85	r
177.	33,59	7,8705	4,053	4,053	-0,00156	-0,1759	0,4133	15,85	77,28	r
178.	33,79	7,8766	3,933	3,933	-0,00152	-0,1698	0,4099	15,72	77,38	r
179.	33,97	7,8815	3,823	3,823	-0,00148	-0,1649	0,4001	15,35	77,69	r
180.	34,14	7,8868	3,721	3,721	-0,00144	-0,1596	0,3981	15,27	77,75	r
181.	34,32	7,8926	3,609	3,609	-0,00139	-0,1538	0,3959	15,18	77,82	r
182.	34,51	7,8993	3,497	3,497	-0,00135	-0,1471	0,4025	15,44	77,62	r
183.	34,71	7,9064	3,376	3,376	-0,00131	-0,1400	0,4082	15,66	77,44	r
184.	34,89	7,9136	3,264	3,264	-0,00126	-0,1328	0,4200	16,11	77,07	r
185.	35,07	7,9189	3,156	3,156	-0,00122	-0,1275	0,4148	15,91	77,23	r
186.	35,25	7,9241	3,045	3,045	-0,00118	-0,1223	0,4070	15,61	77,47	r
187.	35,42	7,9292	2,942	2,942	-0,00114	-0,1172	0,4028	15,45	77,61	r
188.	35,61	7,9338	2,831	2,831	-0,00110	-0,1126	0,3897	14,95	78,01	r
189.	35,81	7,9393	2,710	2,710	-0,00105	-0,1071	0,3795	14,55	78,33	r

190.	35,99	7,9453	2,596	2,596	-0,00101	-0,1011	0,3785	14,52	78,36	r
191.	36,17	7,9524	2,489	2,489	-9,67E-04	-0,0940	0,3913	15,01	77,96	r
192.	36,34	7,9584	2,386	2,386	-9,28E-04	-0,0880	0,3958	15,18	77,82	r
193.	36,53	7,9648	2,274	2,274	-8,85E-04	-0,0816	0,3995	15,32	77,71	r
194.	36,71	7,9687	2,164	2,164	-8,43E-04	-0,0777	0,3796	14,56	78,33	r
195.	36,90	7,9742	2,050	2,050	-7,99E-04	-0,0722	0,3738	14,34	78,51	r
196.	37,10	7,9803	1,929	1,929	-7,53E-04	-0,0661	0,3694	14,17	78,65	r
197.	37,30	7,9875	1,807	1,807	-7,07E-04	-0,0589	0,3758	14,41	78,45	r
198.	37,48	7,9944	1,699	1,699	-6,65E-04	-0,0520	0,3866	14,83	78,11	r
199.	37,65	8,0000	1,596	1,596	-6,26E-04	-0,0464	0,3872	14,85	78,09	r
200.	37,84	8,0057	1,476	1,476	-5,80E-04	-0,0407	0,3795	14,56	78,33	r
201.	38,05	8,0126	1,353	1,353	-5,33E-04	-0,0338	0,3827	14,68	78,23	r
202.	38,23	8,0195	1,241	1,241	-4,91E-04	-0,0269	0,3912	15,00	77,97	r
203.	38,41	8,0256	1,131	1,131	-4,48E-04	-0,0208	0,3926	15,06	77,92	r
204.	38,60	8,0316	1,017	1,017	-4,05E-04	-0,0148	0,3917	15,02	77,95	r
205.	38,78	8,0376	0,910	0,910	-3,64E-04	-0,0088	0,3937	15,10	77,89	r
206.	38,95	8,0435	0,807	0,807	-3,25E-04	-0,0029	0,3972	15,23	77,78	r
207.	39,13	8,0491	0,695	0,695	-2,82E-04	0,0027	0,3930	15,07	77,91	r
208.	39,32	8,0537	0,584	0,584	-2,40E-04	0,0073	0,3800	14,57	78,32	r
209.	39,50	8,0580	0,471	0,471	-1,97E-04	0,0116	0,3621	13,89	78,87	r
210.	39,68	8,0626	0,363	0,363	-1,55E-04	0,0162	0,3503	13,44	79,24	r
211.	39,85	8,0679	0,261	0,261	-1,16E-04	0,0215	0,3483	13,36	79,30	r
212.	40,04	8,0763	0,148	0,148	-7,33E-05	0,0299	0,3713	14,24	78,59	r

__Temperaturangaben__ beziehen sich auf die Skala der ITS-90. __Standardabweichungen:__ Verschiedentlich werden Regressionsfunktionen mit Standardabweichungen bzw. Varianzen qualifiziert. Diese Angaben werden berechnet aus der Summe der Quadrate der Abweichungen der Einzelwerte zu jeweils berechneten Funktionswerten dividiert durch die Anzahl der Werte weniger 1. Sofern nicht anders bezeichnet, werden für ±(Standardmess-)Unsicherheiten einfache Standardabweichungen - ohne Erweiterungsfaktoren - angegeben, d.h. die Überdeckung betrifft 67% der Werte.

Programm

Data created during execution of the IMPro *"ContactAngle_atConstantLevel"*, type 4/4. Automatic self-repetition of the IMPro - the 11. Repetition. IMPro finished as projected.

(the digital twin of process IDN°18753 provides on demand reports with more details, audit-log protocol and structured raw data)

Prüfmittel

Das Wägesystem (WZA224) wurde 6,9 Stunden vor dieser Messung von *Labor* justiert.
IMETER ID23903733: Technische Daten: Auflösung des Wägesystems 0,1 mg, Messunsicherheit (Linearität) 0,2 mg, Dichte der Justiermasse ρ_{cal} 8,00 g/cm^3, Luftdichte ρ_{air} 1,116464 kg/m^3; Schwerebeschleunigung g 9,80769 m/s^2. Pt100-Temperaturmessung: Auflösung 0,001 K, Messunsicherheit ±0,01 K, R° 100.0056 Ω, Kalibrierintervall 30 min (BN°2, -25/152°C, 3S, FS15,8, Korrekturfunktion: -0 +0,998743·ϑ°C). Die Messauflösung der sekundären Temperaturmessung beträgt 0,01 K, die Unsicherheit 0,03 K. Akquisitions-Softwareversion IMETER 7.4.2, LizenzN° * 3037-4759*, W. 6.2- Betriebssystem auf PC Ser.N°6995684 (C, SSD).