

Report

Analysis of the measurement system SIG-500SP

The analysis was done in May 2010 by Dr. Joachim Bankmann.

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Experimental procedure:

Equipment:

- 3 Users (Dr. Stefan Wagner, Dr. Jörg Hoffman, Dr. Andreas Meschede, University Göttingen, Institut für Materialphysik)
- 12 samples (Glas, 150µm thick, size: 40mm x 12 mm)
- 1 SIG-500SP

Procedure:

- 1) User 1 put one of the samples into the device
- 2) The distance of the laser beams was measured
- 3) User 1 put the sample out of the system and back again
- 4) The distance was measured a second time, and, after repeating step3), a third time
- 5) This was done with all of the twelve samples
- 6) This (step 1 to 5) was done also by User 2 and 3
- 7) The samples were placed into sample holders and brought to a coating company
- 8) 4 days later the samples were coated, all have been coated under the exact same conditions
- 9) 1 day later the samples were measured again following the procedure from step 1) to 6)

The film has a thickness of $d_{\text{film}} = 375\text{nm}$

The parameters for calculating the stress are:

- $E_{\text{sub}} = 72,9 \text{ GPa}$ (modulus substrate)
- $\nu = 0,208$ (Poisson ratio substrate)
- $d_{\text{sub}} = 150\mu\text{m}$ (thickness substrate)
- $a = 20\text{mm}$ (distance laser beams at the sample)
- $L = 35\text{cm}$ (distance detector – sample)

The three Users were introduced into the system for the first time. They never used the system before. The data measured were directly the first one from them. They were not trained in the use of the system.

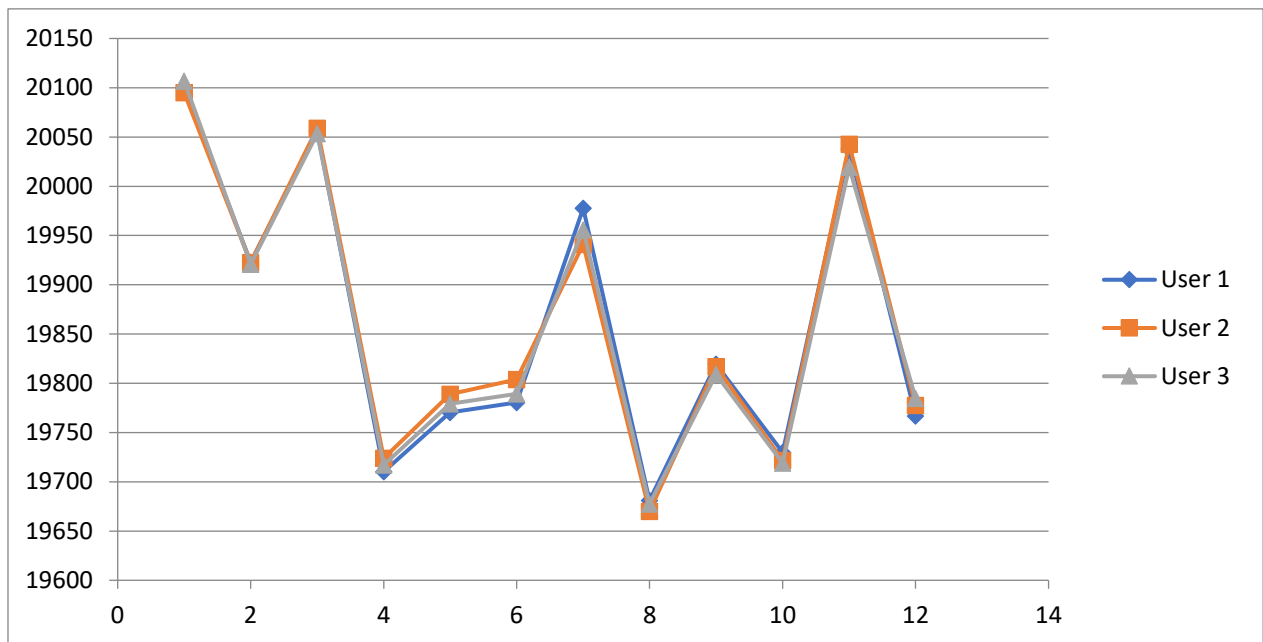
The following tables show the data before and after the coating.

		before coating			Meanvalue	Spread	Standard deviation
	Sample	A	B	C	MW	R	STABW()
<i>User 1</i>	1	20098,1	20094,6	20107,4	20100,0	12,8	6,6
	2	19919,0	19928,8	19920,8	19922,9	9,8	5,2
	3	20054,9	20057,1	20056,5	20056,2	2,2	1,1
	4	19694,5	19713,1	19723,6	19710,4	29,1	14,7
	5	19772,0	19771,9	19767,2	19770,4	4,8	2,7
	6	19778,3	19776,4	19786,9	19780,5	10,5	5,6
	7	19970,1	19979,2	19984,2	19977,8	14,1	7,1
	8	19666,9	19682,3	19693,7	19681,0	26,8	13,4
	9	19818,5	19819,5	19820,9	19819,6	2,4	1,2
	10	19722,8	19736,1	19730,6	19729,8	13,3	6,7
	11	20042,9	20033,6	20037,2	20037,9	9,3	4,7
	12	19766	19767	19767,1	19766,7	1,1	0,6
<i>User 2</i>	1	20095,5	20098,3	20091,5	20095,1	6,8	3,4
	2	19921,3	19924,4	19921,5	19922,4	3,1	1,7
	3	20063,1	20056,3	20057,8	20059,1	6,8	3,6
	4	19731,4	19724,1	19716,1	19723,9	15,3	7,7
	5	19788,4	19790,9	19787,9	19789,1	3,0	1,6
	6	19808,3	19801,4	19802,1	19803,9	6,9	3,8
	7	19932,9	19948,6	19941,6	19941,0	15,7	7,9
	8	19650,9	19677,7	19681,6	19670,1	30,7	16,7
	9	19815,9	19817,6	19817,6	19817,0	1,7	1,0
	10	19717,9	19723,9	19723	19721,6	6,0	3,2
	11	20039,2	20050	20038,6	20042,6	11,4	6,4
	12	19777	19777,3	19778,2	19777,5	1,2	0,6
<i>User 3</i>	1	20135	20092,9	20092,4	20106,8	42,6	24,5
	2	19916,5	19925,2	19920,5	19920,7	8,7	4,4
	3	20051,6	20059,1	20049,9	20053,5	9,2	4,9
	4	19734,2	19702,7	19714,2	19717,0	31,5	15,9
	5	19783,5	19777,6	19776,5	19779,2	7,0	3,8
	6	19786,8	19792,7	19788,2	19789,2	5,9	3,1
	7	19953,5	19954,1	19959,1	19955,6	5,6	3,1
	8	19684,4	19690,4	19657,5	19677,4	32,9	17,5
	9	19811,5	19815,8	19799,8	19809,0	16,0	8,3
	10	19723,2	19714,9	#na	19719,1	8,3	5,9
	11	20026,7	20029,7	20001,2	20019,2	28,5	15,7
	12	19778,8	19790,6	19784,3	19784,6	11,8	5,9

Red: worst measurement

		After coating			Meanvalue	Spread	Standard deviation
	Sample	A	B	C	MW	R	STABW()
<i>User 1</i>	1	24199,2	24199,4	24205,6	24201,4	6,4	3,6
	2	24089	24082,7	24090,1	24087,3	7,4	4,0
	3	24117,6	24122,4	24132,4	24124,1	14,8	7,6
	4	23819,3	23832,1	23813,3	23821,6	18,8	9,6
	5	23914,4	23916,3	23911,9	23914,2	4,4	2,2
	6	23930,8	23923,3	23935,5	23929,9	12,2	6,2
	7	24002,2	24003,3	24003,4	24003,0	1,2	0,7
	8	23829,5	23811,5	23830,8	23823,9	19,3	10,8
	9	24047,7	24051,5	24042	24047,1	9,5	4,8
	10	24008,1	23999,8	24000,1	24002,7	8,3	4,7
	11	24361,3	24360,1	24356,3	24359,2	5,0	2,6
	12	24036,1	24029,7	24033,1	24033,0	6,4	3,2
<i>User 2</i>	1	24216,2	24215,4	24217,6	24216,4	2,2	1,1
	2	24081,4	24080,3	24078,3	24080,0	3,1	1,6
	3	24126,7	24126,5	24125,2	24126,1	1,5	0,8
	4	23799	23820,2	23807,5	23808,9	21,2	10,7
	5	23907,9	23905,1	23907,6	23906,9	2,8	1,5
	6	23917,1	23914,8	23926,7	23919,5	11,9	6,3
	7	24001	23998,5	23998,4	23999,3	2,6	1,5
	8	23845,2	23837,3	23843,9	23842,1	7,9	4,2
	9	24044,2	24045,3	24044,1	24044,5	1,2	0,7
	10	23997,1	24000,9	24001,3	23999,8	4,2	2,3
	11	24362,7	24362,6	24363,3	24362,9	0,7	0,4
	12	24031,8	24038,7	24036,7	24035,7	6,9	3,6
<i>User 3</i>	1	24202,9	24205,8	24215,3	24208,0	12,4	6,5
	2	24089,2	24081,7	24097	24089,3	15,3	7,7
	3	24133,3	24146,5	24133,2	24137,7	13,3	7,7
	4	23814,8	23813,2	23821,6	23816,5	8,4	4,5
	5	23915,8	23916,6	23914,5	23915,6	2,1	1,1
	6	23917,4	23938	23929,5	23928,3	20,6	10,4
	7	24000,2	23999,9	24006,4	24002,2	6,5	3,7
	8	23840,9	23843,6	23837,6	23840,7	6,0	3,0
	9	24049,8	24054,4	24048,5	24050,9	5,9	3,1
	10	24010,7	24014,3	24009,2	24011,4	5,1	2,6
	11	24358,8	24361,5	24363	24361,1	4,2	2,1
	12	24031,5	24034,6	24036,5	24034,2	5,0	2,5

The plot of the values for all Users BEFORE the coating:



Standard deviations (= sigma) before:

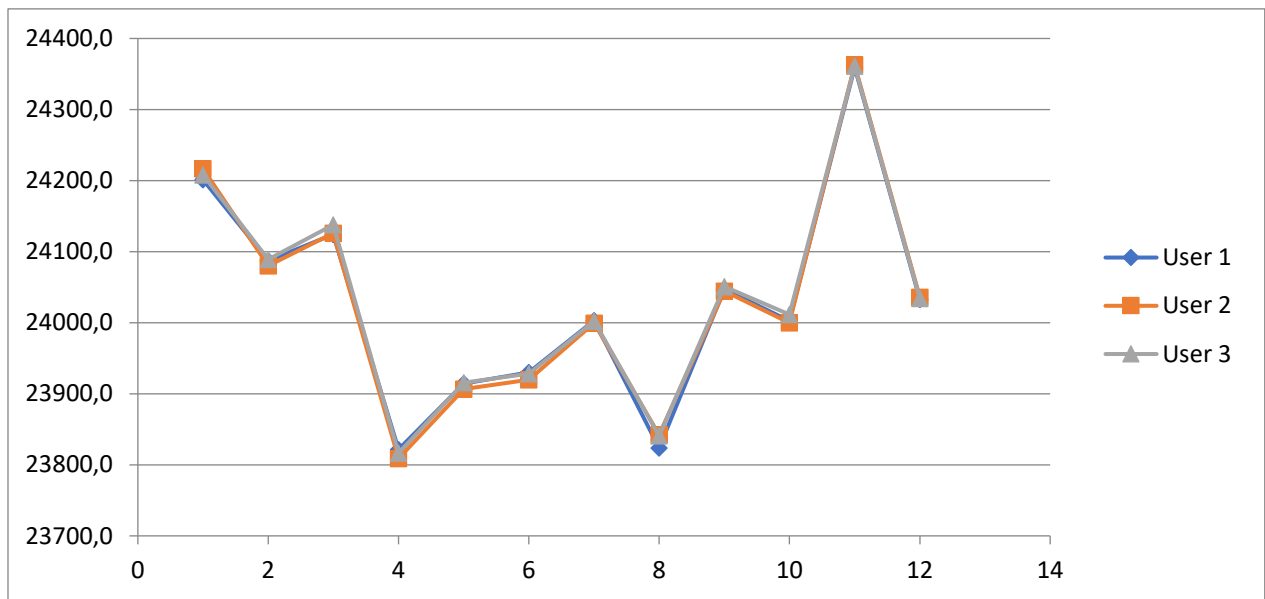
sigma 6 x sigma (== 99,7% accuracy)

User 1: 5,8µm 34,8µm
 User 2: 4,8µm 28,8µm
 User3: 9,4µm 56,4µm

Sample	Mean (of the Users)	sigma	6 * sigma
1	20100,6	13,7	82,5
2	19922,0	3,6	21,8
3	20056,2	3,9	23,4
4	19717,1	12,9	77,4
5	19779,5	8,5	50,8
6	19791,2	10,9	65,4
7	19958,1	17,0	<u>101,9</u>
8	19676,2	14,7	88,0
9	19815,2	6,4	38,2
10	19724,1	6,7	40,1
11	20033,2	13,9	83,1
12	19776,3	8,3	50,1

The worst set is high lightend

The same can be seen in the values after the coating:



Standard deviations (= sigma) after the coating:

	STABW()	6 x STABW() == 99,7% accuracy
User 1:	5,0µm	30,8µm
User 2:	2,9µm	17,4µm
User3:	4,6µm	27,4µm

sample	Mean (of the Users)	sigma	6 * sigma
1	24208,6	7,5	45,1
2	24085,5	6,1	36,6
3	24129,3	8,3	49,9
4	23815,7	9,3	56,0
5	23912,2	4,3	25,9
6	23925,9	8,3	50,0
7	24001,5	2,6	15,7
8	23835,6	10,6	63,7
9	24047,5	4,0	24,0
10	24004,6	6,0	36,1
11	24361,1	2,3	13,9
12	24034,3	3,0	17,7

The worst set is high lightend

The values are even better than in the uncoated case. This results from the better reflection behavior of the sample after the coating.

The following table shows the change (after value – before value) and the resulting stress of the samples:

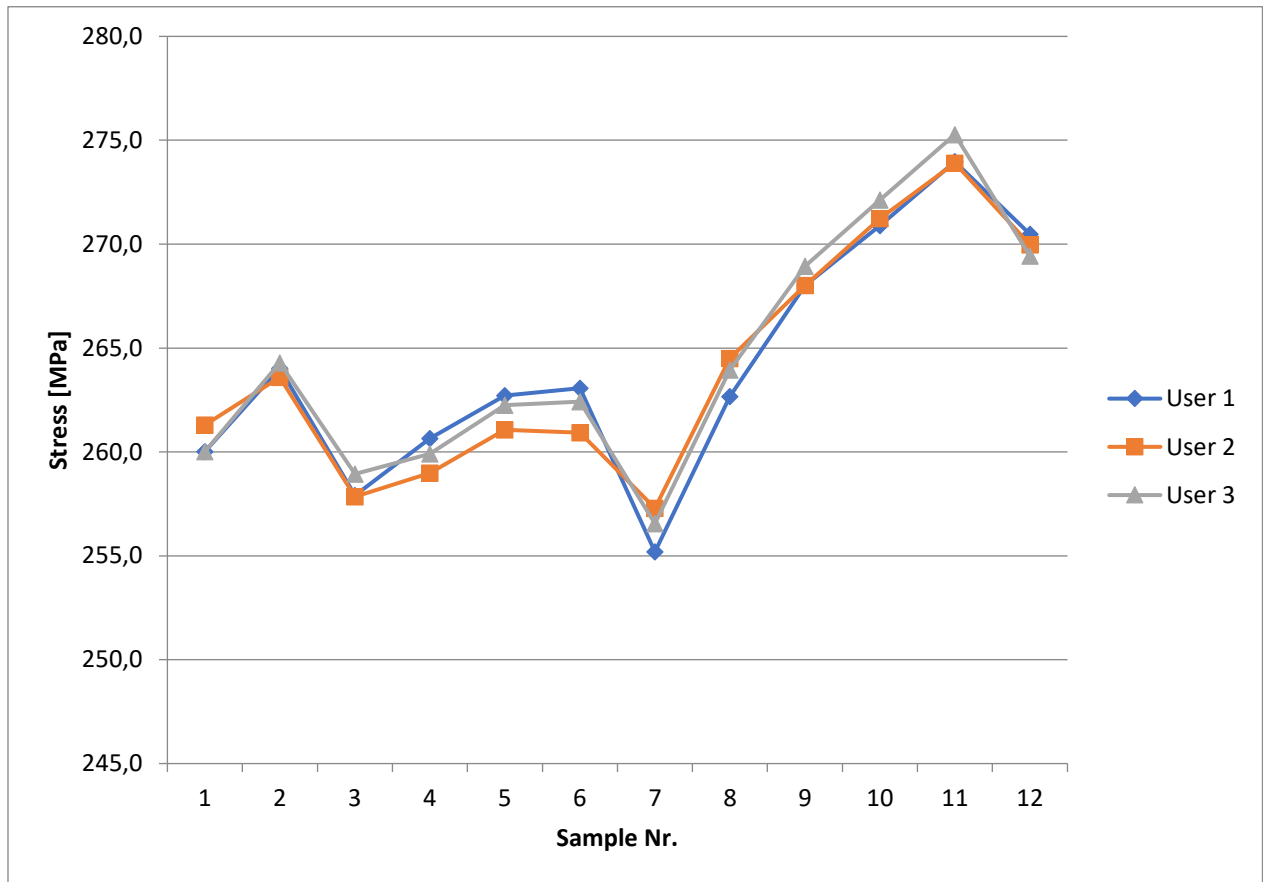
<i>sample</i>	Delta after - before [µm]			Stress [Mpa]		
	<i>User 1</i>	<i>User 2</i>	<i>User 3</i>	<i>User 1</i>	<i>User 2</i>	<i>User 3</i>
1	4101	4121	4101	260,0	261,3	260,0
2	4164	4158	4169	264,0	263,6	264,3
3	4068	4067	4084	257,9	257,8	258,9
4	4111	4085	4100	260,6	259,0	259,9
5	4144	4118	4136	262,7	261,1	262,2
6	4149	4116	4139	263,1	260,9	262,4
7	4025	4058	4047	255,2	257,3	256,6
8	4143	4172	4163	262,7	264,5	263,9
9	4227	4228	4242	268,0	268,0	268,9
10	4273	4278	4292	270,9	271,2	272,1
11	4321	4320	4342	274,0	273,9	275,3
12	4266	4258	4250	270,5	270,0	269,4

Calculating the accuracy:

Stress [MPa]	Sigma [MPa]	6 * Sigma [MPa]	6 * Sigma *100% / Stress
260,4	0,7	4,4	1,7%
264,0	0,4	2,1	0,8%
258,2	0,6	3,7	1,4%
259,8	0,8	5,0	1,9%
262,0	0,9	5,1	1,9%
262,1	1,1	6,6	2,5%
256,3	1,1	6,4	2,5%
263,7	0,9	5,7	2,2%
268,3	0,5	3,2	1,2%
271,4	0,6	3,8	1,4%
274,4	0,8	4,6	1,7%
270,0	0,5	3,2	1,2%

That means, that the stress value in the analyzed system can be determined with an accuracy better than + / - 3,3 MPa or 3 %

Plotting the resulting stress values:



There is a difference of 20 MPa visible comparing the samples 7 and 11 with each other. This difference obviously occurs due to the different thickness of the substrates. Using the Stoney-Calculator one can easily see, that the error of 20 MPa can be explained by a difference of 5 μ m in the thickness of the substrate. The glass is only specified to +/-5 μ m.

We could measure that sample 7 is slightly thicker than sample 11. Therefore it can be helpful to determine the substrate thickness as good as possible.

Our result:

The stress measurement system can determine the distance of the two laserbeams (in the case of glass substrates) with an accuracy better than +/-28 μ m (For a single user; the accuracy is still much better +/- 51 μ m if results between the users are compared).

In this study that leads to an resolution of +/-3 MPa in a 375nm thick film. This also means a resolution better than 3% in the case of 260MPa. The influence of the sample properties are obviously bigger than the error from the system, even if different users are measuring.