ICT INGENIEURBÜRO für CHEMIE und TECHNOLOGIE

(ICT ENGINEERING OFFICE FOR CHEMISTRY AND TECHNOLOGY)

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Von-Eichendorff-Str. 46A, 33106 Paderborn 15.02.2021

Test report no.: 202012105-15V3

Client:

MIG mbH Material Innovative Gesellschaft mbH

Am Grarock 3

33154 Salzkotten

on 15.12.2020

Commissioned task:

Determination of the emissivity of a new, innovative product generation MIG-ESP®.

Contractor: ICT, Paderborn

Sample name: Heat reflective coating

Nature of the task: Determination of the emissivity 1 to 23.3 µm

Description of the measurement: Measuring device FTIR Bruker Vertex 70

Wavelength range 5.5 to 23.3 µm, measurement of spectral reflectance at 283°K, **DIN EN 12898:2019-06**

Description of samples: 2 samples from the company MIG:

A) MIG-ESP® Interior, layer thickness 400µ, dimensions of the prepared sample 30x30 mm.

B) MIG-ESP® Exterior, layer thickness 400µ, dimensions of the prepared sample 30x30 mm.

MIG's products reflect a new state of the art. Existing test standards cannot do full justice to the breadth and depth of innovation that MIG's products represent.

MIG Sample A Interior is characterised by the following three properties:

1. Reflection of IR radiation
2. Comfort behaviour
3. Indoor climate

Regarding 1: The IR radiation reflection is measured according to the standard at wavelengths from 5.5 to 23.3 µm. This is part of the task and will be performed according to DIN EN 12898-2019. However, this alone is not sufficient for the new, innovative coating system.

Regarding 2: The comfort behaviour of humans or animals is determined by the fact that both species consist of at least 75 % water. This means that the animal organism is particularly sensitive to heat through its physical water content. Therefore, it is essential to also measure the range of wavelengths where water essentially absorbs thermal energy. This is the case in the wavelength range from 1.9 to 3.1 µm.

Regarding 3: In a room, atmosphere consists of different gases and moisture. This conglomerate absorbs thermal energy at completely different wavelengths. Therefore, a complete observation of the IR range from 1.1 - 23.3 µm is essential.

As a result, the mean value of the emissivity of 1 - 3 should be determined at the end of the investigation.

Particularity:

The emissivity of MIG-ESP® products cannot be determined with an integrating sphere, as provided for in some standards such as DIN EN 16012:2015-05!

The standard DIN-EN 12898: 2019-06 can be used to test the emissivity of MIG-ESP® and thus provide a comprehensive description of the particularly outstanding additional properties of the MIG coating technology.

Note: MIG-ESP® products do not have a transmittance.

MIG Sample B Exterior is a thermal coating applied to the façade. The emissivity is determined exclusively according to the current DIN standard.

Kirchhoff's law of radiation -grey emitters- and MIG-ESP®

The thermal radiation of real bodies can be described in many technical applications as grey radiators with a good approximation!

The following applies to the grey radiator:

$$\mathbf{0 < \epsilon < 1}$$

For all bodies it is true that - depending on temperature T and wavelength λ - the emissivity ϵ is equal to the absorptivity α:

$$\mathbf{\epsilon(\lambda,T) = \alpha(\lambda,T)}$$

where: ϵ = Emissivity, α = Absorptivity, λ = wavelength, T = temperature

This is Kirchhoff's law of radiation.

Determination of emissivity of MIG-ESP®:

Using an FTIR-Bruker Vertex 70, the reflectance of the sample at a given temperature (283°K) is determined. This is done by means of the IR spectrum with wavelengths of (standard: 5.5 to 23.3 µm), (comfort: 1.9 to 3.1 µm) and (indoor climate: 1.1 to 23.3 µm).

1 – reflection of heat energy = absorption of heat energy

According to standard **DIN EN 12898:2019-06** (regarding 1), the total reflectance Rn at a temperature of 283° K is determined from the curve of the spectral reflectance Rn(λi). λi is formed from the 24 wavelengths given in Table 1 (Annex).

$$\mathbf{R_n} = \frac{\mathbf{1}}{\mathbf{24}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{i=24}} \mathbf{R}\boldsymbol{n}\ (\boldsymbol{\lambda i})$$

The wavelengths in the middle of the wavelength intervals were selected for which the energy of the Planck radiation function for a black body is constant at 283° K.

Emissivity

The normal total emissivity ϵn at 283° K is given through:

$$\boldsymbol{\epsilon_n} = \mathbf{1} - \mathbf{R_n}$$

Result and evaluation:

Determination of emissivity for MIG-ESP® products as follows:

Spectrum and tables result in the following emissivities for the product **MIG-ESP® Interior** (Appendix 1,2,3,4):

Regarding 1: MIG-ESP® Interior (for 5.5 to 23.3 µm): a mean value of the emissivity according to DIN-EN 12898:2019-06: **0.285**

Regarding 2: MIG-ESP® Interior (for 1.9 to 3.1 µm): a mean value of the emissivity: **0.052**

Regarding 3: MIG-ESP® Interior (for 1.1 to 23.3 µm): a mean value of the emissivity: **0.092**

Average emissivity:

MIG-ESP® Interior: 0.143

Spectrum and table result in the following emissivity for the product **MIG-ESP® Exterior** (Appendix 5 and 6):

Regarding 1: MIG-ESP® Exterior (for 5.5 to 23.3 µm): a mean value of the emissivity according to DIN-EN 12898:2019-06: **0.315**

Average emissivity:

MIG-ESP® Exterior: 0.315

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Appendix

Serial no. i	Wavelength (λ) µm
1	5.5
2	6.7
3	7.4
4	8.1
5	8.6
6	9.2
7	9.7
8	10.2
9	10.7
10	11.3
11	11.8
12	12.4
13	12.9
14	13.5
15	14.2
16	14.8
17	15.6
18	16.3
19	17.2
20	18.1
21	19.2
22	20.3
23	21.7
24	23.3

Appendix 1: Standard measuring points according to wavelengths at 283 ° K

		MIG-ESP® Interior	
Serial no. i	**Wavelength (λ) µm**	**Reflection**	**Emission**
1	5.5	0.974	0.026
2	6.7	0.800	0.200
3	7.4	0.695	0.305
4	8.1	0.793	0.207
5	8.6	0.768	0.232
6	9.2	0.726	0.274
7	9.7	0.705	0.295
8	10.2	0.757	0.243
9	10.7	0.826	0.174
10	11.3	0.819	0.181
11	11.8	0.829	0.171
12	12.4	0.789	0.211
13	12.9	0.802	0.198
14	13.5	0.751	0.249
15	14.2	0.669	0.331
16	14.8	0.648	0.352
17	15.6	0.626	0.374
18	16.3	0.635	0.365
19	17.2	0.623	0.377
20	18.1	0.615	0.385
21	19.2	0.589	0.411
22	20.3	0.572	0.428
23	21.7	0.566	0.434
24	23.3	0.575	0.425
Mean value		**0.715**	**0.285**

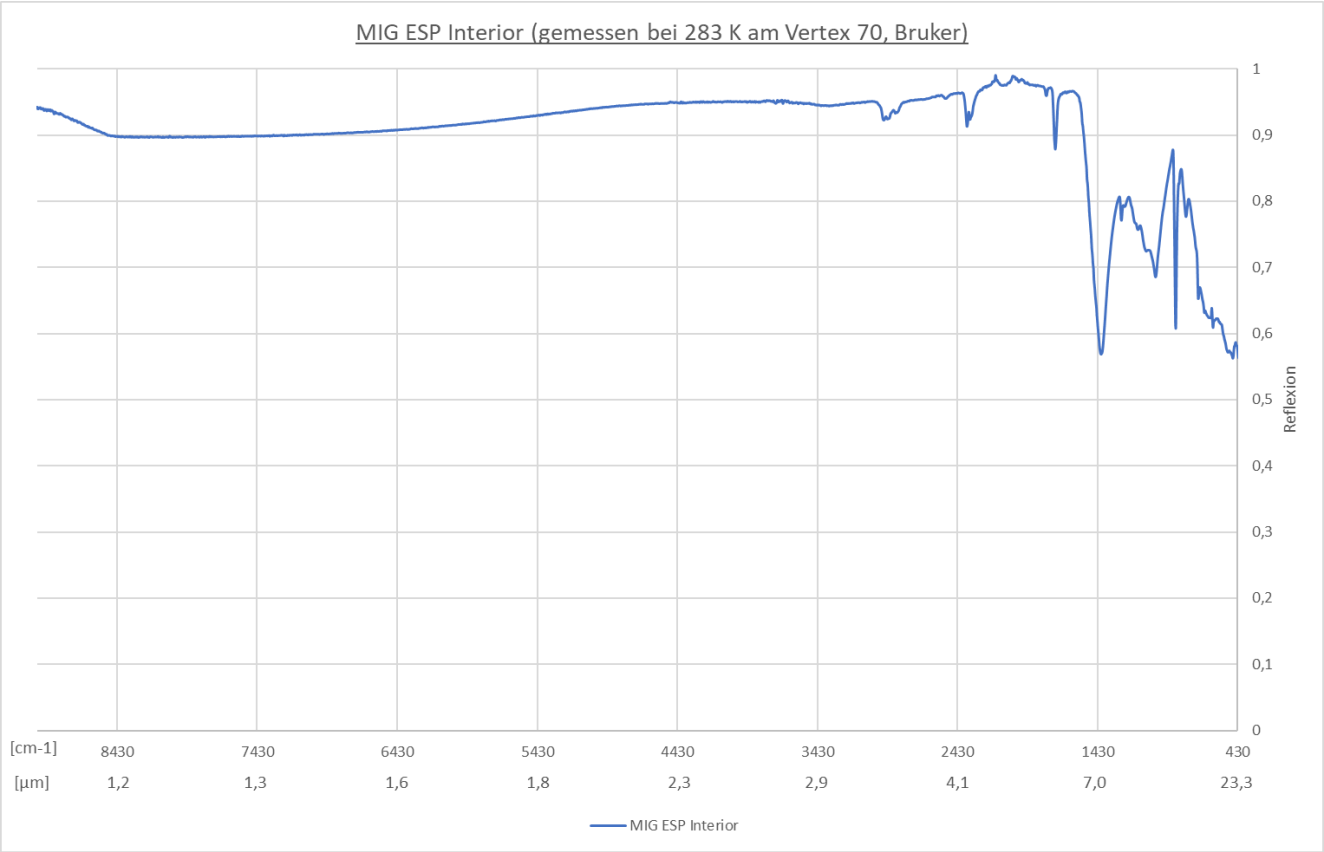
Appendix 2: *Reflection and emission values MIG-ESP® Interior 5.5 - 23.3 µm (values at 283°K)*

		MIG-ESP® Interior	
Serial no. i	**Wavelength (λ) µm**	**Reflection**	**Emission**
25	1.9	0.934	0.066
26	1.96	0.939	0.061
27	2	0.941	0.059
28	2.04	0.943	0.057
29	2.08	0.945	0.055
30	2.12	0.947	0.053
31	2.16	0.948	0.052
32	2.2	0.948	0.052
33	2.24	0.950	0.050
34	2.28	0.950	0.050
35	2.32	0.950	0.050
36	2.36	0.950	0.050
37	2.4	0.951	0.049
38	2.44	0.951	0.049
39	2.48	0.951	0.049
40	2.52	0.951	0.049
41	2.56	0.951	0.049
42	2.6	0.951	0.049
43	2.64	0.953	0.047
44	2.68	0.949	0.051
45	2.72	0.948	0.052
46	2.76	0.950	0.050
47	2.8	0.950	0.050
48	2.84	0.949	0.051
49	2.88	0.947	0.053
50	2.92	0.946	0.054
51	2.96	0.945	0.055
52	3	0.945	0.055
53	3.04	0.946	0.054
54	3.1	0.948	0.052
Mean value		**0.948**	**0.052**

Appendix 3: *Reflection and emission values MIG-ESP® Interior 1.9 - 3.1 µm (values at 283°K)*

		MIG-ESP® Interior	
Serial no. i	**Mean value Wavelength range (λ) µm**	**Reflection**	**Emission**
55	**23.3 – 1.1**	**0.908**	**0.092**

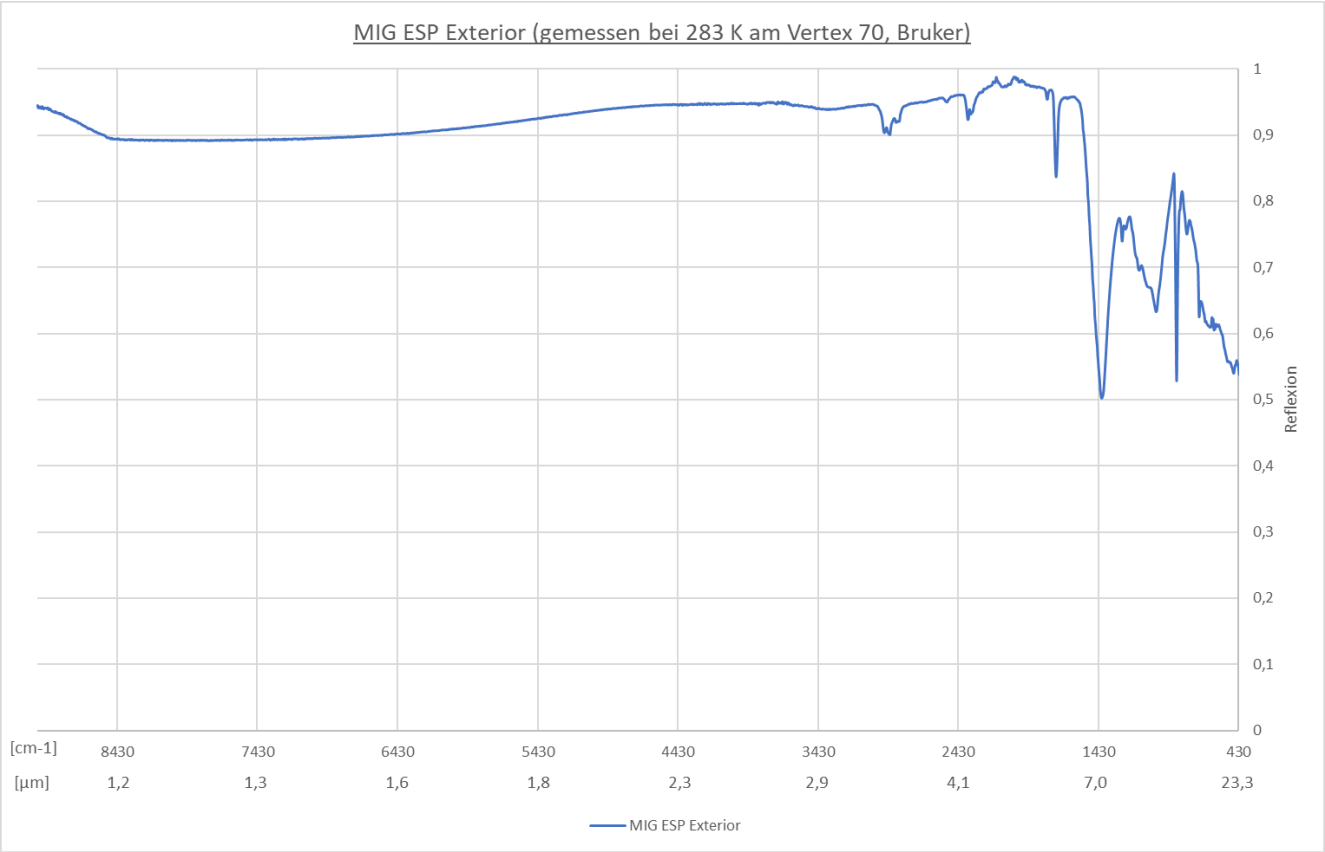
Appendix 4: *Reflection and emission values MIG-ESP® Interior 23.3 - 1.1 µm (values at 283°K)*



Appendix 5: *IR spectrum MIG-ESP® Interior (values at 283°K)*

		MIG-ESP® Exterior	
Serial no. i	**Wavelength (λ) µm**	**Reflection**	**Emission**
1	5.5	0.971	0.029
2	6.7	0.767	0.233
3	7.4	0.656	0.344
4	8.1	0.759	0.241
5	8.6	0.718	0.282
6	9.2	0.675	0.325
7	9.7	0.646	0.354
8	10.2	0.699	0.301
9	10.7	0.775	0.225
10	11.3	0.787	0.213
11	11.8	0.789	0.211
12	12.4	0.760	0.240
13	12.9	0.770	0.230
14	13.5	0.732	0.268
15	14.2	0.648	0.352
16	14.8	0.631	0.369
17	15.6	0.612	0.389
18	16.3	0.621	0.379
19	17.2	0.612	0.388
20	18.1	0.600	0.400
21	19.2	0.569	0.431
22	20.3	0.557	0.443
23	21.7	0.544	0.456
24	23.3	0.547	0.453
Mean value		**0.685**	**0.315**

Appendix 6: *Reflection and emission values MIG-ESP® Exterior 5.5 - 23.3 µm (values at 283°K)*



Appendix 7: *IR spectrum MIG-ESP® Exterior (values at 283°K)*