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M. ČEKON

SPECTRAL EMISSIVITY PROPERTIES OF REFLECTIVE COATINGS

Miroslav ČEKON
email: miroslav.cekon@stuba.sk
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Address:
Department of Building Construction,
Faculty of Civil Engineering,
Slovak University of Technology,
Radlinského 11,
813 68 Bratislava

ABSTRACT

This article deals with the spectral radiative properties of coatings consisting of hollow ceramic microspheres. They were selected from the commercial coatings available in the Slovak and Czech Republics. The aim was to measure and compare their spectral emissivity properties with standard facing coatings by means of infrared spectroscopy. The measured data demonstrates that the coatings have the same radiative properties as a standard building coating. Two reflective measurement methods (DRIFT and ATR) were used for this purpose. These results have been compared, and the DRIFT method was finally recommended for determining the spectral radiative properties of the materials measured.

KEY WORDS

- *Reflective coatings,*
- *Low emissivity surfaces,*
- *Spectral radiative properties,*
- *Infrared spectroscopy.*

1. INTRODUCTION

There have been many discussions that building coatings can markedly improve the thermal properties of building constructions. Radiative properties are neglected many times in building practice. Standard building surfaces have emissivity values of around 0.90, which means that they can absorb about 90% of the incoming longwave (thermal) radiation. The incident radiation on a surface is absorbed on the bigger parts and reflected on the smaller parts. Therefore, we can influence heat transfers to the outside environment and improve thermal comfort as well by decreasing the emissivity values of building surfaces [10, 11, 12]. As a part of introducing new technologies and materials, spectral emissivity properties are among many other factors, which have to be taken into account. Although there are a lot of expectations and many doubts, they have still not been equally investigated in many cases. At the present time, more precise evaluation and measurement methods [2, 13], which are not commonly used in the area of building physics, have come to the attention of the building industry.

The starting point of our research comes from the fact that there are coatings on the market whose properties guaranteed by their producers can reduce costs for energy demands in buildings. In practice, their properties extensively depend on various dynamic changes. The basic principles were derived at the peak of the space age, when similar coatings were developed for space shuttle shields. However, the different dynamic effects and conditions for such shields are not compatible with building envelopes. In general, coatings mainly create thin surface layers. Their character does not have much of an influence on the thermal resistance of building constructions. However, they can markedly influence transfer effects on building surfaces and can therefore be relevant to the thermal performance of buildings.

In the advertising materials from many producers we can find, among other things, that coatings consisting of hollow ceramic microspheres can reduce heat losses in winter and heat gains in the summer, improve thermal comfort, decrease the possibility of the condensation of water vapor, increase surface temperatures, etc. These statements are often based on proofless and unverifiable

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assertions. They stem from the feelings and hypotheses of people who have used these products for improving their internal building environments. Moreover, some materials call for the total replacement of standard insulation materials. These uncertainties mainly occur due to inadequate research on their properties, which are under the influence of various dynamic changes.

Research on coatings is carried out at various institutions. The Institute of Technology of Building Materials and Components at the Faculty of Civil Engineering in Brno, the Czech Republic, is one where much research work about low emissivity coatings has been conducted [4]. The research has focused on direct and indirect methods, especially with infrared thermography as well as spectroscopy. Some of the applications supported by Fourier that transform infrared (FTIR) spectrometers and the Diffuse Reflectance Infrared Fourier Transform (DRIFT) method are referenced in [4, 5, 6]. The results of this research bring us some new knowledge but also some disadvantages of the measurement techniques. A research project [14] at the Department of Building Structures (FCE SUT) in Bratislava is also aiming at investigating the thermodynamic properties and effects of the energy balance of low emissivity building surfaces. For this purpose, our first step leads us to determine the spectral radiative properties of some building coatings by means of infrared spectroscopy.

2. THE LABORATORY MEASUREMENT TECHNIQUES AND EXPERIMENTAL METHODS OF SPECTRAL EMISSIVITY

As is well known, the main optical properties of opaque building surfaces are absorbance, emissivity and reflectance. We cannot measure emissivity directly, because the measurement devices usually obtain these values from several parameters. Various measurement techniques have been developed, which may be divided into three loosely defined groups: calorimetric emission measurements, radiometric emission measurements and reflection measurements [1]. Moreover, we can divide reflection measurements into two subgroups. The more easily obtainable ones are based on the monitoring of the intensity of the radiation reflected from a surface. The simplest measurement is based on the integral measurement of the reflected diffusive radiation from the surface implemented by the FTIR spectroscopy also known as DRIFTS spectroscopy. For more technical information and descriptions, see [2]. The second technique is based on the Attenuated Total Reflection (ATR) method [8]. Diffuse reflectance measurements are carried out to determine the bidirectional reflection function and the directional-hemispherical and the hemispherical-directional reflectance [1]. From these values we can derive other required parameters, such as emissivity or absorbance, which result from the law of the conservation of energy and Kirchhoff's laws, where we suppose that:

$$\varepsilon = \alpha = 1 - \rho \text{, or more precisely } \varepsilon_\lambda = \alpha_\lambda = 1 - \rho_\lambda \text{, [-]} \quad (1)$$

Two similar methods are usually used for the most common reflection DRIFT techniques. The main difference between those two methods is in the type of reflectometers. The first one employs integrating sphere reflectometers, while the second one employs integrating mirror reflectometers. A detailed description can also be found in [1].

3. EXPERIMENTAL IR SPECTROSCOPY MEASUREMENTS OF THE COATINGS STUDIED

There are several kinds of coatings on the market, which consist of hollow ceramic microspheres. In the building practice, a coating composition which consists of a filler (TiO2, CaCO3 approximately 32.3% of the total amount), a filler of hollow ceramic microspheres from 5 to 60 micrometers (approximately 8.3% of the total amount), a binding material (PVAc variance), other helpful ingredients (approximately 12.6% of the total amount) and water (approximately 46.9% of total amount) [3] is considered. To make a comparison between them and the standard facing coating, almost all of the coatings available in the Slovak and Czech Republics for this purpose were selected. The aim was to compare their spectral emissivity properties with standard facing coatings by means of the two reflective measurement methods (DRIFT [2] and ATR [8]). This comparison is also linked to a previous, partly referenced, work [9].

3.1 Brief Description of the Method and Measuring Instruments

The basic principle of the experimental verification is focused on a spectral analysis with the application of infrared spectroscopy in a region of longwave radiation. In order to compare the reflective methods available, three measurement methods were used, depending on the measurement device applied:

- DRIFT method – the Nicolet Magna 750 infrared spectroscopy measurement device (Figure 1 on the left) was used. This measurement device handles a wide spectral range from the mid wavelength infrared domain (MWIR) to the far infrared one (FIR), or in practice (for our purpose), the wavelengths from roughly 2.0 to 50.0 μm. For more technical details, see [7]. Although the device belongs among older instruments, it still provides a precise method. Because the main experimental principle consists of

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the DRIFT method [2], we need to use a special measuring attachment for such a purpose. The shape of the measuring attachment and the type of detector applied are some of the most important parts of this experimental method. This experiment was conducted on an available measuring instrument consisting of an integrating mirror with a hemispherical shape (Fig. 1 on the right). The measurements were carried out at the Institute of Chemistry at the Slovak Academy of Sciences in Bratislava.

- ATR I. method – the Nicolet 5700 FT-IR infrared spectroscopy measurement device with a Nicolet Smart Orbit attachment (Fig. 2 on the left) was used. The measurements were carried out at the Laboratory of Spectral Methods (Department of Inorganic

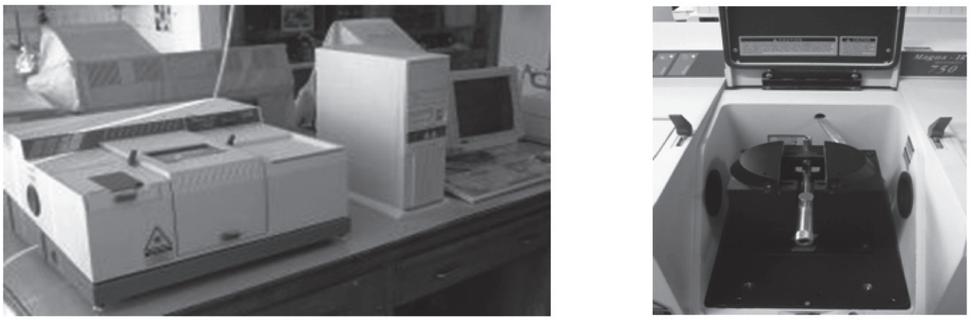

Fig. 1 *The Nicolet Magna 750 infrared spectroscopy measurement device (on the left) and a view of the integrating mirror used with a hemispherical shape (on the right).*

Fig. 2 *The Nicolet 5700 FT-IR infrared spectroscopy measurement device (on the left) and a view of the measurement attachment (on the right).*

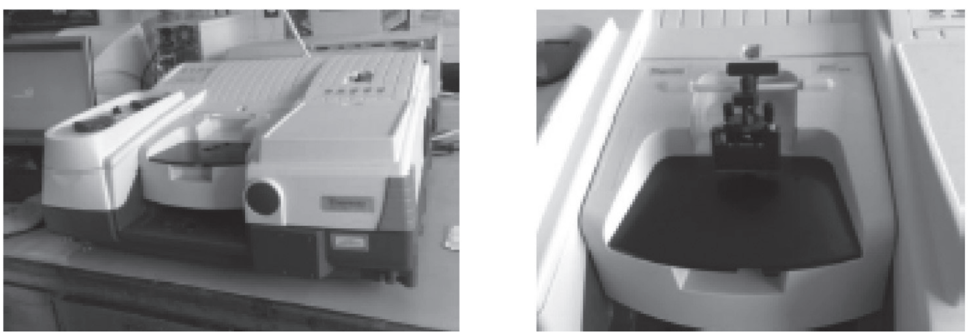

Fig. 3 *The Nicolet 6700 FT-IR infrared spectroscopy measurement device (on the left) and a view of the measurement attachment (on the right).*

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Tab. 1 *Description of samples measured.*

Sample	Sample description	Application	Colour
S1	Disperse acrylate facing coating, reference	Internal and external	White
S2	Facing coating of hollow ceramic microsphere base	External	White
S3	Flexible coating consisting of hollow borosilicate microspheres	Internal and external	White
S4	Coating of hollow ceramic microsphere base	Internal and external	White
S5	Coating consisted of hollow ceramic and silicone microspheres	Internal and external	White
S6	Thermography etalon - thermaspot	Lab. known emissivity 0.95	White
S7	Aluminum foil, both sides tested, S7_a – mat, S7_b - glossy	Reflective material	Silver grey
S8	Aluminum pigmented coating	Internal	Silver grey
S9	Coating based on aerogels	Automobile industry	White

Chemistry, Technology and Materials, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava).

- ATR II. method – the Nicolet 6700 FT-IR infrared spectroscopy measurement device with a Nicolet Smart SpecularATR attachment (Fig. 3 on the left) was used. It provides a spectral optical analysis of the reflective materials of a mirror. The measurements were carried out at the Institute of Chemistry at the Slovak Academy of Sciences in Bratislava.

3.2 Description of the Samples Prepared

The measurement devices which were used require specimens of a size of roughly 10 × 10 mm. Therefore, we prepared several samples from four white commercial coatings with various coating techniques and some other materials for the comparison. All of these samples were prepared with a coating on a drawing (A3 format) and were then cut to the required size. The descriptions and characteristics are briefly given in Tab. 1.

3.3 Results of the Experiment and Discussion

The results evaluated were obtained by the DRIFT and ATR measurement methods. The measurements were performed on an adequate amount of samples (about five samples from each type). Each type of sample was measured several times. The precision of each method and instrument was verified using an adequate amount of measurements. The same results were obtained for each type of coating, so only the one selected was presented.

The results seen in Figs. 4 and 5 were measured by means of the DRIFT method. The spectral reflectance curves of the samples measured as a function of the wavelength are shown (in a spectral range from 2.5 to 25.0 μm – the range of the long-wavelength radiation).

Equation (1) can be used for determining the measurement results in terms of the emissivity values. The measured data are represented in (Tab. 2) as integral emissivity values. The most important region is somewhere between 8.0 and 14.0 μm, where all the standard bodies radiate the maximum of their energy (roughly on the 10.0 μm).

As can be seen, there are no differences between the S1 standard building surfaces (reference standard facing coating) and those which consist of hollow ceramic microspheres (S2-5). The standard reference coating has even higher reflectance values than the others compared. Sample S5 had the worst results and the biggest difference from the others. The rest of the samples were roughly at the same level. The aluminum foil (S7) was measured on both sides. The difference between them is in the 20% reduction of their reflective properties as is shown in Fig. 4. Also evident is a thin visible foil (S7_a), which markedly filters the spectral properties of the side measured. Sample S8 with its metallic particles can be considered based on its results as a coating with low emissivity properties (spectral reflectance of more than 70%). The spectral properties of sample S9 are more than 10% higher in some regions than those consisting of hollow ceramic microspheres. This effect causes a higher gloss and smoother surface of the coated sample than the others. It is also important to measure and compare the same degree of roughness of all the measured surfaces using this method.

The results from the ATR measurement method (Fig. 6) indicate significant differences in the infrared spectrums in comparison with the DRIFT measurement method. However, there are considerable differences in some areas; the results indicate non-standard and unreal values. These results only have an exploratory nature; they

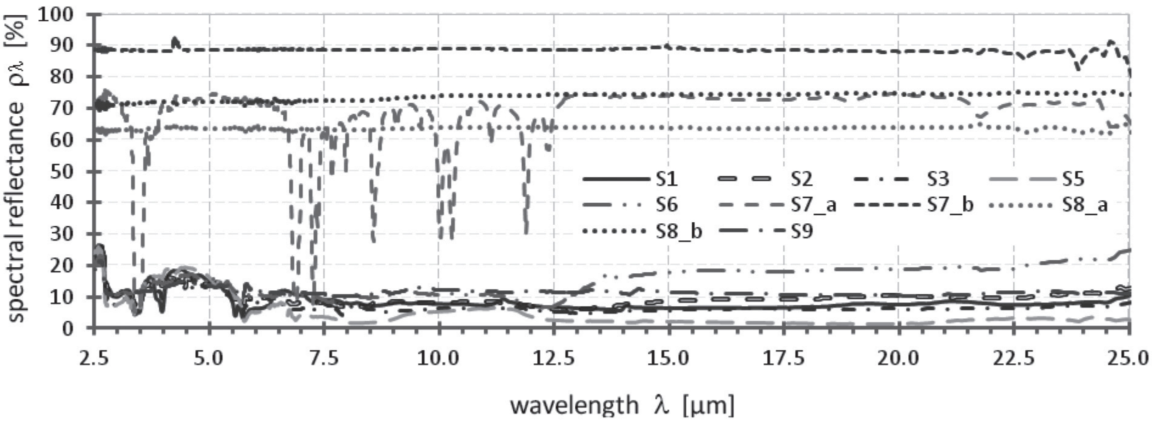

Fig. 4 *Progress of spectral reflectance of coatings measured (the DRIFT method).*

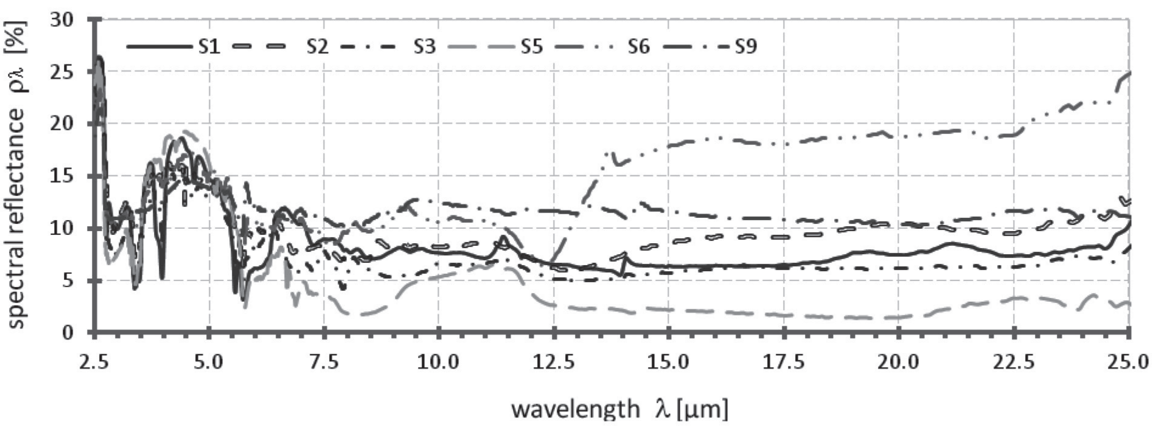

Fig. 5 *Progress of spectral reflectance of coatings selected from Fig. 4 (the DRIFT method).*

do not represent the optical properties of the coatings measured, but affect their internal structure and material composition.

The results on Fig. 7 were measured by means of the ATR II. method, by which an almost perfect match can be obtained with the aluminum foil sample (S7) in comparison with the DRIFT method. Some samples were partly recorded only with their glossy surface. Other samples were not recorded because of their increasing ability to reflect the diffuse radiation on their surface. This method is not appropriate for diffuse reflectance surfaces, because it employs mirror reflectance techniques from the surface measured.

These methods also result in some defects and disadvantages, which accrue from using the technique and measurement method. Measuring a mirror´s reflected surfaces is more precise than measuring matt, rough and diffuse reflected surfaces. More detailed information can be found in [4].

Tab. 2 *Final spectral emissivity as integral values in the selected infrared spectrums (DRIFT method).*

sample: emissivity ε_λ	S1	S2	S3	S5	S6	S7_a	S7_b	S8	S9
2.5 – 25.0 μm	0.87	0.88	0.90	0.90	0.87	0.35	0.12	0.32	0.87
8.0 – 15.0 μm	0.93	0.92	0.94	0.96	0.90	0.35	0.11	0.31	0.88

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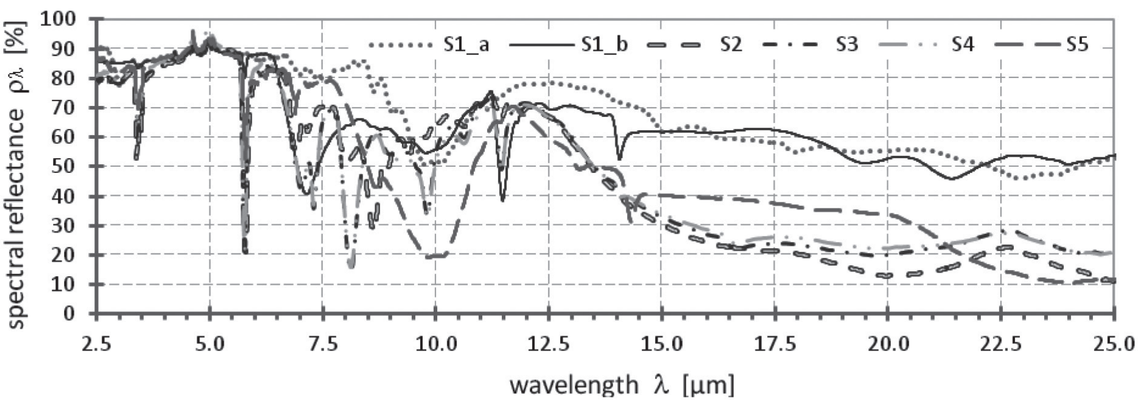

Fig. 6 *Progress of spectral reflectance of the coatings selected (the ATR I. method).*

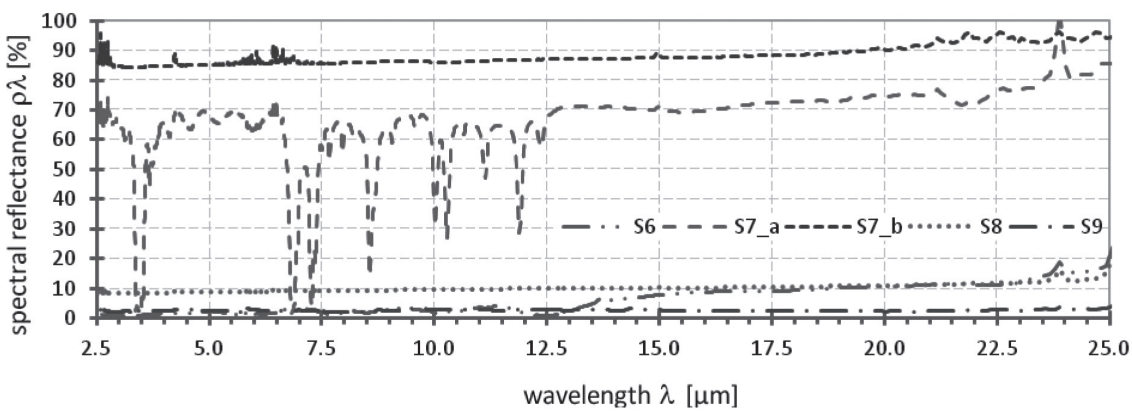

Fig. 7 *Progress of spectral reflectance of the coatings selected (the ATR II. method).*

4. CONCLUSION

The infrared spectroscopy method applied is useful and available for determining spectral radiative properties. The application of this method is not commonly implemented in the building physics area. The results obtained from the infrared spectroscopy (the DRIFT method) indicate that there are no differences in the spectral reflectance (emissivity) values between standard building surfaces (reference standard facing coating) and those consisting of hollow ceramic microspheres.

The DRIFT method provides a wide range of possibilities of spectral measurements for all the tested samples, whether diffuse or mirror reflective, so these results can be considered as a starting point for future work. Furthermore, the results indicate that the final values are more credible (Tab. 2) than the other methods used.

On the other hand, the ATR methods are not appropriate for the spectral analysis of diffuse reflective materials, because they employ mirror reflectance techniques from the surface measured. While the results from the ATR I. method only have an exploratory nature, which do not represent the optical properties of the samples measured, but influence their internal structure and material composition, the results from the ATR II. method are only appropriate for ideal mirror reflective surfaces and materials.

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REFERENCES

[1] Modest, M. F. *Radiative heat transfer*. New York: McGraw-Hill, Inc. 1993, vol. 832 pp.128-145. ISBN 0-07-042675-9.

[2] Madejová, J. *Laboratory Methods of Research Acrimonious Minerals: Infrared spectroscopy (Laboratórne metódy výskumu nerudných surovín: Infračervená spektrometria)*. Scientific and technology transfer in the area of natural nanomaterial research and development (Vedomostný a technologický transfer v oblasti výskumu a vývoja prírodných nanomateriálov) [online], vol. 31, 2005, pp. 10-11 [quoted 2009-02-07]. http://www.pvoc.sk/nano/skripta/6_IC_spektroskopia_skripta_madejova.pdf

[3] Vávra, R. Radiative Properties of Surface Layers of Building Structures (Sálavé vlastnosti povrchových vrstev stavebních konstrukcí), *Thermal performance of Buildings (Tepelná ochrana budov)* 3/2005, pp. 8-12 (in Slovak).

[4] Steuer, R. *Analysis of Physical Properties of Materials of External Insulation of Buildings in Relation to the Decrease of Moisture Load* (Studium fyzikálních vlastností materiálů vnějšího zateplení budov z hlediska snížení vlhkostní zátěže): dissertation thesis. Brno, 2008. 134 pp. (in Czech).

[5] Kalousek, M. *Examination of Thermal Properties of Coating Supertherm (Posouzení teplně technických vlastností nátěru Supertherm)*. Brno: FAST in Brno, 2007. vol. 10 (in Czech). http://www.reflexe.nazory.cz/download/Posouzen%ED_SUPERTHERM_z%E1klad.pdf

[6] Šťasník, S., Kalousek, M., Steuer, R. Examination of Thermoshield Coating Composition in Terms of Energy Balance Influence of Buildings (Posouzení nátěrové hmoty Thermoshield zhlediska projevu na tepelnou bilanci budov). In *Expertise (Znalecký posudek)* 12/2008. Brno, FAST VUT v Brne. 2008. vol. 60 (in Czech).

[7] Uachsav [online]. Institute of Inorganic Chemistry, Slovak Academy of Sciences, 2008, [quoted 2009-02-11]. http://www.uach.sav.sk/web/index.php?option=com_content&task=view&id=16&Itemid=50

[8] Harrick, N. J. *Internal Reflection Spectroscopy*. John Wiley & Sons Inc. 1967, 270 pp. ISBN 978-0470352502, quoted in MIRABELLA, F. M. Jr. – HARRICK, N. J.Internal Reflection Spectroscopy: Review and Supplement. Ossining: Harrick Scientific, 1985. 195 pp.

[9] Čekon, M. The Experimental Verification of the Spectral Properties of Low-Emissivity Coatings of Building Surfaces, Proceeding of international conference Mladý vedec 2009, 1st International conference of Civil Engineering and Architecture of PhD students. Podbanské, SR, 15.-16.4.2009, ISBN 978-80-553-0176-1.

[10] Šikula, O., Kalousek, M. Theoretical Assessment of the Impact Low-Emission Plaster on the Microclimate of Buildings, CESB 10: Central Europe towards sustainable building - from theory to practice, Prague 2010, Grada Publishing for Building Structures and CIDEAS Research Centre, Faculty of Civil Engineering, Czech Technical University in Prague, pp. 521-524. ISBN 978-80-247-3624-2.

[11] Synnefa, A., Santamouris, M., Livada, I. A Study of the Thermal Performance of Reflective Coatings for the Urban Environment. In *Solar Energy*, 2005, vol. 80(8), pp. 968–981. [quoted 2011-05-21]. http://dx.doi.org/10.1016/j.solener.2005.08.005

[12] Kersken, M., Schade, A. Experimental and Numerical Investigations to Compare the Thermal Performance of IR Reflecting Insulation and Mineral Wool, In *9th Nordic Symposium on Building Physics - NSB 2011*, Tampere, Finland, 29.5.-2.6.2011, vol. 1, 2011, pp. 215-222.

[13] Koirala, L. R. FTIR – *Spectroscopic Measurement of Directional Spectral Emissivities of Microstructured Surfaces: dissertation thesis*. University of the Federal Armed Forces, Hamburg, Germany, Hamburg, 2004. 245 pp.

[14] Čekon, M. *Thermodynamic Properties of Low-Emissivity Coatings of Building Surfaces* (Termodynamické vlastnosti nízkoemisných náterov stavebných povrchov): dissertation thesis. Bratislava, 2011. 127 pp. (in Slovak).