

## **Analysis of cosmetic products using different IR spectroscopy techniques**

Sylvia Pasieczna-Patkowska<sup>a</sup> and Tomasz Olejnik

*Department of Chemical Technology, Faculty of Chemistry,  
Maria Curie-Skłodowska University,  
pl. M. Curie-Skłodowskiej 3, 20-031 Lublin, Poland*

*<sup>a</sup>sylvia.pasieczna@poczta.umcs.lublin.pl*

This article describes the application of IR spectroscopic methods in the study of the composition of finished cosmetic products. Four spectroscopic techniques: TS (transmission spectroscopy), PAS (photoacoustic spectroscopy), ATR (attenuated total reflectance) and DRS (diffuse reflectance spectroscopy) were used for this purpose. Tested cosmetic products were of different consistency and application. The choice of spectroscopic techniques was dictated by the physical state and consistency of the sample.

### 1. INTRODUCTION

The cosmetic is any substance intended for external contact with the human body (skin, lips, nails, hair, teeth and mucous membranes of the mouth and external genital organs), whose aim is to keep it clean, to protect, nurture, beautify or perfume [1]. A cosmetic product put on the market can not endanger human health. In the cosmetics Act [1] there was defined the list of prohibited substances (420 substances), substances allowed in limited quantities (67 substances) and substances allowed for use in cosmetics. Among the substances permitted for the use in cosmetic formulations are dyes, preservative agents or UV protection substances. The Act also determines what information should appear on the

packaging of cosmetics (trade name, manufacturer's data, ingredients, durability term, special warnings when applying, data allowing to determine the series of cosmetics). The list of cosmetic ingredients, appearing on the packaging, is written by contractual systems. INCI (*International Nomenclature of Cosmetic Ingredients*) is a naming system designed to standardize the nomenclature of ingredients.

In order to ensure the safety of their use, cosmetics are subjected to numerous tests. Research on cosmetics are divided into two groups – obligatory and additional. Clinical tests, sensory and instrumental tests belong to additional tests. Among the obligatory tests there are application tests, dermatological tests, recipe's stability tests or the safety assessment of cosmetic products. Cosmetic product safety assessment is intended to primarily assess its composition in terms of quantity and quality [2].

In the legislation and other legal documents there have been developed a number of procedures for quantitative and qualitative analysis of finished cosmetic products and raw materials for cosmetics production. The example of such procedure may be the identification and determination of benzyl alcohol, silver nitrate or selenium disulphide in anti-dandruff shampoos. These procedures are very laborious, and their repeatability is often low, due to mistakes made during the measurements. When analyzing cosmetics and their raw materials different methods are used: chromatographic (liquid, gas and thin layer chromatography), calorimetric, acid-base titration, UV-VIS spectrophotometric, refractometric methods or mass spectrometry. These methods are associated with a specific, often laborious, sample preparation and usage of numerous measuring equipment. The analysis of the cosmetic products is difficult due to their complex composition and, as it was mentioned above, often involves variety of methods, what can increase the possibility of making mistakes and increases the time of analysis.

The solution to this problem may be the application of IR spectroscopic techniques. This is due to the fact that minimal cosmetic sample preparation is required, so that its composition is not significantly changed. The time of analysis is short and the results of such analysis are highly reproducible. Another advantage of IR spectroscopy is the ability to simultaneously obtain information about several of its components. During the analysis of cosmetic with infrared spectroscopy techniques *fingerprint* method is used, so that IR spectroscopy can be used as an analytical sifting technique. Fingerprint region ( $1300\text{-}700\text{ cm}^{-1}$ ) has the characteristic arrangement of the molecules bands. This range is used to

identify tested substance by comparing its spectrum with the spectrum of a model substance. The identity of both spectra in the fingerprint region is a confirmation of the identity of the tested compound with the standard one. Infrared spectroscopy methods allow not only for determination of the composition of the cosmetic product in quantitative or qualitative terms, but can also be used in assessing the effectiveness of their components [3].

Minimal sample preparation when performing measurements using IR spectroscopy techniques is very important because many times during the preparation of the sample, the composition of cosmetic products may be irreversible modified, and then the results are not reliable. However, IR spectroscopy techniques are more appropriate to determine qualitative cosmetics composition than the quantitative one. For example, the ATR technique is restricted to examine a layer of cosmetic sample what, in the case of inhomogeneity of the cosmetic formulation, does not reflect its actual quantitative composition. IR spectroscopy is a very good technique for the analysis of mineral pigments used in cosmetic products [4].

A non-destructive infrared spectroscopy has been used in the analysis of archaeological finds, including cosmetics used in prehistoric times. Using IR spectroscopy it is possible to determine the composition of cosmetics from before hundreds of years. However, it is very difficult or even impossible to determine the presence of trace amounts of the sample's components and then the application of the additional methods is advisable (chromatography, Raman spectroscopy). Usually the combination of two methods (e.g. FT-IR and Raman spectroscopy) gives more complete and more explicit knowledge about the composition of the sample [5]. Infrared spectroscopy was used to determine the presence of surfactants [6,7], emulsifiers [8] and alcohols [6].

## 2. MATERIALS AND METHODS

The aim of this study was to analyze the finished cosmetic products using various IR spectroscopic techniques: TS (*Transmission Spectroscopy*), PAS (*Photoacoustic Spectroscopy*), ATR (*Attenuated Total Reflectance*) and DRS (*Diffuse Reflectance Spectroscopy*) and then evaluation the usefulness of those techniques in the analysis of selected cosmetics. Tested cosmetic products were of different consistency and application. The choice of spectroscopic technique was dictated by the physical state and consistency of the sample. Eye shadow, red lipstick,

black eye pencil and depigmentant cream were analyzed. In the last case (depigmentant cream) photoacoustic spectroscopy could not be used because of the fact that humidity in such liquid formulation could damage the sensitive microphone in the photoacoustic cell.

TS spectra were recorded by means of Bio-Rad Excalibur FT-IR spectrometer over the  $4000\text{-}600\text{ cm}^{-1}$  range at room temperature, resolution  $4\text{ cm}^{-1}$  and maximum source aperture. Preparation of materials for spectroscopic measurement was based on (1) application of a small amount of the greasy sample (red lipstick, black eye pencil, depigmentant cream) on the compressed KBr pellet or, in the case of powdery materials (eye shadow), (2) the sample ( $\sim 5\text{ mg}$ ) was mixed and ground in an agate mortar with  $400\text{ mg}$  of spectroscopically pure dry potassium bromide to a fine powder and then it was pressed to form a disk less than  $1\text{ mm}$  thick. Data were collected in the transmission mode at room temperature under air. Interferograms of 64 scans were average for each spectrum.

FT-IR/ATR spectra were recorded at room temperature using a Nicolet 6700 spectrometer equipped with ATR detector with the diamond crystal. A sample of the tested material was mechanically pressed onto the diamond crystal. Interferograms of 64 scans were average for each spectrum.

FT-IR/DRS spectra were obtained by placing the sample mixed with a small amount of KBr in a metal container. Spectra were recorded using Nicolet 6700 spectrometer equipped with a DRS detector at room temperature, in the  $4000\text{-}600\text{ cm}^{-1}$  range. Interferograms of 256 scans were average for each spectrum. Normalization of the spectra was made by comparing the obtained spectra to the background spectrum (KBr).

FT-IR/PAS studies were performed by means of Bio-Rad spectrometer and helium purged MTEC300 photoacoustic detector, over the  $4000\text{-}600\text{ cm}^{-1}$ . Spectra were measured at room temperature at  $4\text{ cm}^{-1}$  resolution. The spectra were normalized by computing the ratio of a sample spectrum to the spectrum of a MTEC carbon black standard. A stainless steel cup (diameter  $10\text{ mm}$ ) was filled with a sample (thickness  $<6\text{ mm}$ ). Before each data collection, the PA cell was purged with dry helium for 5 minutes. Interferograms of 1024 scans were average for each spectrum.

For a better comparison of individual bands on the IR spectra obtained for particular cosmetic products, TS, ATR, DRS and PAS spectra were normalized with respect to  $-\text{CH}$  band ( $2920\text{ cm}^{-1}$ ).

### 3. RESULTS AND DISCUSSION

Interpretation of the IR spectra of cosmetic products is complicated due to the fact that each of the functional groups visible on the IR spectrum may be responsible for the appearance of multiple bands in a wide range of wavenumbers, so that each band may have a contribution of many functional groups. Additionally, the presence of substances such as water or paraffin compounds may also impede the analysis. These paraffin substances are visible in the IR spectrum in the range of 3000-2800  $\text{cm}^{-1}$  ( $-\text{CH}$  bands) and 1500-1100  $\text{cm}^{-1}$ . Water reveals bands within 3600-2800  $\text{cm}^{-1}$  and 1700-1300  $\text{cm}^{-1}$  range, and those bands may overlap with the bands of tested cosmetics and hinder the interpretation of the spectra. As it was mentioned, photoacoustic spectroscopy is not an appropriate technique for the analysis of liquid cosmetics. Such samples contain in its composition a significant amount of water. The incident beam of infrared radiation could cause the evaporation of water from the sample and damage the microphone in photoacoustic detector.

For the purpose of better visibility, FT-IR spectra presented further in this work were divided into two ranges: 4000–2000  $\text{cm}^{-1}$  (where mainly  $-\text{OH}$  and  $-\text{CH}$  groups vibrations are visible) and 2000–600  $\text{cm}^{-1}$  (fingerprint region).

#### 3.1. Eye shadow

Figure 1 shows the FT-IR spectra of analyzed eye shadow. In all IR spectra (PAS, TS, ATR, DRS) there are bands indicating the presence of compounds containing  $-\text{CH}$  groups: 2978, 2955, 2925, 2852, 1456, 1376  $\text{cm}^{-1}$ . The sharp band of  $-\text{OH}$  at 3676  $\text{cm}^{-1}$  and a broad band of SiO in the range of 1270-850  $\text{cm}^{-1}$  indicates the presence of silica. The broad band within 3600-3000  $\text{cm}^{-1}$  indicates the presence of intramolecular hydrogen bonding. The presence of the band with maximum at  $\sim 3070$ , 1560 and 670  $\text{cm}^{-1}$  may indicate the presence of aromatic compounds in the tested cosmetic product. These bands are most apparent in the TS, PAS and DRS spectra and practically absent in the ATR spectrum. In the case of the DRS spectrum (Fig. 1b) the latter band at  $\sim 670$   $\text{cm}^{-1}$  (out-of-plane deformation vibration of aromatic rings) is slightly shifted towards higher wavenumbers ( $\sim 700$   $\text{cm}^{-1}$ ). This band (670  $\text{cm}^{-1}$ ) and the band at 986  $\text{cm}^{-1}$  may also indicate the presence of talc or mica (2925, 1017 and 700  $\text{cm}^{-1}$ ) [9]. The amino group bands are visible at about 3309 and 1610  $\text{cm}^{-1}$ , although the latter may also indicate the presence of  $\text{C}=\text{O}$  groups (ketones, esters) [10]. The presence of ester bonds in the

cosmetic can be also confirmed by the appearance of 1735 and 1715  $\text{cm}^{-1}$  bands. These bands are absent in the ATR spectrum. Moreover, the ATR spectrum does not allow for any profound analysis. The most intense band in the ATR spectrum is the band of silica groups within 1270-900  $\text{cm}^{-1}$  range. Although the  $-\text{CH}$ ,  $\text{C}=\text{O}$  and amine groups bands have the same position in the TS, PAS and DRS spectra, large differences appear in the range of  $\text{SiO}$  groups (1270-850  $\text{cm}^{-1}$ ).

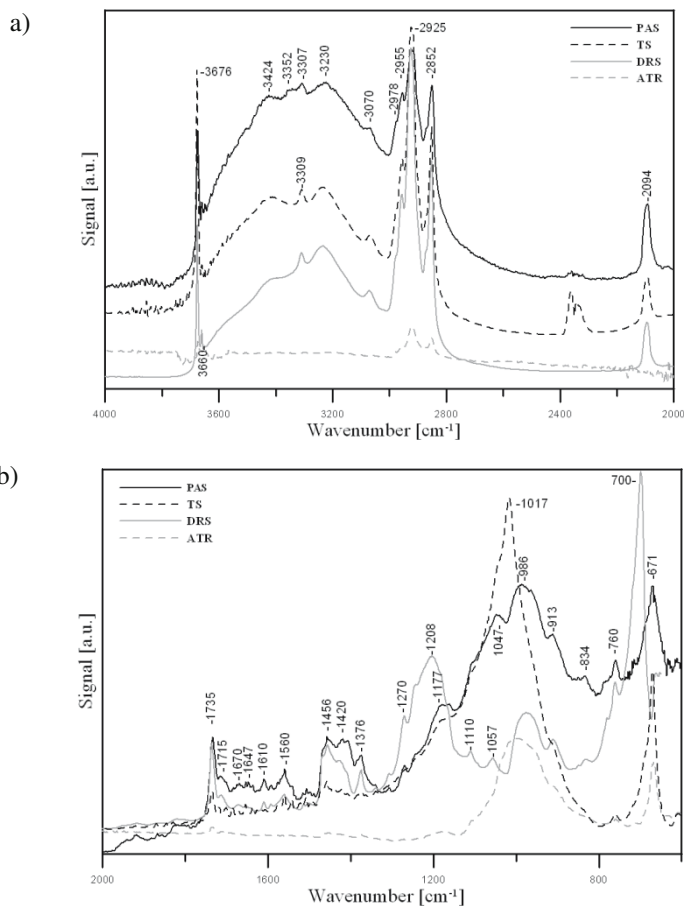


Fig. 1. FT-IR spectra of eye shadow: a) 4000-2000  $\text{cm}^{-1}$  range, b) 2000-600  $\text{cm}^{-1}$  range.

### 3.2. Red lipstick

Figure 2 shows the FT-IR spectra of analyzed red lipstick. In all IR spectra of tested lipstick the absorption bands have the same position, but the greatest similarity can be observed in the photoacoustic and transmission

spectra. Although, there are bands in the  $1650\text{--}1500\text{ cm}^{-1}$  range, which are not visible on ATR or DRS spectra. Additionally, the bands at  $3212$  and  $825\text{ cm}^{-1}$  are present only in the photoacoustic spectrum (Fig. 2a, 2b).

Broad band in the range of  $3600\text{--}3000\text{ cm}^{-1}$  indicates the presence of intramolecular hydrogen bonds. The bands in  $3000\text{--}2800\text{ cm}^{-1}$  ( $2957$ ,  $2924$ ,  $2852\text{ cm}^{-1}$ ) indicate the presence of aliphatic hydrocarbons in the tested cosmetic. The latter may be confirmed analyzing the spectra in the  $1460\text{--}1379\text{ cm}^{-1}$  range (aliphatic  $\text{--CH}$  groups). The bands at  $\sim 1560$  and  $\sim 1370\text{ cm}^{-1}$  indicate the presence of aromatic compounds. The wide band of SiO in the  $1270\text{--}850\text{ cm}^{-1}$  range indicates the presence of silicates in considered cosmetic product. Obtained IR spectra display multiple bands which correspond to the wavenumbers characteristic for propyl ester of hexanoic acid ( $1743$ ,  $1460$ ,  $1418$ ,  $1379$ ,  $1363$ ,  $1163$ ,  $1109$ ,  $1040$ ,  $723\text{ cm}^{-1}$ ) [11].

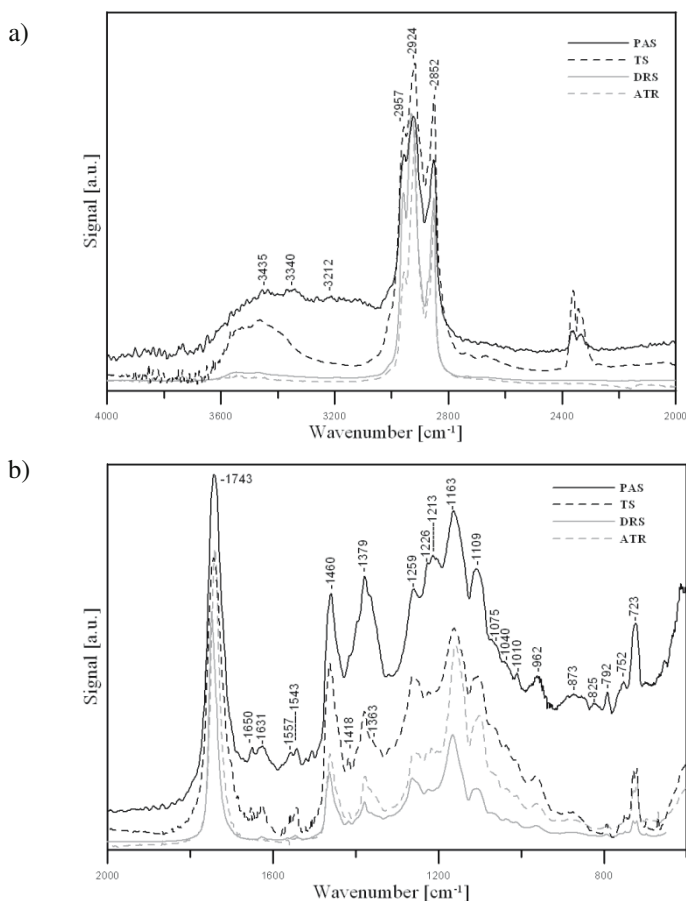


Fig. 2. FT-IR spectra of red lipsticks: a)  $4000\text{--}2000\text{ cm}^{-1}$  range, b)  $2000\text{--}600\text{ cm}^{-1}$  range.

### 3.3. Black eye pencil

While interpreting the IR spectra of black eye pencil (Fig. 3) one can observe that aromatic compounds ( $3026, 1750, 1450, 730\text{ cm}^{-1}$ ), esters ( $1744\text{ cm}^{-1}$ ) and amino compounds ( $3300, 1637\text{ cm}^{-1}$ ) are present in the examined cosmetic. These bands are the most visible in the photoacoustic spectrum. The bands at  $2953, 2921, 2851, 1456$  and  $1376\text{ cm}^{-1}$  indicate the presence of aliphatic compounds and the bands in the  $1100\text{-}700\text{ cm}^{-1}$  range indicate the presence of silica compounds in the tested sample.

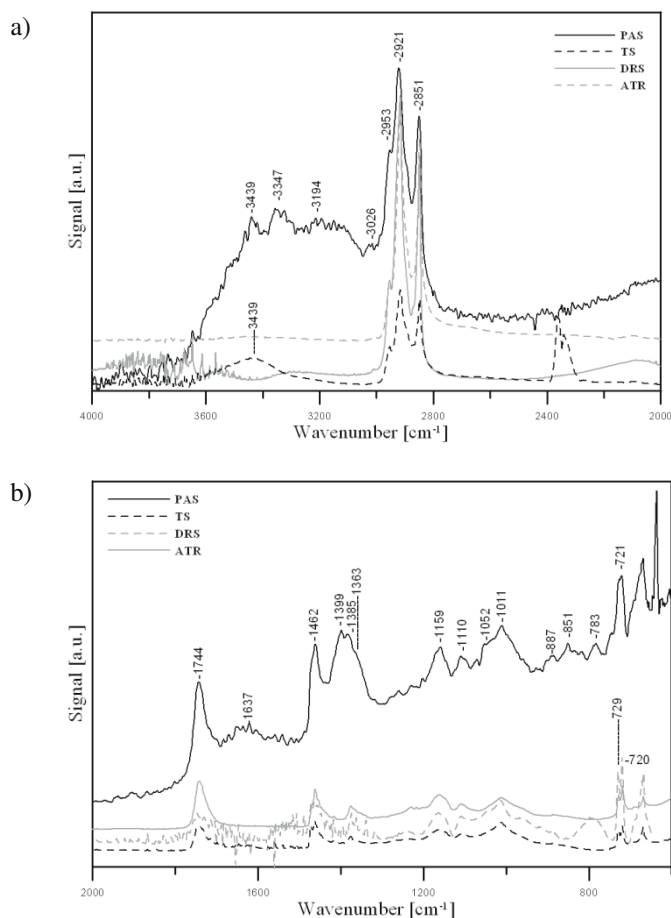


Fig. 3. FT-IR spectra of black eye pencils: a)  $4000\text{-}2000\text{ cm}^{-1}$  range, b)  $2000\text{-}600\text{ cm}^{-1}$  range.

The bands at  $2920, 2850, 1462, 1363, 1159$  and  $720\text{ cm}^{-1}$  indicate the presence of paraffin compounds. Another compound whose presence can be confirmed when analyzing the obtained IR spectra is polyethylene



glycol [11]. The bands characteristic for that compound are visible at 3347, 1637, 1462, 1159, 1110 and 887  $\text{cm}^{-1}$ . There are also bands corresponding to the presence of mica (1390, 1011 or 720  $\text{cm}^{-1}$ ) [9].

The most information about the composition of the black eye pencil can be obtained by analyzing the photoacoustic spectrum. This fact indicates that photoacoustic technique is the best IR technique for the analysis of such cosmetic product.

### 3.4. Depigmentant cream

Interpretation of TS and ATR spectra of depigmentant cream (Fig. 4a) and confirming the presence of water (broad and intense band in the 3700-3000  $\text{cm}^{-1}$  range) excludes IR analysis using photoacoustic technique.

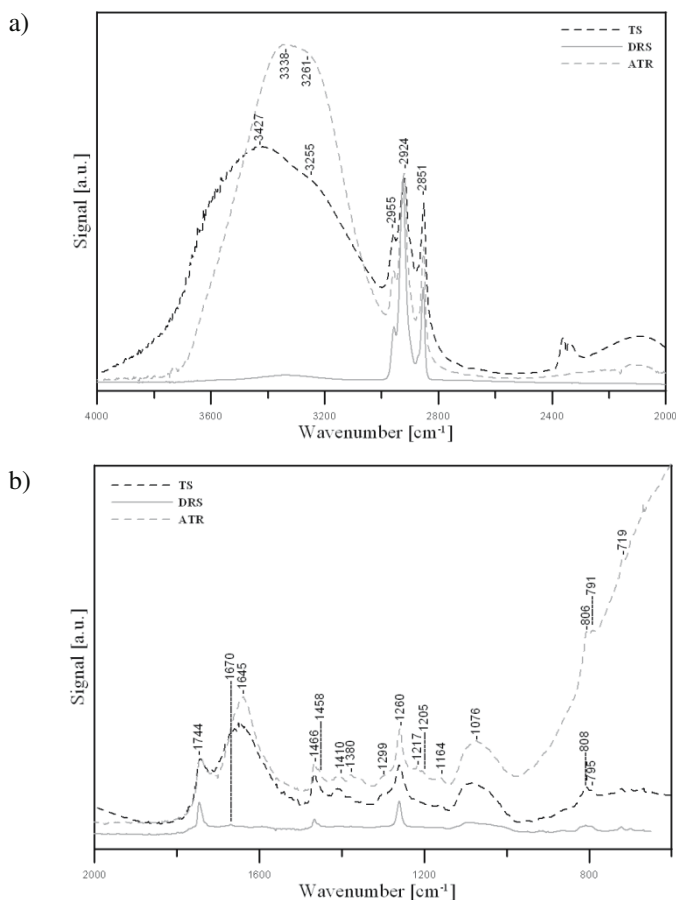


Fig. 4. FT-IR spectra of depigmentant cream: a) 4000-2000  $\text{cm}^{-1}$  range, b) 2000-600  $\text{cm}^{-1}$  range.

The bands appearing at  $\sim 1744$  and  $1645\text{ cm}^{-1}$  (Fig. 4b) may indicate the presence of C=O groups in carboxylic acids and aromatic ketones, respectively [10]. Another group identified on the basis of IR spectra is aliphatic  $-\text{CH}$  ( $2955$ ,  $2924$ ,  $2851$  and  $1380\text{ cm}^{-1}$ ). The IR spectra of the tested cream have a number of bands located at wavenumbers similar to cetyl alcohol (e.g.  $2955$ ,  $2851$ ,  $1466$  or  $719\text{ cm}^{-1}$ ) and cyclopentasiloxane ( $1645$ ,  $1410$ ,  $1260$ ,  $1076$  and  $806\text{ cm}^{-1}$ ) [11]. Obtained DRS spectrum is of poor quality (Fig. 4a, 4b).

#### 4. CONCLUSION

An unambiguous analysis of the IR spectra of cosmetics is difficult due to the presence of many ingredients. The signals coming from one compound can be masked by other or may even overlap. It is hard to distinctly confirm the presence of the compound in the cosmetic, but one can confirm the presence of specific functional groups.

Based on the results presented in this paper for various types of cosmetic, the following conclusions can be made:

- similar information can be obtained by analyzing the TS and ATR spectra, the bands have similar intensity at similar wavenumbers;
- DRS spectra usually differ significantly from the TS, ATR and PAS spectra;
- DRS technique is not suitable for the analysis of liquid samples;
- in the case of liquid samples the ATR technique was the best choice, while PAS could not be used at all;
- transmission technique have to be modified in some cases (greasy samples have to be applied on the compressed KBr pellet) and the measurement had to be made relatively quickly, to avoid the destruction of KBr pellet;
- in the case of powdery samples with low water content (i.e. eye shadow) PAS and TS techniques have proved to be the best;
- the best analysis of solid samples with oil consistency (lipsticks, eyeliners) can be performed using the TS and PAS technique;

Not all techniques are suitable for the analysis of various types of cosmetics which was confirmed by research done in this work. Selection

of the appropriate technique must be dictated by the physical state, the content of water, consistency and homogeneity of the cosmetic sample.

## REFERENCES

- [1] Ustawa o kosmetykach z dnia 30 marca 2001 (Dz. U. nr. 42, poz. 473 z późniejszymi zmianami) (in Polish).
- [2] P. Pietruszka, *Wiadomości kosmetyczne*, **3**, 21, (2008) (in Polish).
- [3] W. Zieliński, *Metody spektroskopowe i ich zastosowanie do identyfikacji związków organicznych*, Wydawnictwo Naukowo-Techniczne, Warszawa, (1995) (in Polish).
- [4] E. Ribechini, F. Modugno, J. Pérez-Arantegui, M. P. Colombini, *Discovering the composition of ancient cosmetics and remedies: analytical techniques and materials*, Springer-Verlag, (2011).
- [5] M. C. Gamberini, C. Baraldi, F. Palazzoli, E. Ribechini, P. Baraldi, *Vibrational Spectroscopy*, **47**, 82, (2008).
- [6] N. A. Puttnam, B. H. Baxter, S. Lee, P. L. Stott, *J. Soc. Cosmetic Chemists*, **17**, 9, (1966).
- [7] J.C. Bowman, *Qualitative Analysis and Structural Confirmation of Several Surfactants by FT-Raman and FT-IR Spectroscopies*, Nicolet Application Note, Madison, (1993).
- [8] A. Rohman, Y. B. Che Man, *Middle-East Journal of Scientific Research*, **5**, 7, (2011).
- [9] N. V. Chukanov, *Infrared spectra of mineral species*, Extended library, Vol. 1, Springer (2014).
- [10] G. Socrates, *Infrared and Raman Characteristic Group Frequencies. Tables and Charts*, John Wiley&Sons Ltd. (2001).
- [11] OMNIC<sup>TM</sup> Spectra Software, *database of spectral data*

## CURRICULA VITAE



**Sylwia Pasieczna-Patkowska** was born in Lublin, Poland in 1974. She studied chemistry at the Maria Curie-Skłodowska University, graduated in 1998. Received her Ph.D. (2006) in physical chemistry from the UMCS in Lublin. Since 2007 she is an adjunct at UMCS. She is an author and co-author of 73 articles in science-technical press, the author and co-author of 126 papers and posters at domestic and foreign conferences. Scientific interests: infrared spectroscopy, chemical technology. She is member of Polish Chemical Society (1998- ) and Polish Catalysis Club (1998- ).



**Tomasz Olejnik** was born in Radom in Poland in 1988. He studied Basic and Applied Chemistry at Maria Curie-Skłodowska University in Lublin. In 2012 he obtained M.Sc. degree based on master thesis entitled: “The ordered mesoporous silica materials – influence of modification on the physicochemical properties of silica”. His master thesis was awarded by the Polish Chemical Society. After graduation from the Faculty of Chemistry, Maria Curie-Skłodowska University in August 2012, he started Ph.D. studies in Department of Chemical Technology, M.C.S. University in Lublin. He is member of Polish Chemical Society (2010- ) and Polish Catalysis Club (2012- ).