ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 21, No. 1. 2015

Thermal Analysis of Braille Formed by Using Screen Printing and Inks with Thermo Powder

Svitlana HAVENKO [1], Victoria KOCHUBEI [2], Marta LABETSKA [3], Svitlana KHADZHYNOVA [1], Edmundas KIBIRKŠTIS [4]*, Ingrida VENYTĖ [4]

[1] *Technical University of Lodz, Skorupki 10/12, r. 105, 90-924 Lodz, Poland*
[2] *Lviv Polytechnic National University, Bandery 12, 79013 Lviv, Ukraine*
[3] *Ukrainian Academy of Printing, Pidholosko 19, 79020 Lviv, Ukraine*
[4] *Kaunas University of Technology, Studentų 56, LT-51424 Kaunas, Lithuania*

crossref http://dx.doi.org/10.5755/j01.ms.21.1.5702

Received 12 November 2013; accepted 16 June 2014

In order to improve the integration of blind people into society, suitable conditions should be provided for them. The expansion of Braille (BR) use could serve the purpose. Depending on the materials used for Braille, it can be formed or printed in different ways: embossing, screen printing, thermoforming, digital printing.

Thus the aim of the presented paper is to determine the influence of thermal effects of screen printing inks and inks with thermo-powder on the BR inks mass change.

Screen printing inks and inks with thermo-powder were chosen for the research. Carrying out the qualitative analysis of printouts with Braille, the thermal stability was evaluated by analyzing the thermograms obtained with derivatograph Q-1500.

This paper presents the findings of the thermogravimetric (TG), differential thermogravimetric (DTG) and differential thermal analysis (DTA) of printouts printed on paperboard Plike and using traditional screen printing inks and screen printing inks with thermo-powder.

Based on the testing findings it is determined that thermal stability of printouts printed with thermo-powder ink is higher than printed with screen printing inks. It is determined that the appropriate drying temperature range of screen printing inks with thermo-powder is 98 ºC – 198 ºC because in this case better relief of Braille dots is obtained.

Keywords: Braille screen printing, screen printing inks with thermo-powder, thermal analysis.

1. INTRODUCTION

It is important to improve the integration of blind people into society by providing suitable conditions for them. The expansion of Braille use would give a great impulse in this area.

According to international standards, packaging manufacturers must apply Braille marking on goods [1 – 3]. Therefore, improving the technology of reproducing relief-dot images has become a burning issue solution, which is to use the latest achievements in printing and related industries.

Depending on the materials used for Braille, it can be formed or printed in different ways: embossing, screen printing, thermoforming, digital printing.

Recently Braille formed by embossing on pharmaceutical paperboard packaging has been widely used. The change of Braille geometrical parameters formed in this way was determined in [4].

Braille by using screen printing is being increasingly used because it is easy to make relief images due to thick layer of inks and print on various materials: paper, paperboard, textile, metal, PE and PP coated material, adhesive foil, foil or PVC coated PET, etc [5, 6]. The Braille reading depends on the material type and the size of Braille geometrical parameters when Braille is formed using screen printing [7].

Traditional screen printing inks or water-based UV curing clear inks (varnish) are used in screen printing to produce the relief (tactile) elements. These inks are viscous, odourless, fast drying and have good adhesive properties. Due to light sensitive resins, these inks polymerize when cured with UV and very well adhere to the printing substrate, thus making relief elements. The water-based UV-curing inks, containing about 35 % – 45 % of water, after the drying form smaller height Braille elements than just after the coating of inks, comparing with traditional UV-curing inks (5 % pigments, 5 % additives, 45 % reactive diluents or monomers, 45 % reactive resins or oligomers) [8, 9].

An water based ink composition with thermo-powder for the screen printing of relief images is proposed in this paper. It will enable to extract higher relief Braille dots [10].

Thus the aim of the presented paper is to determine the influence of thermal effects of screen printing inks and inks with thermo-powder on the BR inks mass change.

2. EXPERIMENTAL EQUIPMENT AND METHOD

The research object was Braille images printed by using screen printing machine TX-2530 on a design cardboard of Plike type (thermal resistant, pure cellulose, coated, grammage of 250 g/m^2). The samples were printed at certain optimal printing regimes using screen printing water-based inks PASSAD AQ 0-51 and the same inks

*Corresponding author. Tel.: +370-37-451684; fax.: +370-37-353989
E-mail address: *edmundas.kibirkstis@ktu.lt* (E. Kibirkštis)

including additives (thermoplastic material styrene maleic anhydride and solvent dimethyl sulfoxide, 30 % mass of total composition). To achieve the desired height relief images, the Braille printouts were dried for 15 s – 35 s at the temperature of 200 °C [8 – 13].

The thermal stability was determined by analyzing the thermograms obtained with derivatograph Q-1500 D (F. Paulik, J. Paulik, L. Erdey system). The samples were analyzed in a dynamic mode at the heating speed of 5 °C/min in the ambient air. The mass of samples was 200 mg. The standard substance was aluminum oxide, which is one of the recommended materials for thermogravimetric analysis and does not react with the studied models during heating. The samples were heated to the temperature of 350 °C to discover their degradation limits.

The Braille elements images were analyzed using light microscope Biolam C-11 with the lense magnification of ×90.

The above mentioned equipment, the test scale specially designed on a clear film and Braille Dot Checker (BRAI[3]) were used to control Braille geometrical parameters (dot diameter, character height, dot height, distance between symbols and line (see Fig. 1) [14].

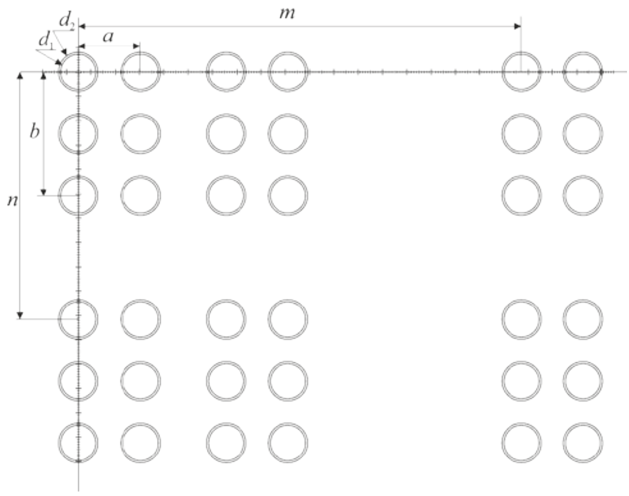


Fig. 1. Test scale for the control of the geometric parameters in Braille, where: d_1, d_2 – min and max dot diameter, a – distance between dot centers, b – character height, m – character spacing, n – line spacing

3. RESULTS AND DISCUSSION

When applying the thermogravimetric analysis method, a change of the sample mass was registered (TG curve) by heating the sample to a high temperature. In this case the thermal stability and the degradation processes were determined. The first derivative (DTG curve) was recorded, including the TG curve. The highest speed of the sample mass decrease was determined by analyzing the obtained differential thermogravimetric curve (DTG).

The results of thermogravimetric (TG), differential thermogravimetric (DTG) and differential thermal (DTA) analyses for samples, i. e., BR used for printing ink (sample 1, sample 2) and printed on cardboard Plike (sample 3, sample 4), are given in Table 1.

The thermograms of the samples were obtained after carrying out the thermal analysis (see Figs. 2, 3, 5, 6).

Fig. 2 and Fig. 3 shows the thermograms TG, DTA, DTG of screen printing inks (sample 1) and screen printing inks with additives (sample 2).

Table 1. The results of thermal analysis of samples

No.	Sample	Stage	Temperature range, °C	Mass loss, %
1	Screen printing ink	1	20 – 179	4.1
		2	179 – 214	4.0
		3	214 – 307	21.5
2	Screen printing ink + thermo powder	1	20 – 198	4.1
		2	198 – 227	2.8
		3	227 – 295	15.4
3	Screen printing ink + cardboard	1	20 – 197	4.8
		2	197 – 227	4.3
		3	227 – 306	30.9
4	Screen printing ink + thermo powder + cardboard	1	20 – 205	4.8
		2	205 – 232	4.9
		3	232 – 309	29.9

The differential thermal analysis curve was obtained by changing the temperature and registering the difference of temperature between the tested and standard substance. The first shallow endothermic effect (of heat absorption) of sample 1 (Fig. 2) in DTA curve occurs in the temperature range of 20 °C – 179 °C, while that of sample 2 in the temperature range of 20 °C – 198 °C (Fig. 3). The mass losses seen in TG curve do not have any effect on this change. It coincides with the softening process of high-molecular compounds existing in the inks and thermo-powder, and the release of volatile compounds which are added to the structure of samples.

The next endothermic effect occurs in the temperature range of 96 °C – 198 °C. As it can be seen from TG curve (Figs. 2, 3), in this range the mass losses start under the influence of the volatile compounds existing in the mass of both samples. The chemical composition of both samples is different, thus the endothermic processes run in different temperature ranges. The thermogravimetric analysis suggests that sample 1 and sample 2 start losing mass intensively at temperatures higher than 179 °C. Thermal degradation occurs in the temperature range of 179 °C – 227 °C, and heat is not discharged. A low-level mass loss is obtained during this process, thus only a low-level peak can be seen in the DTG curve (Figs. 2, 3). The DTG curves show the speed of the mass change.

Temperature higher than 214 °C features the thermo-oxidative degradation of the organic component (Figs. 2, 3). Such a process for screen printing inks occurs in the temperature range of 214 °C – 307 °C (sample 1, Fig. 2), and for inks with thermo-powder 227 °C – 306 °C (sample 2, Fig. 3). This process is accompanied by a large mass loss in TG curve and a distinct peak in the DTG curve. The origin of the exothermic effect in the DTA curve corresponds to the beginning of the sample thermo oxidative degradation.

The comparison of the analysis results (Figs. 2 – 4) has shown that screen printing inks with thermo-powder (sample 2) inhibit higher heat resistance than screen printing inks (sample 1). Temperature intervals of thermal and thermo-oxidative degradation of this sample are shifted to the region of higher temperatures (Table 1). During heating and expansion, sample 2 loses mass less intensively in contrast to sample 1 that is clearly fixed at the temperature of 200 °C (Fig. 4).

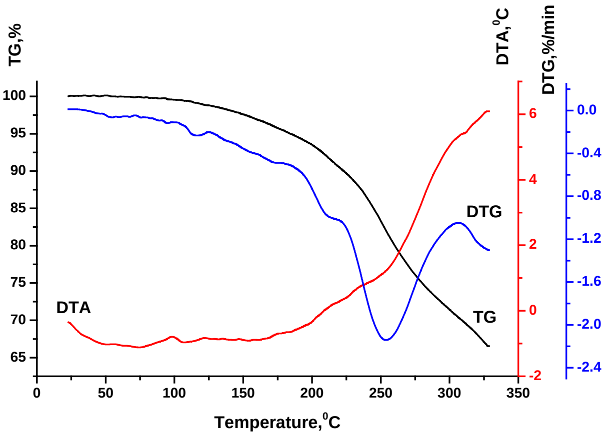


Fig. 2. Experimental thermograms of screen printing inks (sample 1): DTA – differential thermal changes curve, TG – mass change curve, DTG – differential mass change curve

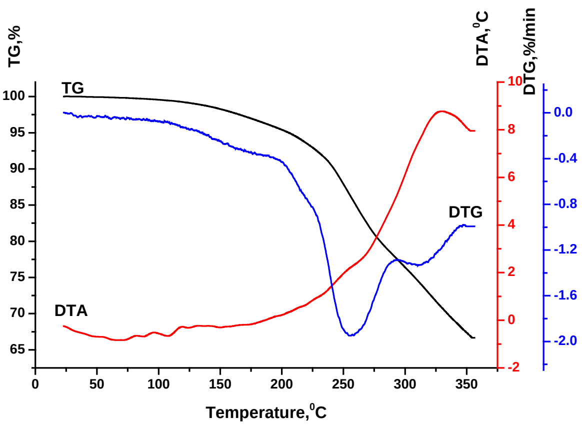


Fig. 3. Experimental thermograms of screen printing inks with additives (sample 2): DTA – differential thermal changes curve, TG – mass change curve, DTG – differential mass change curve

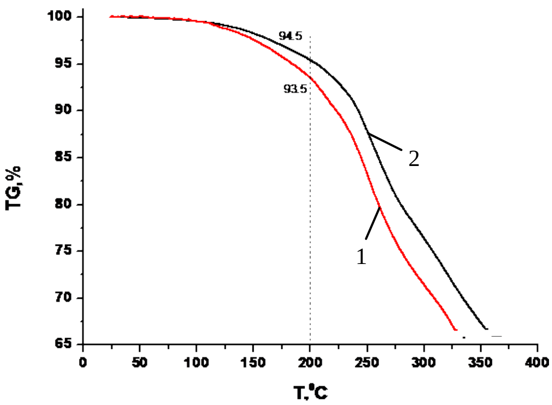


Fig. 4. Experimental curves of dependence of ink mass change on temperature (TG): sample 1 – 1; sample 2 – 2

The thermograms of samples printed on paperboard with screen printing inks (sample 3, Fig. 5) and inks with thermo-powder (sample 4, Fig. 6) are shown in Fig. 5 and Fig. 6. In TG curves, low-level mass change can be noticed which occurs in the temperature range of 20 °C – 197 °C for sample 3 (Fig. 5) and 20 °C – 205 °C for sample 4 (Fig. 6). The shallow endothermic effect in the DTA curves of both samples can be seen. Such a process can be explained by the release of volatile components as constituents from the samples, as well as by softening of highly-molecular compounds. A higher level of volatile compounds exists in sample 3 and sample 4 than in samples 1 and 2 because the paperboard contains water.

The temperature range of 197 °C – 232 °C demonstrates endothermic processes of thermal destruction of sample 3 and sample 4 components (Fig. 6), which are followed by the formation of volatile decomposition products. It should be noted that sample 3 and sample 4 show a higher thermal stability compared with samples 1 and 2. The thermal degradation of these samples occurs at higher ranges of temperatures (above 197 °C) (Figs. 5, 6). This fact can be explained by adhesive interactions that occur between the ink, the powder and the cardboard surface.

The exothermic processes of thermo-oxidative decomposition of organic components of sample 3 (Fig. 5) and sample 4 (Fig. 6) occur at temperatures above 227 °C in the DTA curves. In the temperature ranges of 227 °C – 306 °C for sample 3 (Fig. 5) and in the temperature ranges of 232 °C – 309 °C for sample 4 (Fig. 6) in the TG curve a large loss of mass occurs and a distinct peak can be seen in the DTG curve at a higher temperature. In this temperature range, sample 3 and sample 4 lose the mass more intensively than sample 1 and sample 2, which may be due to the formation and flame burning of gaseous products of pyrolysis of paper at high temperatures.

It is worth mentioning that the thermal stability of samples 3 and 4 is much higher than that of samples 1 and 2.

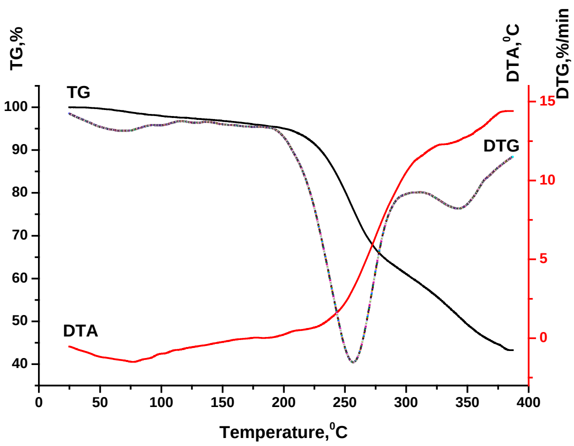


Fig. 5. Experimental thermograms of screen printing inks printed on paperboard (sample 3): DTA – differential thermal changes curve, TG – mass change curve, DTG – differential mass change curve

Based on the study of thermal stability of sample 3 and sample 4 (Figs. 5 – 7) it can be concluded that inks with thermo-powder (sample 4) printed on paperboard have higher thermal stability than just inks (sample 3) because the components of sample 4 lose the mass less intensively at heating and thermal degradation stages. Besides, the start of thermal degradation of sample 4 starts at higher temperatures (Table 1).

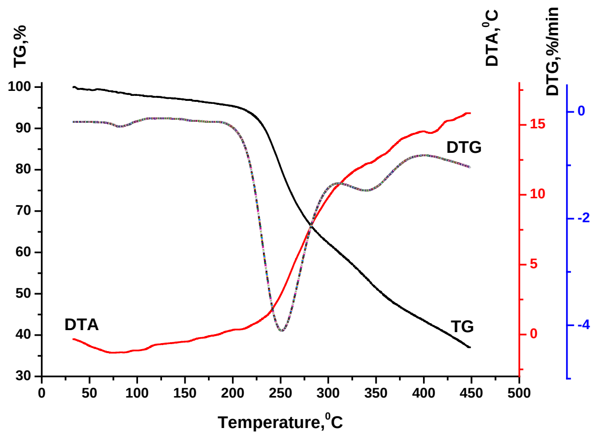


Fig. 6. Experimental thermograms of screen printing inks with thermo-powder printed on paperboard (sample 4): DTA – differential thermal changes curve, TG – mass change curve, DTG – differential mass change curve

The comparison of TG curves of sample 3 and sample 4 is shown in Fig. 7. From the graph it can be seen that the loss of the mass begins at the temperature of 200 °C, similarly as in the case of sample 1 and sample 2 (Fig. 4).

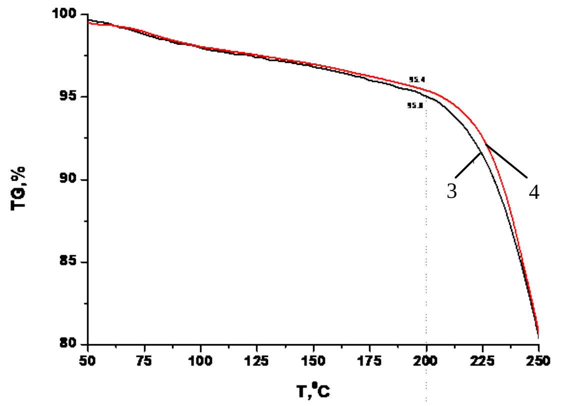
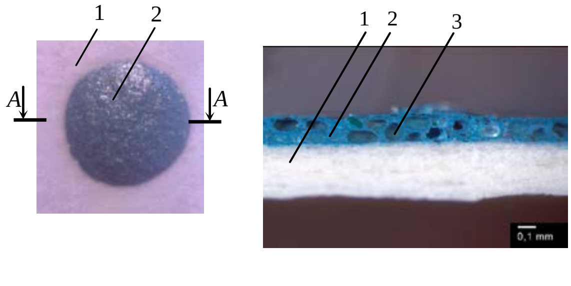


Fig. 7. Experimental curves of dependences of change of inks mass on the temperature (TG): sample 3 – 3; sample 4 – 4

The findings of thermal analysis have shown the working ranges of temperature of screen printing inks and inks with thermo-powder. The first one corresponds the range 96 °C – 179 °C (sample 1) and the second – 98 °C – 198 °C (sample 2) (see Table 1). The lower point of working range shows the temperature at which the softening process of high-molecular compounds, which exist in the samples, ends. The upper point corresponds the temperature above which the degradation of components occurs. The presence of thermal powder in synthesized printing compositions, based on screen printing ink, leads to the expansion of boundaries of the operating temperature range and improvement of the composition performance. The residual mass of the samples, compared with their thermal stability, is shown in TG curves in Fig. 4 and Fig. 7, and corresponds to the upper limit of the working temperature range of the sample of synthesized compositions.

Thus, the thermal analysis has shown that the appropriate working range of temperature for drying Braille elements printed with screen printing inks with thermo-powder is 98 °C – 198 °C because in this case a better Braille relief is obtained. The results of research are consistent with the known theories of thermal analysis [15, 16].



a b

Fig. 8. Braille dots for the sample of a screen printing ink with thermo powder on the cardboard (sample 4): a – top view: 1 – cardboard, 2 – Braille dot; b – cross-section A–A: 1 – cardboard, 2 – ink, 3 – baked granules of thermo powder

The Braille quality analysis carried out by applying the above described methodology, special designed testing scale (Fig. 1) and optical measuring device BRAI³ has shown that Braille dots are readable and meet the normative geometric parameters of Braille (Braill dot diameter – $(1.60 \pm 0.10)\times10^{-3}$ m, Braille dot height $(0.16 – 0.20 \pm 0.10)\times10^{-3}$ m) [3]. The Braille dots printed on paperboard using inks with thermo-powder are contrasting and of sufficient height $(0.20\times10^{-3}$ m) (Fig. 8) because these inks allow to obtain the Braille dots of higher relief comparing with dots obtained using traditional screen printing inks.

4. CONCLUSIONS

1. Thermal analysis has shown that Braille elements formed using screen printing inks with additives are more thermally stable than elements formed using traditional screen printing inks. It extends the capabilities of this technology of forming Braille elements.
2. It is determined that screen printing inks with thermo-powder used for the forming Braille elements should be dried in the working temperature range 98 °C – 198 °C because in this case a better relief of Braille dots can be obtained. The results of research are consistent with the known theories of thermal analysis.
3. By using specially designed testing scale and carrying out the analysis of samples images, it was determined that Braille dots printed with screen printing inks with thermo-powder meet the qualitative requirements: Braill dot diameter – $(1.60 \pm 0.10)\times10^{-3}$ m, Braille dot height $(0.16 – 0.20 \pm 0.10)\times10^{-3}$ m. The designed testing scale allows an operational control of geometrical parameters of Braille elements and its quality in general.

REFERENCES

1. **Golob, G.** Braille Legibility on the Pharmaceutical Packaging *VIIIth Seminar In Graphic Arts* 2007: p. 98.
2. **Vakulich, D.** Labeling for the Blind on Packaging for Pharmaceuticals *Packing* 1 2010: pp. 44 – 46.

3. LST EN 15823:2010. Packaging – Braille on Packaging for Medicinal Products, 2010.
4. **Kibirkštis, E., Venytė, I., Mayik, I., Vakulich, D.** Investigation of Geometrical and Physical-mechanical Parameters of Braille by Assessing the Different Types of Cardboard Materials *Mechanika* 17 (6) 2011: pp. 656 – 660. http://dx.doi.org/10.5755/j01.mech.17.6.1010.
5. **Motyka, M. T.** Screen Printing as a Technology of Tactile Books *Technology and Technique of Printing* 2 (32) 2011: pp. 39 – 46 (in Ukrainian).
6. **Levi, F.** Using Silk Screen Printing for Relief Drawings: Examples from Guides to Turin and Venice *New Technologies in the Education of the Visually Handicapted* 237 1996: pp. 89 – 94.
7. **Childs, T. H. C., Henson, B.** Human Tactile Perception of Screen-printed Surfaces: Self-report and Contact Mechanics Experiments *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology* 221 (3) 2007: pp. 427 – 441. http://dx.doi.org/10.1243/13506501JET217.
8. Sericol IPS Ltd. A Guide to Screen Printing Halftones. Sericol International Limited, 2000: 72 p. (in Russian).
9. **Pan, J., Tonkay, G. L., Quintero, A.** Screen Printing Process Design of Experiments for Fine Line Printing of Thick Film Ceramic Substrates *Journal of Electronics Manufacturing* 9 (203) 1999: pp. 203 – 213.
10. **Havenko, S. F., Labetska, M. T.** Method of Application Braille. Utility Model Patent Number 77373. Appl. 06.08.2012. Publ. 11.02.2013. Bull. № 3, 2013.
11. ISO 12647-5:2001. Graphic Technology – Process Control for the Manufacture of Half-tone Colour Separations, Proof and Production Prints. Part 5: Screen Printing, 2001.
12. **Thomas, G.** Transmission Electronic Microscopy of Materials: Trans. from English. Nauka, 1983: 320 p.
13. NIIR Board. Screen Printing Technology Handbook. Asia Pacific Business Press Inc, 2003: 672 p.
14. **Havenko, S. F., Labetska, M. T., Havenko, M. M.** Test Scale to Control the Braille Characters. Utility Model Patent Number 80437. Appl. 18/12/2012. Publ. 27.05.2013. Bull. № 10, 2013.
15. **Tracton, A.** Coatings Technology Handbook. Third Edition. Taylor & Francis, 2005: 936 p. http://dx.doi.org/10.1201/9781420027327
16. **Wunderlich, B.** Thermal Analysis of Polymeric Materials. Berlin: Springer, 2005: 894 p.