Opacity of White Envelope Papers

Lan-Sheng Kuo[1,3], Haw-Farn Lan[2], Yin-Li Chen[1] and Ya-Yuei Chen[1]

【Summary】

Although the concept of higher opacity of envelope paper is well understood, methods of increasing the opacity of envelope paper are made more difficult by a conflict between increasing transportation and mailing costs and decreasing basis weight. The increase in the opacity of paper envelopes (weight range: 50-110 g/m^2) is strongly dependent upon the scattering coefficient, *s*, and absorption coefficient, *k*. The tendency of 14 commercial white paper envelopes from Taiwan and the U.S.A. to gain apparent opacity by printing the high absorption power blue, purple, green, and black inks on 1 side of the envelope paper was evaluated by comparing with filled white papers of a similar basis weight level.

Key words: opacity, white envelope paper, basis weight, scattering coefficient, absorption coefficient.

Kuo, L. S., H. F. Lan, Y. L. Chen, and Y. Y. Chen. 1997. Opacity of white envelope papers. Taiwan J. For. Sci. 12(1): 53-59.

白信封紙之不透明度

郭蘭生[1,3] 藍浩繁[2] 鄭殷立[1] 鄭雅月[1]

摘 要

雖然人人皆知白信封紙應有較高的不透明度以達保密及保護之效，由於為降低信件運費或郵資，生產信封紙者面臨既要基重下降又同時兼顧高不透明度之困境。理論上，欲增加市售白信封紙(基重： 50~110 g/m^2) 之不透明度則應增加紙之散射係數， *s* ，及吸收係數， *k* ，方為宜。比較在 14 種市售白信封紙中添加填料、增加紙之基重及於紙之背面印以藍、綠、紫及黑色印墨等增加信封紙不透明度之諸法效果，吾人發現在不增加白信封紙基重大前提下，以單面印刷印墨者對白信封紙不透明度之改善效果最佳。

關鍵詞：不透明度，白色信封紙，基重，散射係數，吸收係數。

郭蘭生、藍浩繁、鄭殷立、鄭雅月 1997 白信封紙之不透明度。台灣林業科學 12(1): 53-59 。

1) 國立中興大學森林系，台中市國光路250號 Department of Forestry, National Chung Hsing University, 250 Kuokwang Rd. ,Taichung, Taiwan 402, R.O.C.

2) 國立屏東技術學院林產加工技術系，屏東縣內埔鄉學府路1號 Dept. of Forest Products Technology, National Pingtung Polytechnic, 1 Shuei-Fu Rd., Pingtung, Taiwan, R.O.C.

3) 通訊作者 Corresponding author

1996年7月送審 1996年11月通過 Received July 1996, Accepted November 1996.

INTRODUCTION

Usually the opacity of commercial translucent white paper envelopes,whose basis weights range 50 to 110 g/m^2, is defined as the reciprocal of transmittance. The opacity refers to the property of a sheet that obstructs the passage of light and prevents seeing through the sheet images from the opposite side. Because of 2-sided-printing, protection, and confidentiality, opacity is essential for printing paper and paper envelopes.

Opacity is determined by the amount of light transmitted by the paper. If all the light is transmitted and none is reflected or absorbed, the opacity will be 0%. If no light is transmitted and all reflected or absorbed, the opacity will be 100%. Most papers fall between these 2 extremes.

The opacity of paper is expressed as a contrast ratio of reflectances. TAPPI opacity (Casey, 1983) is the ratio of the reflectance of a single sheet over a black cavity, R_0, divided by the reflectance of the same sheet backed by an arbitrary white body of absolute reflectance of 89%. Printing opacity is the ratio of the reflectance of a single sheet over a black body divided by an opaque pad of similar paper which is R_∞.

If we multiply the scattering coefficient, *s*, of a paper sheet by its basis weight, *W*, the product *sW* is the scattering power of the paper. Likewise, *k* (absorption coefficient)*W* is the absorption power of the paper. As pointed out above (Judd, 1975), higher opacity denotes paper properties of increasing *s* or *k* values of a paper sheet. In filled paper, the increase in opacity is due to an increase in the scattering coefficient of the paper with the addition of pigment. In practice, ink on 1-sided printed envelope paper will create more absorption power than white paper of identical basis weight.

The important properties of white paper envelopes are for (1) packaging , (2) protection, and (3) confidentiality. It is obvious that higher opacity of envelope paper is essential to maintain confidentiality of its contents.

Although the concept of higher-opacity paper envelopes is well understood, methods for increasing the opacity are made more difficult by a conflict between increasing transportation or mailing costs and decreasing basis weight of commercial paper envelopes. Therefore, our objective in this study was to determine whether opacity gains could be made for 14 commercial envelope papers that we collected from Taiwan and the U.S..

MATERIALS AND METHODS

Table1contains information on 14 commercial white envelope papers selected for the study. Basis weights of these envelope papers collected from Taiwan and the States range from 50 to 110g/m^2.

With the exception of white envelope papers A, B, and C with no printing on both sides, all the other papers, D to N, have green, blue, violet, or black ink printed on 1 side.

TAPPI opacity, brightness, caliper, and basis weight were measured using CNS (China National Standard) methods. We also measured the color (expressed as CIE L*a*b*; L* for lightness, a* from green to red, b* from blue to yellow) of printed and unprinted sides of papers with spectrophotometer (Macbeth Color-Eye 3000, U.S.A.). Color values might help evaluate the opacifying (absorption) effects of inks printed on 1 side of the envelope papers.

In order to calculate *s* (scattering coefficient) and *k* (absorption coefficient) values which are indicators of opacifying power of each envelope paper, we determined the value of *sW* from the following formula (Robinson, 1975):

$$sW = 1/b\,(\mathrm{Ar\ ctgh}(1 - aR_0)/(bR_0))$$

Where $a = [(1/R_\infty) + R_\infty]/2$

$$b = [(1/R_\infty) - R_\infty]/2$$

Ar ctgh = Arc cotangent

R_∞ = Reflectivity of opaque (or infinite pile of) paper.

R_0 = Reflectance of a single sheet backed by black body.

And then it is easy to determine the value s by dividing *W* into *sW* ; *k /s* can be calculated by the Kubelka- Munk equation (Rydholm, 1965):

$$k / s = (1 - R_\infty)^2 / 2R_\infty$$

The value of *k* can then be determined by multiplying the value *k/s* by the value of *s*.

In addition, we also used the scanning electron microscope (Topcon ABT-150S SEM, Bausch and Lomb Co., USA) in combination with EDXA (Energy Dispersive X-Ray Analyzer) analysis to differentiate the elements in filled envelope papers. Knowing elements might reveal the opacifying power (expressed as 's' value) of high-refractive-index fillers, i.e., titanium dioxide, calcium carbonate, or clay.

It is obvious that increasing the sheet weight will increase the opacity of the paper. What is the real effect of grammage on the opacity of papers of similar opacity? We use the opacity/weight ratio to approximate the calculated opacity that would originate from its own weight.

RESULTS AND DISCUSSION

Fundamental properties of commercial white envelope papers

We found that, for some white envelope papers, *i.e.*, paper specimens A, J, K, and M, opacity was not correlated to basis weights as shown in Table 1, which is contrary to the maxim, "increasing the basis weight will increase the opacity of the paper " (Wang,1982).

It is obvious that due to density, brightness, and filler and ink effects, the opacity/weight ratio (opacity index) must be asymptotic. The Tappi opacities of white envelope papers A, S, and C, should be closely related to scattering coefficient at almost equal weights (92 ~ 95 g/m^2). In addition, as for aerogrammes K and L, the American aerogramme showed a higher opacity of 98.03% even at a lower weight (70 g/m^2) when compared with the higher-weight (90g/m^2) Taiwan aerogramme. Apparently, because the U.S. aerogramme has a higher *k* value (6.48) and lower L* (82.78) than the Taiwan aerogramme (1.50 and 91.73, respectively), so the light absorbed by the U.S. sheet will be much higher. In addition to this, the high refractive index of TiO_2 present in the lower basis weight (70 g/m^2) U.S. aerogramme (see specimen K of Table 2) results in a comparable scattering coefficient (45.30 m^2/g) with that of the higher basis-weight (90 g/m^2) Taiwan aerogramme (53.65 m^2/g). Comparing the density with its corresponding opacity for all envelope papers, we found that no apparent correlation exists between them. It is clear that fillers, ink, and even basis weight give envelope papers significant opacity gains. This is especially true regarding Taiwan aerogramme (paper specimen L in Table 1) of 1.06 g/cm^3 density with only 94.80% opacity and a higher weight of 90 g/m^2 when compared with the U.S. aerogramme of 98.03% opacity at a lower weight of 70 g/m^2 and 0.78 g/cm^3 density.

Opacifying effect of 1-side printed white envelope papers

Cellulose, which absorbs very little light, is the essential constituent of paper. Therefore, most of the absorption power must be derived from noncellulosic components of the pulp, such as residual lignin. Blue, purple or black inks have very high absorption power,therefore, very small quantities of ink printed on 1 side of the paper will greatly increase the absorption power or opacifying effect of white envelope paper.

Table 1. Opacity, brightness, *k* and *s* coefficients, and color of commercial white envelope papers.

Specimens	Basis weight	Caliper thickness	Density	Tappi opacity	Opacity index	Brightness	Absorption coefficient	Scattering coefficient	*k* / *s*	CIE LAB (unprinted)		
	$(g/m^2)(1)$	$(mm\times10^{-2})$	(g/cm^3)	(%)(2)	(2)/(1)	(% GE)	k (m^2/g)	s (m^2/g)	$(\times10^{-3})$	L*	a*	b*
A	95	14	0.68	88.57	0.93	79.45	0.46	37.8	12	90.57	0.49	2.31
B	94	12	0.78	95.19	1.01	89.65	0.95	56.42	17	91.84	0.71	1.61
C	92	12	0.77	92.76	1.01	80.48	0.74	48.51	15	91.07	0.20	2.56
D (Printed violet ink)	95	13	0.72	96.99	1.02	74.11	2.14	47.57	45	90.50	-0.17	-0.44
E (Printed light blue pattern)	100	13	0.76	96.55	0.97	79.04	1.37	52.8	26	92.18	-0.76	-0.14
F (Printed dark green pattern)	90	12	0.75	91.15	1.06	72.15	1.38	32.17	43	88.91	-0.29	-1.37
G (Printed blue spot)	74	11.5	0.64	98.45	1.28	81.07	3.2	78.52	41	90.93	-0.29	-3.49
H (Printed green pattern)	68	10	0.68	97.44	1.43	67.96	3.22	69.33	46	89.22	-2.28	2.56
I (Printed blue pattern)	78	10.5	0.74	98.99	1.27	73.12	4.02	74.51	54	87.99	-0.58	-0.51
J (Printed blue pattern)	58	7	0.84	84.44	1.46	81.34	1.22	39	31	89.85	-0.03	-4.89
K (Aerogramme, USA)	70	9	0.78	98.03	1.4	64.41	6.48	45.3	143	82.78	-3.50	-3.84
L (Aerogramme, Taiwan)	90	8.5	1.06	94.8	1.05	78.41	1.5	53.65	28	91.73	-2.15	1.05
M (Printed blue pattern)	50	6	0.83	89.65	1.79	67.64	3.34	43.55	77	83.98	-0.95	-2.81
N (Printed black ink)	110	11	1	100	0.9	68.21	3.31	91.16	36	89.78	-1.39	5.46

In practice, Table 1 and Figure 1 indicate that ink has a pronounced effect on the opacity of paper envelopes. We found that ink on the reverse side will absorb light and that the opacifying effect may be caused from the following factors:

(i)Opacity index: Except for specimens A, E, M and N, an increase in opacity index approximately indicates an increase in opacity.

(ii)*k/s*: Except for specimen N with black ink printed on the reverse side, if the *k/s* value is greater than 20 or the weight is over 60 g/m^2, it seems that the opacity of the envelope paper increases from 92% upwards to a maximum of 98.99%. Regardless an opacity of over 85% should be available for paper envelopes.

Considering the brightness of paper specimens (see Table 1), we noted that paper N backed with black ink (CIELAB = 44.82 darker, -1.16 greener, 2.90 yellower as shown in Figure 1) has the highest opacity (100%) at the expense of its brightness (68.21%). Therefore, one should be careful of how the opacity of envelope paper is increased to avoid a reduction of brightness at a lower weight.

Wang et al. (1992) showed that green, blue, violet, and black dyes in colored papers absorb an appreciable amount of light in the visible spectrum

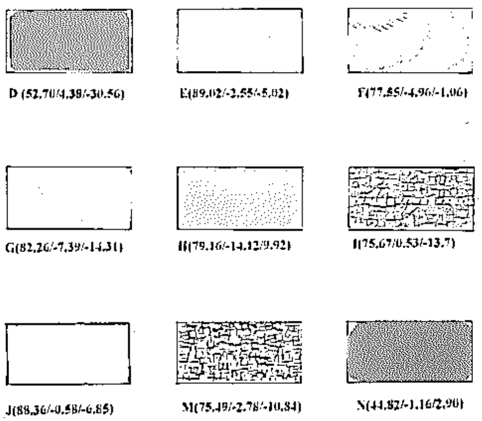

Fig. 1. Color of white envelope papers with 1-sided printing. (Figures in parentheses indicate CIE L*/a*/b* of printed side)

from 400 to 700 nm. On the other hand, certain blue, green, violet, and black inks printed on 1 side of envelope paper (Fig. 1) may result in an apparent increase in opacity without apparently altering the basis weight or brightness.

Effect of fillers on the opacity of white envelope papers

The main advantage of filling is that it improves the opacity of white envelope paper. This implies that the opacity increase results from the high scattering coefficient of fillers ,*i.e.*, clay, calcium carbonate or TiO_2 in the paper sheet.

By EDXA (Energy Dispersive X-Ray Analyzer) and Scanning Electron Photomicrograph methods, it was shown that fillers are predominantly deposited in fiber matrices (see Fig. 2 and 3). As is shown in Tables 1 and 2, the type and amount of elements in filled envelope papers vary, in other words, Ca from $CaCO_3$, Al and Si from clay, and Ti from TiO_2. As mentioned above, the TiO_2-containing paper specimen N in combination with a high-absorption-power black ink backing had the highest opacifying effect (100% opacity).

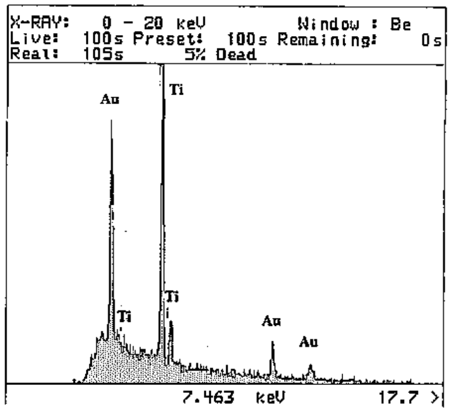

Fig. 2. Typical EDXA curve for titanium dioxide-filled paper specimen N with solid black ink printed on 1 side of bill envelope (100% opacity). Ti from titanium dioxide and Au from gold coated on paper specimen.

Table 2. Major constituents of fillers from 14 envelope papers.

Specimen	Filler composition			
	Al	Si	Ca	Ti
A	+	+	+++	
B	+	+	+++	
C	++	++	+	
D	+	++	+++	
E	+++	+++		+
F	+++	+++	++	
G			+++	
H			+++	+
I	+++	+++		
J	+	+	+++	
K	+	++		++
L	+	++		
M	++	+++	+++	
N				+++

Notes: All elements were analyzed by EDXA.
Order of amount of elements in paper: +++ > ++ > +.

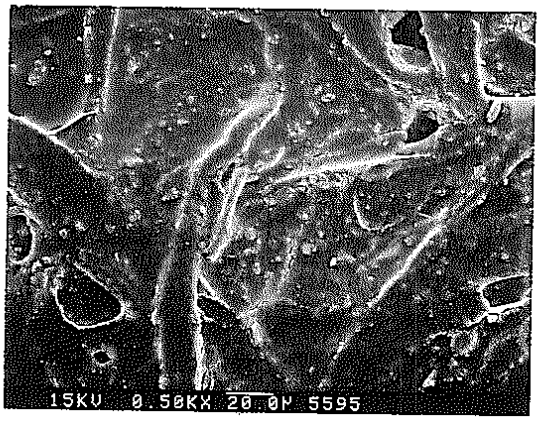

Fig. 3. Scanning electron photomicrograph of paper specimen M printed blue ink pattern (highest opacity ratio: 1.79 and lowest weight: 50g/m^2). Deep shading of the ink film and lots of filler particles can be seen on the surface of salary envelope paper.

CONCLUSION

Practically, higher opacity of white envelope papers is desired to meet the requirements of packaging, protection, and confidentiality of the enclosed material. Besides, due to increasing transportation and mailing costs, a decreased basis weight envelope paper with higher opacity is essential. The increase in the opacity of envelope paper is made more difficult by the conflict between increasing opacity and decreasing weight of paper. Considering the opacity of 14 commercial envelope papers (weights ranged 50 to 110 g/m^2) investigated in this study, on the whole, opacity gains are strongly dependent on the scattering coefficient, s, and absorption coefficient, k. The most efficient way to increase the opacity of papers as compared with conventional filled white paper at similar basis weight level is by printing high-absorption-power blue, green, and/or blacks on 1 side of the paper.

We also found that printing blue ink on 1 side of white envelope paper resulted in a marked opacity gain and also an increasing brightness to a certain extent.

REFERENCES

Casey, J. P. 1983. Pulp and paper chemistry and chemical technology. 3rd ed. Vol. 3. Wiley Interscience Publication, U.S.A. 1853pp.

Judd, D. B. 1975. Color in business, science and industry, 3rd ed. John Wiley & Sons, U.S.A. p. 444-446.

Robinson, J. V. 1975. A summary of reflectance equations for application of the Kubelka - Munk theory to optical properties of paper, Tappi 58(10): 152-153.

Rydholm, S. 1965. Pulping processes, Chapter 12. II. Optical properties of pulp. Interscience Publishers, John Wiley and Sons, New York-London-Sydney. 851 pp.

Wang, H., L.-S. Kuo, and H.-F. Lan. 1982. Effect of dyes on the opacity of papers, Pulp and Paper Monthly (Taiwan Ed.) 8: 15-21.