Acrylic Identification by Using Near-Infrared to Visible Light Transmission Ratio

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Abstract

In the utilization of the acrylic material for building constructions or medical equipments requires some criteria of good quality. The types of thickness, color and material characteristic are important things for product consumers. This paper describes the investigation result that has been done upon the some acrylic material specimens with various colors. The specific form data the acrylic has been detected and identified by putting it in a tungsten-halogen light beam scanning coverage. The measurement system is based on the two-wavelength ratio technique of visible to near-infrared absorpted radiation energy of the acrylic from the scanned area. By using scanning monochromator and a photomultiplier tube (PMT) used in the experiment. By combining with the X-Y recorder, the curve of acrylic characteristic can be plotted.

1. Theory.

The absorption is a result of contribution energy that performing conduction current at the material, general figure with power density decay (I) and thickness (S) are given by,

$$I = I_0 e^{-as} \quad (1)$$

Radiation traversing a medium (e.g. air) will be weakened by its interaction with matter. The intensity of the radiation I_λ, after traversing a distance ds, becomes $I_\lambda + dI_\lambda$, where:

$$dI_l = -k_l r I_l ds \quad (2)$$

ρ is the density of the matter traversed, and k_λ is the mass extinction cross section (area per mass) at wavelength λ. The reduction dI_λ is caused by scattering and absorption. Where scattering can be neglected (e.g.,a blackbody), then k_λ is the mass absorption cross section (or absorption coefficient).

At location $s = 0$, let $I_\lambda = I_\lambda(0)$, and we can integrate the transfer equation to a distance s_1:

$$I_l(s_1) = I_l(0)\exp\left(-\int_0^{s_1} k_l r\, ds\right) \quad (3)$$

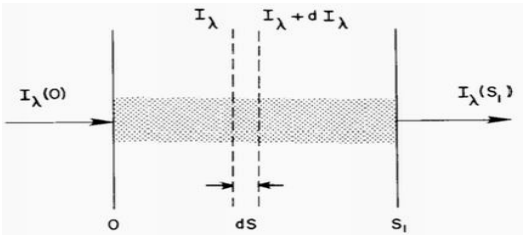

Figure 1. Depletion of the radiant intensity in traversing an absorbing medium.

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In optical system, the energy quantities to be measured are converted into an electric signal and the data results are performing by X-Y recorder. Base on figure (1), these two kinds of outputs can be written as follows,

$$g = \frac{NIR}{VIS} \quad (4)$$

where near-infrared (NIR) and visible (VIS) are the absorption spectrum from scanned objects, which are proportional to the output voltages of PMT. g is a acrylic area index that defined as a ratio of the NIR peak value to VIS peak value.

2. Experimental design.

The parts of main instrument are the optical system and the electric system. Optical system is collected the visible and near-infrared absorption energy from ANRITSU monochromator. The optical signal is converted to the electric signal by HAMAMATSU photomultiplier tube. Then, the PMT has been connected to X-Y recorder that performing of the spectrum pattern of the each specimen.

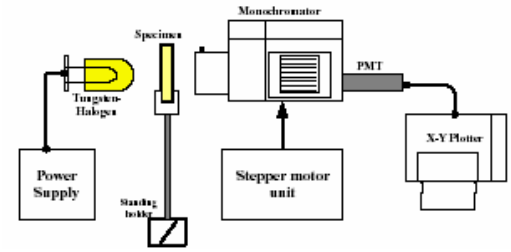


Figure 2. The experiment of the acrylic identification.

As shown in figure 2, the specimen position should be put in front of the monochromator nearly. The function of stepper motor unit is driving of the monochromator scanning speed. This experiment has been started from 200 nm until 1200 nm wavelength. Figure 3 is shown as the investigation result of 5-specimens of the acrylic.

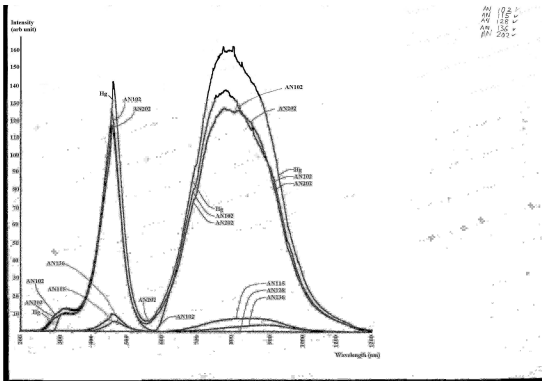


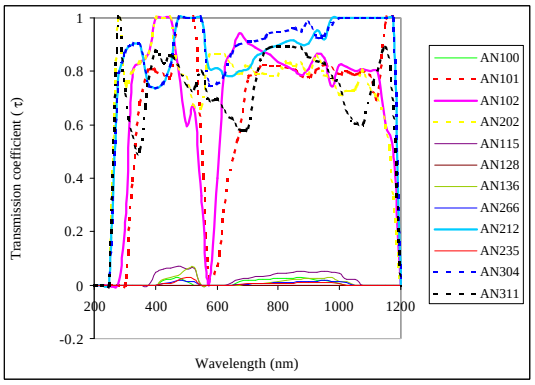
Figure 3. The plotting result of the acrylic specimens (AN102, AN115, AN128, AN136, AN202)

Figure 3 shows the tested acrylic material. According to the data from X-Y plotter, the lower intensity, so the acrylic material is non-transparent material as such as AN115, AN128, and AN136. Therefore for AN102, it could be refine the wavelength from 250 nm until 280nm.

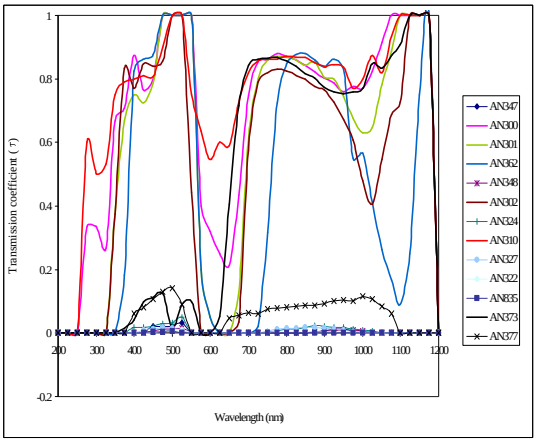
Figure 4. The acrylic specimen.

3. Result and discuss.

The result of investigation is performing two-peaks of the wavelength, there are 460 nm and 760 nm. It could be determined acrylic area index (γ). Figure 5 (a) and (b) show the graphic of the transmission coefficient on the each specimen. Table 1 described the acrylic data of the transmission coefficient that has processed from the X-Y plotter.



(a)



(b)

Figure 5 (a), (b). The graphic of theTransmission Coefficient (τ).

From the equation (4) and figure 5 (a), 5 (b), NIR and VIS will be define as

$$NIR = \frac{\Delta l}{2} \sum_{R=600}^{R=1200} \left(I_R - I_{R-1} \right) \quad (5)$$

And

$$VIS = \frac{\Delta l}{2} \sum_{V=200}^{V=600} \left(I_V + I_{V-1} \right) \quad (6)$$

So

$$g = \frac{\Delta l \sum_{R=600}^{R=1200} \left(I_R + I_{R-1} \right)}{\Delta l \sum_{V=200}^{V=600} \left(I_V + I_{V-1} \right)} \quad (7)$$

Result of from equation (7) above can be seen by at table 3. Assess NIR calculated pursuant to amount of from wavelength 600nm up to 1200nm and VIS reckoned from by wavelength 200 nm up to 600 nm. Determined value (NIR and VIS) taken away from by each; every type of acrylic.

Table 1 and table 2 are transmission coefficient value. It is made from the X-Y plotter in the each specimen, such as figure 2. In this first table exhibits not only AN128 has high absorbance but also AN115, AN136, AN235 and AN266.

Table 1. Transmission coefficient of the acrylic.

Wavelength	**Acrylic serial number**											
l (**nm**)	AN100	AN101	AN102	AN202	AN115	AN128	AN136	AN266	AN212	AN235	AN304	AN311
200	0	0	0	0	0	0	0	0	0	0	0	0
225	0	0	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0	0	0	0
275	0	0	0	1	0	0	0	0	0.75	0	0.75	1
300	0	0	0.2105	0.75	0	0	0	0	0.875	0	0.875	0.7143
325	0	0.3913	0.8	0.8	0	0	0	0	0.9	0	0.9	0.5555
350	0	0.6818	0.8333	0.8333	0	0	0	0	0.9	0	0.9	0.5
375	0	0.8069	0.8667	0.8667	0	0	0	0	0.75	0	0.75	0.7692
400	0	0.8	1	1	0.0469	0	0	0	0.7353	0	0.7353	0.875
425	0.0161	0.7846	1	1	0.0593	0	0.0231	0.0071	0.7571	0.0069	0.7571	0.8333
450	0.0234	0.7818	1	1	0.0619	0	0.0307	0.0083	0.8261	0.0082	0.8261	0.8602
475	0.03	1	0.8182	0.8095	0.0727	0	0.0378	0.0176	1	0.0172	1	0.8247
500	0.0125	1	0.6	0.7778	0.06	0	0.06	0.0135	1	0.0286	1	0.7442
525	0	1	0.6666	0.6666	0.0625	0	0.0667	0.0154	1	0.0231	1	0.7333
550	0	0.5454	0.3333	0.6666	0	0	0	0	1	0	1	0.8
575	0	0.0286	0	0.8571	0	0	0	0	0.8125	0	0.75	0.6923
600	0	0.0714	0.4	0.8667	0	0	0	0	0.8125	0	0.75	0.6956
625	0	0.3077	0.8148	0.8571	0	0	0	0	0.7875	0	0.7857	0.65
650	0	0.4651	0.8723	0.8222	0.0106	0	0	0	0.7826	0	0.8696	0.6212
675	0.0145	0.5714	0.9428	0.7917	0.0208	0	0	0.0028	0.8028	0.0028	0.9014	0.5833
700	0.0167	0.7753	0.9042	0.8191	0.0263	0	0.0053	0.0043	0.8085	0.0053	0.9111	0.589
725	0.0188	0.7917	0.888	0.7891	0.0317	0	0.0055	0.0048	0.8536	0.0056	0.9113	0.7629
750	0.0207	0.8227	0.8725	0.7919	0.0335	0	0.0067	0.0057	0.8705	0.0057	0.9209	0.8632
775	0.0225	0.8212	0.8607	0.7826	0.0377	0	0.0095	0.0069	0.8896	0.0068	0.9414	0.8898
800	0.0252	0.8212	0.8365	0.7862	0.044	0	0.0126	0.0105	0.8951	0.0069	0.9475	0.8915
825	0.026	0.8151	0.8212	0.8333	0.0463	0	0.0165	0.011	0.9118	0.0074	0.9522	0.8924
850	0.0271	0.8071	0.8055	0.8207	0.0483	0	0.0208	0.0116	0.9147	0.0077	0.9612	0.8917
875	0.0275	0.7862	0.7852	0.8283	0.0515	0	0.022	0.0125	0.9	0.0083	0.95	0.8859
900	0.0259	0.7777	0.8083	0.7886	0.0488	0	0.0244	0.0143	0.9048	0.0094	0.9808	0.8558
925	0.0191	0.8041	0.8673	0.8555	0.05	0	0.025	0.0143	0.9524	0.0095	0.9286	0.8391
950	0.0191	0.8235	0.8493	0.7857	0.054	0	0.027	0.0164	0.9193	0.0097	0.9344	0.8281
975	0.0146	0.8085	0.7451	0.7755	0.05	0	0.03	0.0143	1	0.0095	0.9756	0.7777
1000	0.0064	0.7903	0.8235	0.7143	0.0428	0	0.0147	0.0143	1	0.0074	1	0.75
1025	0	0.8	0.8182	0.7273	0.0217	0	0.0136	0.0111	1	0	1	0.65
1050	0	0.7857	0.8	0.7333	0.02	0	0	0	1	0	1	0.6071
1075	0	0.8	0.8095	0.8	0	0	0	0	1	0	1	0.6
1100	0	0.7857	0.8	0.7333	0	0	0	0	1	0	1	0.7143
1125	0	0.7	0.8	0.7	0	0	0	0	1	0	1	0.8

1150	0	1	0.6	0.6	0	0	0	0	1	0	1	0.8888
1175	0	1	0.5	0.33	0	0	0	0	1	0	1	0.6666
1200	0	0	0	0	0	0	0	0	0	0	0	0

Secondly, for AN347, AN348, AN324, AN327, AN322 and AN835 have high absorbance too. The types of the specimens that have high absorbance, it has dark color and non-transparent materials.

Table 2. Transmission coefficient of the acrylic (cont).

Wavelength	**Acrylic serial number**												
l (**nm**)	AN347	AN300	AN301	AN362	AN348	AN302	AN324	AN310	AN327	AN322	AN835	AN373	AN377
200	0	0	0	0	0	0	0	0	0	0	0	0	0
225	0	0	0	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0	0	0	0	0
275	0	0.3333	0	0	0	0	0	0.6	0	0	0	0	0
300	0	0.3333	0	0	0	0	0	0.5	0	0	0	0	0
325	0	0.2667	0	0	0	0	0	0.5333	0	0	0	0	0
350	0	0.6667	0.375	0	0	0.375	0	0.75	0	0	0	0	0
375	0	0.7083	0.6667	0.1818	0	0.8333	0	0.7917	0	0	0	0.0167	0
400	0	0.875	0.75	0.8261	0	0.7692	0.0192	0.8	0	0	0	0.0417	0.0612
425	0	0.7647	0.7255	0.8627	0	0.849	0.0185	0.8113	0.0092	0	0	0.1	0.08
450	0.02	0.8	0.7865	0.8764	0.0055	0.8387	0.0215	0.8064	0.0112	0.0022	0.004	0.1123	0.1079
475	0.0202	1	1	1	0.0112	0.8571	0.0294	0.9	0.0172	0.0056	0.0047	0.1236	0.1294
500	0.0222	1	1	1	0.0128	1	0.0333	1	0.0143	0.0054	0.0057	0.0143	0.1428
525	0.0333	1	1	1	0.0154	1	0.05	1	0.0091	0.01	0	0.0909	0.0909
550	0	1	1	1	0	0.4444	0	0.75	0	0	0	0.1	0
575	0	0.4	0.2	0.2	0	0	0	0.6364	0	0	0	0	0
600	0	0.3182	0.05	0.05	0	0	0	0.5454	0	0	0	0	0
625	0	0.25	0	0	0	0	0	0.6	0	0	0	0.0526	0
650	0	0.2121	0	0	0	0	0	0.5882	0	0	0	0.4062	0.0469
675	0	0.4339	0.1296	0	0	0.0357	0	0.7273	0	0	0	0.7169	0.0555
700	0	0.7465	0.6056	0	0	0.5753	0	0.8194	0	0	0	0.8428	0.0643
725	0	0.8526	0.8	0.0208	0	0.79	0	0.8557	0.002	0	0	0.8632	0.0625
750	0	0.8596	0.8596	0.3158	0	0.8189	0.0043	0.8621	0.0044	0.0017	0	0.8661	0.0759
775	0	0.878	0.8699	0.7236	0	0.8293	0.0081	0.8618	0.0123	0.0025	0	0.8672	0.0788
800	0	0.871	0.8669	0.8468	0	0.8238	0.0122	0.8694	0.0161	0.0032	0	0.8554	0.0826
825	0	0.8583	0.8583	0.876	0	0.8119	0.0128	0.8686	0.0167	0.0042	0.0008	0.8389	0.0847
850	0.0017	0.8435	0.8435	0.8783	0.0017	0.8	0.0177	0.8672	0.0173	0.0043	0.0017	0.8158	0.0877
875	0.0035	0.8219	0.8527	0.8584	0.0037	0.7757	0.0235	0.8505	0.0183	0.0046	0.0009	0.8009	0.0879
900	0.0077	0.8016	0.8061	0.8367	0.0061	0.7659	0.0213	0.8404	0.0153	0.0041	0	0.7732	0.0928
925	0.0114	0.7875	0.8	0.8625	0.0074	0.7273	0.0195	0.8441	0.0128	0.0038	0	0.7595	0.1013

950	0.0125	0.7586	0.7458	0.8305	0.0102	0.6727	0.0182	0.8364	0.0088	0.0037	0	0.7544	0.1053
975	0.0046	0.775	0.675	0.55	0.0093	0.6053	0.0128	0.7692	0.005	0.0025	0	0.7595	0.1026
1000	0.0032	0.7692	0.6296	0.566	0.0077	0.48	0.01	0.8	0.0038	0	0	0.7692	0.1154
1025	0	0.8235	0.647	0.4118	0	0.4062	0.0063	0.875	0	0	0	0.8485	0.1071
1050	0	0.913	0.7826	0.2609	0	0.5454	0	0.8182	0	0	0	0.8333	0.0833
1075	0	1	0.8888	0.1667	0	0.6875	0	0.9333	0	0	0	0.875	0.0625
1100	0	1	1	0.0909	0	0.7273	0	1	0	0	0	0.9091	0
1125	0	1	1	0.25	0	1	0	1	0	0	0	1	0
1150	0	1	1	0.75	0	1	0	1	0	0	0	1	0
1175	0	1	1	1	0	1	0	1	0	0	0	1	0
1200	0	0	0	0	0	0	0	0	0	0	0	0	0

In thirdly, It has get data that could be found NIR and VIS values as shown in equation (5) and (6). The visible wavelength and near infrared wavelength are 200-600 nm and 600-1200 nm respectively, as seen as in table 3.

Table 3. The result of g is get from each specimen.

No	Acrylic Serial Number	NIR	VIS	γ
1	AN100	0.2850	0.0820	3.4756
2	AN101	17.7310	7.3295	2.4191
3	AN102	19.0090	8.1206	2.3408
4	AN202	18.3325	10.0276	1.8282
5	AN115	0.6483	0.3633	1.7844
6	AN128	0	0	0
7	AN136	0.2336	0.5585	0.4183
8	AN266	0.1550	0.0619	2.3417
9	AN212	23.1679	11.3060	2.0491
10	AN235	0.1020	0.0840	1.2143
11	AN304	22.7918	11.2935	2.0271
12	AN311	17.3990	8.8848	1.9583
13	AN347	0.0446	0.0957	0.4660
14	AN300	18.5740	9.1480	2.0304
15	AN301	16.7110	7.5037	2.2270
16	AN362	11.1457	6.9470	1.6044
17	AN348	0.0461	0.0449	1.0267
18	AN302	14.8782	6.9667	2.1356
19	AN324	0.1667	0.1719	0.9697
20	AN310	11.0474	9.8791	1.1183
21	AN327	9.1473	0.0610	149.9557
22	AN322	0.0346	0.0232	1.4914
23	AN835	0.0034	0.0144	0.2361
24	AN373	18.2077	0.5995	30.3715
25	AN377	1.4971	0.6122	2.4454

4. Conclusion.

The acrylic material is divided by non-transparent and transparent type. The non-transparent has low transmission and will result high absorption level. Therefore transparent material, which has high transmission level, will lower the absorption level.

The acrylic material is also as a particular wavelength filter. Table 3 shows if acrylic area index (γ) less than 1 the material will absorb more light and the other hand, the material such as AN128, AN347, AN324, AN835 indicate that the acrylic material cannot be use as the wavelength filter.

By using wide of trapezium will be got by wide of comparison of infra-red wavelength area broadly visible wavelength area.

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