COLOR CHARACTERISTICS OF Cu-Zn-Al ALLOYS①

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ABSTRACT

The changing law of the color characteristics of Cu-Zn-Al alloys with their compositions has been researched systematically and quantitatively. The results show that with an increase in Zn and Al content, the lightness value and yellow content of an alloy increase first to a certain extent and then decrease, while the red content decreases first to a certain extent and then increases; the alloy color changes from copper red to golden yellow, yellow, grey brown, pink, and silver grey. By adjusting Zn and Al content, a series of alloys with 14K or 18K alloy colors can be obtained, but those with 24K gold color can not be obtained.

Key words: Cu-Zn-Al alloys color chromaticity parameters color difference

1 INTRODUCTION

Previous work[1] has shown that Al and Zn are the most reasonable color mixing elements when the alloys with the three kinds of karat gold colors (14K, 18K and 24K gold) are imitated. But the alloys with the three kind of karat gold colors can not be obtained in the binaries of Cu-Zn and Cu-Al, therefore it is necessary to approach the color characteristics of ternary Cu-Zn-Al alloys.

2 EXPERIMENTAL

The content change range of Zn and Al is (0 ~ 50)% and (0 ~ 16)% respectively. Each 5% for Zn is selected as one experimental point and each 2% for Al. The experimental alloy compositions obtained are shown in Table 1.

The experimental alloys were melted and cast into moulds, yielding slabs 42 mm × 42 mm × 7 mm. The as-cast slabs were machined, ground, and polished to a surface finish of 9—10 grade, then rinsed in alcohol and dried in desiccator. The testing researches were performed within 24 h after the samples were finally polished and rinsed.

Table 1 Compositions of Cu-Zn-Al experimental alloys (wt. -%)

Alloy No.	Zn	Al	Alloy No.	Zn	Al
0#	0	0	31#	20	4
1#	5	0	32#	25	4
2#	10	0	33#	30	4
3#	15	0	34#	35	4
4#	20	0	35#	40	4
5#	25	0	36#	45	4
6#	30	0	37#	5	6
7#	35	0	38#	10	6
8#	40	0	39#	15	6
9#	45	0	40#	20	6
10#	50	0	41#	25	6
11#	0	2	42#	30	6
12#	0	4	43#	35	6
13#	0	6	44#	40	6
14#	0	8	45#	5	8
15#	0	10	46#	10	8
16#	0	12	47#	15	8
17#	0	14	48#	20	8
18#	0	16	49#	25	8
19#	5	2	50#	30	8
20#	10	2	51#	5	10
21#	15	2	52#	10	10
22#	20	2	53#	15	10
23#	25	2	54#	20	10
24#	30	2	55#	25	10
25#	35	2	56#	5	12
26#	40	2	57#	10	12
27#	45	2	58#	15	12
28#	5	4	59#	5	14
29#	10	4	60#	10	14
30#	15	4			

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The spectral reflectance-wavelength curves of all samples were measured on a DMR- 22 spectrophotometer. The D65 standard light source and the 0/t observing and measuring condition were adopted. The chromaticity parameters, namely, the L^*, a^* and b^* values, of all samples in the CIE1976 $L^*a^*b^*$ uniform color space were obtained by computer processing according to the colorimetric formulae concerned[2]. In order to compare the color differences between samples and the three kinds of karat alloys under the same conditions, the chromaticity parameters of gold alloys given by Ref. [3] were adopted.

3 RESULTS AND ANALYSIS

The chromaticity parameters of the three kinds of karat alloys are shown in Table 2.

Table 2 Chromaticity parameters of three kinds of karat alloys

Karat Alloys	chromaticity parameters			
	L^*	a^*	b^*	c^*
14K	88.21	1.22	21.85	21.88
18K	85.88	4.73	23.52	23.99
24K	79.80	7.83	27.93	29.00

The chromaticity parameters of all samples and the color differences between each sample and the three kinds of karat alloys are shown in Table 3, where the $\triangle E^*24$, $\triangle E^*18$, and $\triangle E^*14$ values represent the color differences between a sample and 24 K, 18 K, and 14 K gold respectively. The relationship between the variation in L^*, a^* and b^* values and the variation in Zn and Al content is shown in Figs. 1—3, and the relationship between the variation of alloy colors and the variation in Zn and Al content are shown in Fig. 4.

Figs. 1—3 show that with an increease in Zn and Al content, the L^* value and b^* value of an alloy increase first to a certain extent and then decrease, on the contrary, the a^* value decreases first to a certain extent and then increases. This indicates that increasing Zn and Al content within certain range increases the lightness value and yellow content of an alloy but decreases the red content, thereby making alloy color change towards the three kinds of karat alloy colors; increasing Zn and Al content continuously will make the lightness value and yellow content of an alloy begin to decrease while the red content begins to increase, thus making alloy color change against the three kinds of karat alloy colors. Such a change law of the chromaticity parameters results in the following color change law of Cu-Zn-Al alloys (Fig. 4).

For the low-Zn and low-Al portion of α phase ($a^* > 7.8$), neither the red content nor the yellow content of an alloy is within the range of the chromaticity parameters of the three kinds of karat alloys. At the same time the red content is more whereas the yellow content is less (as compared with the chromaticity parameters of the three kinds of karat alloys, similarly hereinafter), therefore the alloy color is still copper red. For the low-Al and medium-Zn portion of α phase ($a^* < 1.2$), the yellow content of an alloy is close to that of 18 karat gold, but the lightness value is relatively high and at the same time there is little red content, thus the alloy color is pure yellow, i. e. the alloys are brass worthy of the name. For the other α phase, $\alpha + \beta'$ phase, and β' phase, the chromaticity parameters, i. e. the L^*, a^* and b^* values, of an alloy are within those of the three kinds of karat alloys, therefore the alloy color is golden yellow (yellow touched with red). For the $\beta' + \gamma$ phase and its neigbouring $\alpha + \beta' + \gamma$ phase, the yellow content of an alloy is less, having been less than that of coppper ($b^* < 18.2$), while the red content is more (the a^* value is close to or greater than 7.8), therefore the alloy color is pink. For the $\alpha + \gamma$ phase and its neigbouring $\alpha + \beta' + \gamma$ phase, the L^*, a^* and b^* values of an alloy are relatively low, therefore the alloy color is grey brown. For the γ phase, the alloy color is silver grey.

Table 3 shows that the minimum of $\triangle E^*24$ values is 6.28, which means a large color difference between the alloy colors and 24 karat gold color. Furthermore, the change tendency of the L^*, a^* and b^* values in Figs. 1—3 shows that the alloy whose L^*, a^* and b^* values are close to those of 24 karat gold can not be found out. Therefore the alloy with 24 karat gold color can not be obtained in Cu-Zn-Al alloys. It can be seen from the $\triangle E^*18$ and $\triangle E^*14$ values in Table 3 that the minimum of $\triangle E^*18$ values is 1.27 (the corresponding alloy

Table 3 Testing results of Cu-Zn-Al experimental alloys (D65 standard light source, 0/t condition, polished surface)

Alloy No.	L^*	a^*	b^*	ΔE^*24	ΔE^*18	ΔE^*14
0#	81.53	14.08	18.22	11.68	11.59	14.94
1#	83.96	11.04	15.96	13.07	10.03	12.21
2#	86.84	7.61	18.90	11.45	5.53	7.17
3#	87.51	5.16	20.10	11.31	3.81	4.37
4#	85.56	3.28	22.35	9.22	1.89	3.39
5#	90.34	-1.27	21.93	15.16	7.64	3.28
6#	88.96	-1.60	24.12	13.32	6.59	3.31
7#	89.00	-0.08	23.09	13.07	5.76	1.97
8#	87.84	2.07	22.69	11.20	3.41	1.57
9#	87.57	3.44	22.45	10.47	3.13	2.40
10#	87.72	4.45	22.04	10.47	2.36	3.15
11#	85.88	9.78	18.13	11.69	7.38	9#62
12#	86.44	7.13	19.20	10.99	4.97	6.71
13#	87.61	6.11	22.39	9.73	2.49	4.96
14#	85.50	5.21	2.41	8.35	1.27	4.86
15#	86.01	4.10	20.22	10.57	3.35	3.97
16#	84.53	3.64	17.08	12.55	6.66	6.49
17#	82.65	3.54	14.13	14.73	10.00	9.85
18#	81.84	3.42	13.01	15.72	11.33	11.11
19#	82.50	9.77	18.72	9.79	7.74	10.75
20#	87.20	4.99	22.42	9.66	1.74	3.94
21#	88.56	2.19	24.69	10.31	3.88	3.02
22#	89.50	-0.16	24.70	12.97	6.20	3.41
23#	87.57	0.41	24.64	11.24	4.78	2.97
24#	87.44	2.16	22.90	10.77	3.06	1.60
25#	86.56	3.55	22.49	9.67	1.70	2.92
26#	86.66	5.42	22.18	9.27	1.70	4.49
27#	84.46	9.41	13.56	15.18	11.09	12.24
28#	84.20	4.95	24.28	6.28	2.02	6.12
29#	88.49	1.67	23.36	11.59	4.02	1.60
30#	88.59	1.01	23.17	12.10	4.61	1.39
31#	86.65	2.55	23.32	10.31	2.60	2.11
32#	85.99	3.45	21.61	9.87	2.30	3.15
33#	86.56	3.78	21.58	10.12	2.27	3.06
34#	83.50	11.36	17.54	11.58	9.24	11.98
35#	82.63	10.21	9.59	18.70	14.50	16.20
37#	87.18	3.59	22.45	10.13	2.04	2.65
38#	87.24	3.59	21.92	10.45	2.38	2.57
39#	86.41	3.37	19.24	11.80	4.52	3.83
40#	86.88	3.34	17.93	13.05	5.60	4.65
41#	85.61	5.97	17.24	12.31	6.41	7.11
42#	82.99	10.11	13.06	15.38	12.12	13.55
43#	81.42	9.36	8.52	19.54	16.32	17.03
45#	87.01	3.04	21.66	10.68	2.76	2.29
46#	86.06	3.29	18.28	12.37	5.44	4.65
47#	86.04	3.01	17.06	13.43	5.69	5.56
48#	83.86	5.27	15.51	13.31	8.28	8.70
49#	83.87	10.10	9.19	19.31	15.44	16.07
50#	81.06	8.73	7.20	20.79	17.48	17.95
51#	85.52	3.12	18.34	12.12	5.43	4.81
52#	84.44	3.42	14.42	15.20	9.58	8.86
53#	83.74	3.47	8.82	19.99	14.91	13.96
54#	82.46	7.64	8.66	19.45	15.52	15.76
55#	83.40	3.50	9.98	18.81	13.82	13.01
57#	83.32	3.38	8.05	22.61	17.71	16.69
59#	82.37	3.44	8.86	19.71	15.13	14.14

composition is Cu-8%Al) and that of ΔE^*14 values is 1.39, which mean that among the alloys investigated, those with 18K or 14Kt gold colors can not be obtained either. But the change tendency of the L^*, a^* and b^* values in Figs. 1—3 shows that a series of alloys whose L^*, a^* and b^* values are close to those of 18K or 14 K gold can be found out. Therefore a series of alloys with 18K or 14 K gold colors can be obtained in Cu-Zn-Al Alloys.

4 CONCLUSIONS

(1) The changing law of the chromaticity parameters of an alloy color with increasing Zn and

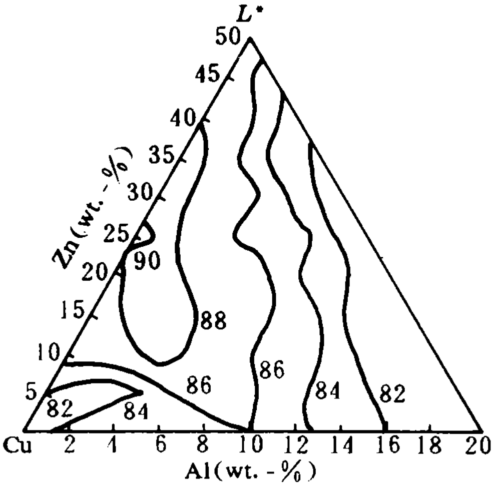

Fig. 1　Variation law of L^* values

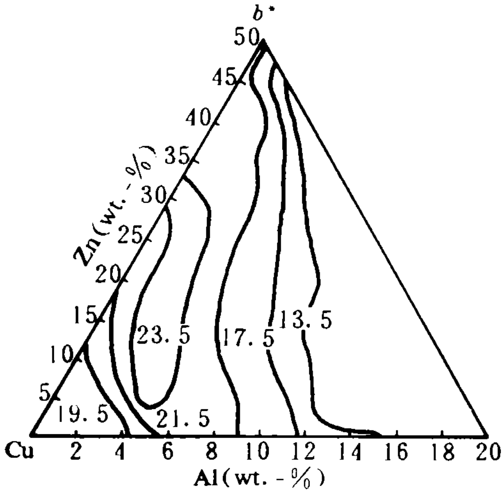

Fig. 3　Variation law of b^* values

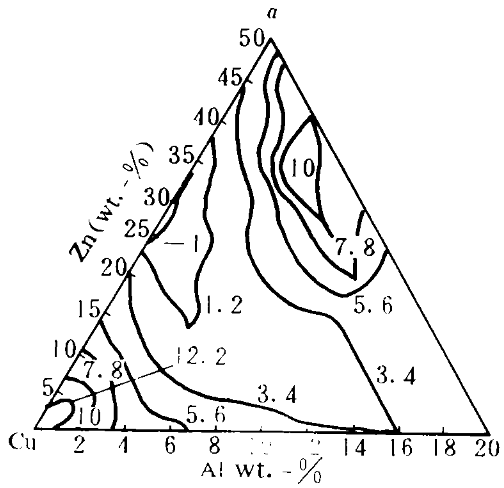

Fig. 2　Variation law of a^* values

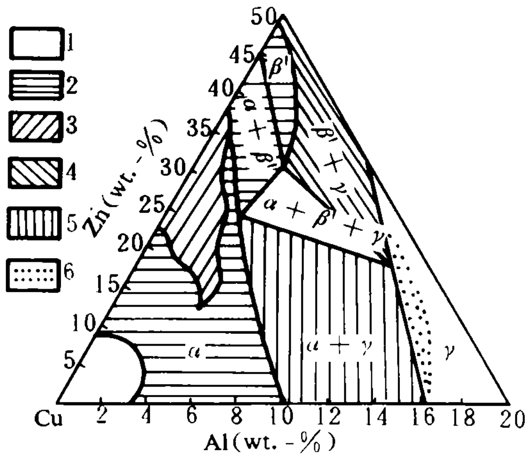

Fig. 4　Variation law of alloy colors

1—copper red; 2—golden yellow; 3—yellow; 4—pink; 5—grey brown; 6—silver grey

Al content is that the lightness value and yellow content increase first to a certain extent and then decrease, on the contrary, the red content decreases first to a certain extent and then increases.

(2) The alloy color can change from copper red to golden yellow, yellow, grey brown, pink, and silver grey with varying Zn and Al content.

(3) By adjusting the Zn and Al content, a series of alloys with 18K or 14K gold colors can be obtained, but those with 24K gold color can not be obtained.

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