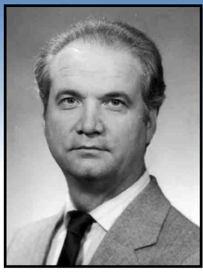

Advice & Counsel

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Training Columbo Returns: Why Are Some Metals Colorful?

After a brief hiatus to take care of some MP&M Issues, we are returning to our efforts at "training" metal finishing troubleshooters. This month we have a very basic question to answer:

Dear Advice & Counsel,

I work in a facility that conducts precious metals plating on various jewelry items. I am a recent hire, and I have three very simple questions:

1. Why are some metals such as copper and gold a color, while most metals are simply grey?
2. Is the eye the best judge of color?
3. What makes different gold alloys different colors?

Signed,
Goldie Azure Verde

Dear Ms. Verde,

I must admit that had I not read some articles on the subject in a magazine called *The Gold Bulletin*. I might be ill equipped to give you an answer. The article cited at the end of this article was most educational on this subject.

The Formation of Color in Metals

The only two metals that exhibit color are copper and gold. Production of various colors of gold alloys can be traced back to as early as 862 B.C.

Metals exhibit a color by the reflection or absorption of different wavelengths of light. Shown in Fig. 1 is an illustration of the visible spectrum, which has a wavelength range of 380–780 nm. The color exhibited by a metal or alloy is dependent upon the electron structure of the atoms of the metals present at the surface. When light impacts the surface of some metals, electrons present on the surface of the metal may go into an excited state, absorbing some wavelengths and emitting others, depending on the atomic orbits involved. If all wavelengths are

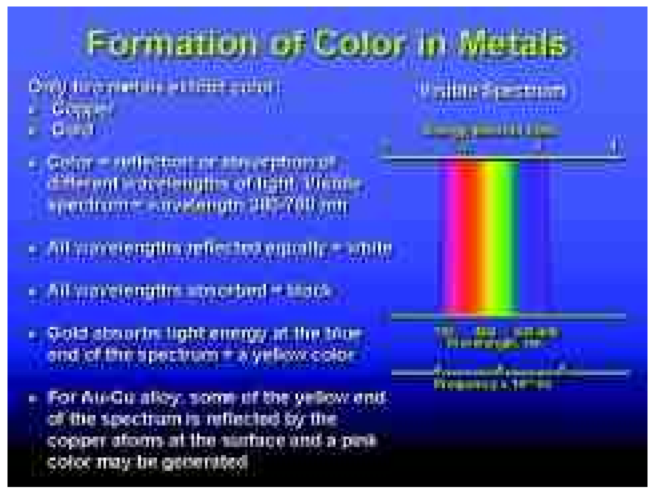

Fig. 1—Visible spectrum of color range in metals.

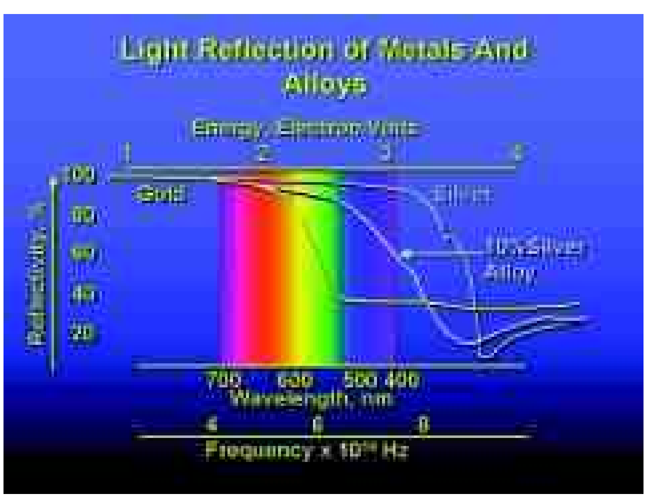

Fig. 2—Illustration of level of reflection of wavelengths across spectrum.

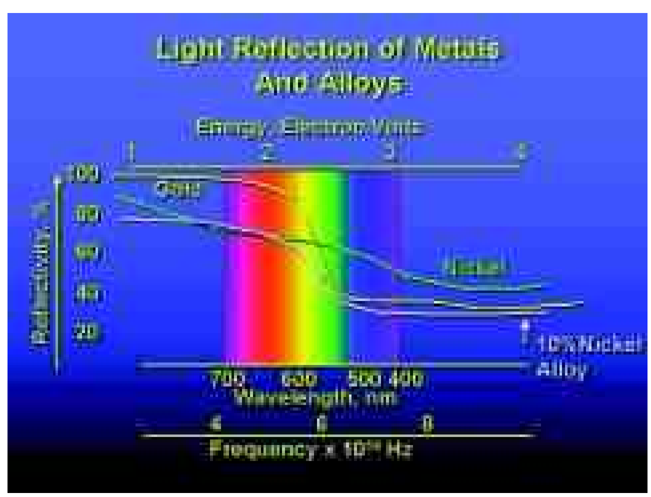

Fig. 3—Illustration for nickel, gold and an alloy of the two metals.

Fig. 4—International color measurement system.

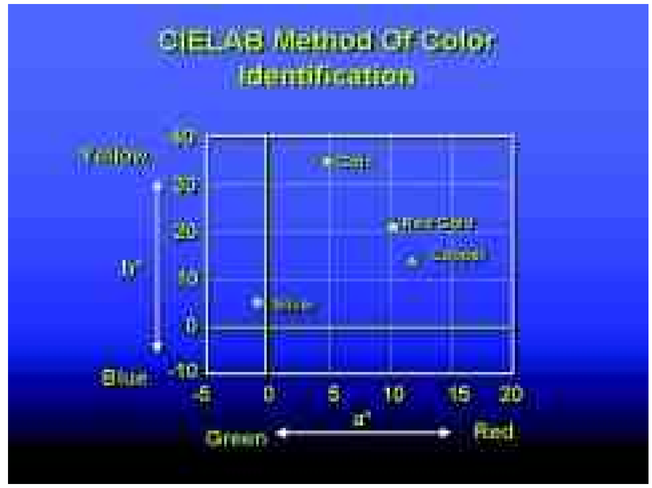

Fig. 5—Color data plotted with a special spectrophotometer.

reflected equally, a white color results. Gold tends to absorb light energy at the blue end of the spectrum, leaving a yellow color. However, if gold is alloyed with copper, some of the yellow end of the spectrum is reflected by the copper atoms at the surface and a pink color may be generated, depending on the number of atoms of copper at the surface, which is, of course, related to the alloy composition.

Shown in Fig. 2 is the visible spectrum with curves illustrating the level of reflection of individual wavelengths of light across the spectrum. A "white" metal such as silver (top curve) tends to reflect all wavelengths of light across the visible spectrum, while gold absorbs the light at the blue end of the spectrum yielding a yellow color.

An alloy of silver and gold can, therefore, be expected to yield a reflection curve somewhere between the two curves for the pure metals (depending upon the alloy composition for the most part), and this is exactly what is found. More green and blue wavelengths are reflected, resulting in lighter yellow-gold color.

Shown in Fig. 3 is the visible spectrum with curves illustrating the level of reflection of individual wavelengths of light across the spectrum, along with reflection lines for nickel, gold, and an alloy of these two metals. In this case, a more green-gold color is produced by the suppression of more of the red-yellow (left side) portion of the spectrum (vs. pure gold). Here, the alloy reflection curve does not fall between the two metals. The actual reflection curve is a result of complex light-atomic structure and the number of electrons at various energy levels.

Measuring Color

For many years, measuring color was left to the human eye, resulting in misinterpretations of color and inconsistencies between assembled components. In fact, the difficulty in detecting color differences between plated components created the "colorist" who specialized in the ability to reproduce various shades of color in gold electroplates.

To produce consistent color interpretations, the International Commission on Illumination developed the CIELAB color measurement system.

CIELAB is recognized internationally and by ASTM. It describes a color based upon a three-dimensional set of coordinates, L*, a*, and b* (as shown in Fig 4), where:

L* = Luminance, measured from 0 (no light) to 100 (all light reflected)
a* = intensity of green (negative) or red (positive) part of spectrum
b* = intensity of blue (negative) or yellow (positive) part of spectrum

The CIELAB system replaces the human eye with a spectrophotometer yielding reproducible results. Often the eye can not distinguish the nuances of color difference readily indicated by this instrument. Figure 5 shows a series of plot data points that would be obtained if various metals were placed up against a special spectrophotometer that is designed to measure CIELAB parameters.

By making a measurement and recording the a* and b* coordinate values (along with intensity "L" which is not shown in this plot), a permanent record of the color of a surface is obtained. Variations in processing conditions can now be made, and the effect of those variations on the color can also be recorded. For example, if a slight adjustment in free cyanide content resulted in a movement of the color coordinated in the desired direction, then that parameter is adjusted and controlled accordingly.

This spectrophotometer and the CIELAB data can and is used in other electroplating applications, where color matching is critical.

P.S. You should consider attending the next offering of the new AESF course "Precious And Related Metals Plating," as this subject along with numerous other jewelry related plating topics are covered. Contact AESF for a schedule. ***P&SF***

Reference

Cristian Cretu & Elma van der Lingen, "Coloured Gold Alloys," *Gold Bulletin*, 1999, **32** (4).