Carbon film thickness determination

The accurate control of the thickness of evaporated carbon films. (From the MSA email list archives)

In the first edition of "Electron Microprobe Analysis" of S.B.J. Reed (Cambridge University Press 1975) you can find the next table.

For Carbon on polished brass:

Thickness in nm	Colour
15	Orange
20	Indigo red***
25	Blue
30	Bluish green
35	Green blue
40	Pale green
45	Silver gold

We determined the thickness with our thin layer program and found out that the values were very good. The table is not found in newer editions of Reed's book.

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*** DAC note. Indigo is considered an archaeic. It descibes a color between violet (~400-440nm) and blue (~440nm-490nm).*

Wikipedia [indigo]: *Indigo is the color on the electromagnetic spectrum between about 450 and 420 nm in wavelength, placing it between blue and violet. Color scientists do not usually recognize indigo as a significant color category, and generally classify wavelengths shorter than about 450 nm as violet.*

Indigo and violet are different from purple, which cannot be seen on the electromagnetic spectrum but can be achieved by mixing mostly blue and part red light.

One can see spectral indigo by looking at the reflection of a fluorescent tube in a non-recordable compact disc. This works because the CD functions as a diffraction grating, and a fluorescent lamp generally has a peak at 435.833 nm (from mercury), as is visible on the fluorescent lamp spectrum.

We also find the red->blue transistion the most easily recognized and the most consistent, even for a multiple-user facility ... and altho it may be considered a bit thick, the transistion is sharp enough to use for EPMA without need for coating standards and unknowns at the same time. However, for the sake of clarification ... the Mineralogy reference would imply "blue" is 24nm ... are you claiming the red->blue transistion (i.e., "purple") is 24nm?? We have been writing our technique up as 22(+/-1)nm.

cheerios, shAf :o)

A clarification on determination of the thickness of carbon films (from A. Eades)

I agree with Jim Darley when he says “However, for most applications it is rather more convenient to determine thickness at the time of coating with fairly good accuracy.” What I find hard to understand is the assumption he and other contributors to this thread have made that the interference color method allows you to evaporate carbon of only one thickness. The brass (or in the method I gave, gold) test sample has always the same thickness of carbon but the thickness of carbon on the sample can be what you like. The idea is that the brass/gold test piece is placed at a distance from the source which is different from the distance between the source and the sample to be coated. Then the thickness on the sample can be calculated from the inverse square law. When I first used this technique, I used it to apply a coating only 1 nm thick.

Principle. When carbon is deposited onto gold, it forms interference colors that are well defined. They can be used to determine the thickness of the carbon.

Colors. If carbon is evaporated onto gold, as the thickness of the carbon increases, the color changes through the following sequence: gold, orange, red, blue, grey. The change of color from red to blue is particularly sharp and clear. The change of color from red to blue occurs when the thickness of the carbon is 24.0 nm +/- 0.5nm. This result was obtained by people at Balzers using a multibeam interference technique for calibration.

Details.
1) Take a glass slide (or any other suitable substrate) and evaporate onto it a layer of gold. The thickness is not critical as long as the gold is thick enough to give an opaque film that looks like gold. Alternatively, freshly polished brass is a very good approximation of a true gold substrate.

2) Mount the slide in the same chamber with the specimen to be coated with carbon. The thickness of the carbon on the slide will be 24 nm (at the specified color transition) so arrange the distance of the slide and the sample so that (by the inverse square law) the desired thickness on the sample will occur when the thickness on the slide is 24 nm.

3) Evaporate the carbon; stop the evaporation as the color changes form red to blue. If you are using a normal arc for the carbon evaporation, the light from the arc will allow you to see the colors. The bell jar will need to be reasonably clean.

Example. Suppose you need to deposit a carbon film of thickness T nm. Let d be the distance from the carbon arc to the gold slide; let D be the distance from the carbon arc to the specimen. Then [d/D]squared = T/24.

Reference: My thesis (1967).

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Notes (dac).

The Eades equation can be re-worked to a more useful form giving the distance of the sample (**D**) <relative to> the distance to the indicator polished brass disk (**d**). Note that the 24 in the equation is the specified indicator transition thickness (a constant), and **T** is the desired sample coating thickness. The distance **d** can be any reasonable distance*, and **D** will then be relative to that distance. For instance, if **d** is set to 10 cm and this is taken as the "unit distance" then solving for a desired thickness of 6 nm yields a value of 2.0 for **D**, or 20 cm actual distance from the source.

$$d/D = (T/24)^{-2}$$

and since **d** is taken as a relative "1.0" distance units, let **D*** be the proportional distance to sample:

$1/D^* = (T/24)^{-2}$, and $D^* = ((t/24)^{-2})^{-1}$

Checking this formula:

T (nm)	d (arbitrary unit)	D*	D (for d = 5cm)
24	1	1	5 cm (for same thickness, same distance)
6	1	2	10 cm (for 0.25 thickness, double distance)
3	1	2.8	14.14 cm

D* is dimensionless proportional value

Notes:

With small evaporator chambers be cautious of reflections changing the results expected from the basic geometric relationships of these equations.

*A larger value of **d** will require more mass of carbon to be evaporated, but too small a value of **d** will make the transition colors on the indicator disc progress too fast to control the thickness easily.

Substrates can be placed on slightly varying heights near the distance (d*D) so that small variations in **T** are achieved within a run.

A small indicator strip of white paper partially covered by the sample or other mask gives a permanent grayscale record that can be taped into a notebook.

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