Deposition and characterization of far-infrared absorbing gold black films

Donna J. Advena, Vincent T. Bly, and J. Thomas Cox

A process is described for producing gold black films with high absorptance in the far IR. The optical and electrical properties of these films have been studied with particular emphasis on the absorptance of films at wavelengths as long as 50 μm. A substantial decrease in absorptance near 50 μm has been observed for pure gold black films on aging in air. This degradation can be largely avoided by alloying the gold with a small percentage of copper during the deposition. Preliminary results on two methods for delineating gold black films are also presented.

Key words: Gold black, absorptance, far infrared, optical.

1. Introduction

Metal blacks were first discovered to be good absorbers of IR radiation by Pfund in the 1930's.[1,2] Similar black films based on gold and other metals were investigated extensively by Harris and others in the 1950's and 1960's.[3–6] Most optical measurements on these films did not extend beyond wavelengths of ~15 μm. Measurements at longer wavelengths were made on blacks deposited onto very thin plastic membranes. Although significant absorption was measured,[6,7] the absorption mechanism at wavelengths greater than the thickness of the black was unclear. Hadley and Dennison[8] have shown that thin conducting unsupported films with sheet resistances of 188 Ω square^{-1} could absorb 50% of incident IR radiation. If this were the mechanism for absorption for metal blacks at long wavelengths, little absorptance would be expected when they were deposited directly onto conducting samples.

Recently there have been applications that require absorbing coatings on detectors with highly reflecting surfaces for wavelengths as long as 50 μm. Some of the applications use detectors that are very thin so that IR absorbing paints or multilayer coatings cannot be used because they have too high a thermal mass. Gold black films, which are extremely porous, have a low thermal mass and offer a possible solution. The primary goal of this study was to find a way to prepare gold black layers that would be good long-wavelength IR absorbers when deposited onto highly reflecting surfaces. It was also important to find how the properties of the gold black layers changed with time on exposure to laboratory air and when baked at moderate temperatures (70–120°C). This change is referred to as aging.

2. Apparatus

The apparatus used for the deposition of gold black is similar to that described by Harris and others.[3,9,10] A rectangular box was built that confined the gold that evaporated from the filament. A side view of the apparatus is shown in Fig. 1. The enclosure consisted of top, bottom, and back plates, machined out of aluminum, and glass sidewalls that slid into grooves at each end of the enclosure. A cold stage, mounted at one end of the enclosure, was cooled with a water–isopropanol mixture. The samples were mounted on a copper palette, shown in Fig. 2, which slid into the front section of the cold stage. A pull-up shutter located in front of the sample palette prevented gold from depositing onto the samples while the gold was premelted. Initially a side opening shutter was used. However, this resulted in a deposit that was nonuniform over the sample palette. Modifying the enclosure to incorporate a pull-up shutter eliminated the nonuniformity problem. A V-shaped tungsten filament, 0.102 cm in diameter, was mounted onto two copper electrode posts. A notched copper shield was placed in front of the filament to shield the sample palette from the heat radiated by the filament, so that the sample saw only the gold ball at the apex of the filament (see Fig. 3).

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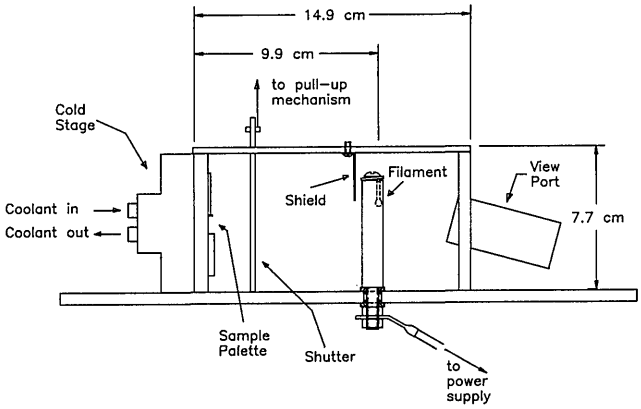

Fig. 1. Side view of the apparatus used to deposit gold black films.

A shield with no notch was tried, but this produced a nonuniform deposit on the sample palette. Therefore the rest of the deposits were made with notched shields. A tube, which served as a viewing port, was incorporated into the end plate of the enclosure opposite the sample palette. A gold-coated mirror was mounted behind the tube to permit monitoring the temperature of the gold with a hot wire optical pyrometer.

3. Procedure

The samples used for the measurement of optical properties of gold black were microscope slides coated with vacuum-deposited layers of 5 nm of chromium plus 100 nm of platinum. After they were vacuum coated, they were stored in a covered dish. They were loaded into the gold black apparatus without further cleaning. The samples used for the resistance and area density measurements were glass cover slips with vacuum-deposited strips of 5 nm of chromium plus 200 nm of gold on each end. These slips were rinsed with acetone and then methanol and blown dry with high-purity nitrogen before being loaded into the gold black apparatus.

Gold wire was wound around the apex of the tungsten filament. The gold, of 99.999% purity, 0.091 cm in diameter, was usually 1.27 cm long. Some deposits also included a small amount of copper

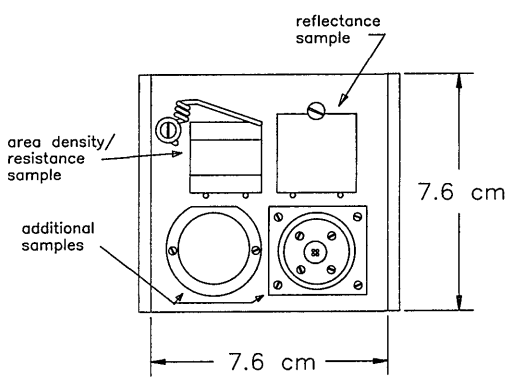

Fig. 2. Sample palette showing placement of the area density/resistance sample, the reflectance sample, and additional samples.

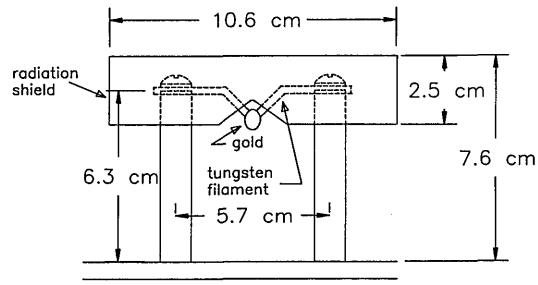

Fig. 3. View of shield and gold black filament as seen from the sample palette.

or palladium, which is described in detail below. The system was evacuated to a pressure of 6×10^{-6} Torr, and the gold wire was premelted, permitting some gold to evaporate from the filament to clean the gold of any foreign material. A circulator was then turned on to cool the samples. After the coolant temperature reached 0°C, ultra-high-purity nitrogen was let into the chamber and the pump valve was closed. The nitrogen was permitted to flow into the chamber until the desired pressure was reached. The system remained in this state for 15 min, thus permitting the samples to come to thermal equilibrium with the cold plate by means of conduction through the nitrogen. A tungsten seven-turn helix was then heated for 1 min to getter any oxygen that may have been in the gas.[9] Most of the evaporations were performed at 2.5 Torr of nitrogen, as read by a Granville–Phillips 275 convectron gauge. Other pressures were tried but did not yield desirable results. At 1 Torr the area density was much too low, ~50 μg/cm², and the film was only 5 μm thick. A pressure of 5 Torr yielded results that are similar to those obtained with 2.5 Torr, except the gold black did not cover as large an area over the sample palette.

The deposition of the gold black was made by heating the gold alloy to a temperature of 1320°C. The current for this initial temperature was then kept constant throughout the rest of the evaporation process. The shutter was opened just after the gold black was observed depositing on the bottom plate of the enclosure. The temperature of the gold slowly increased as more gold evaporated from the filament. One deposit was made when the temperature was kept constant rather than the current. The resulting gold black film had properties similar to the films made at a constant current, except that the area density was 10% higher and the evaporation time was approximately doubled.

The procedure used in the present work differed from that of others in two respects: (1) The 15-min time delay after letting in the nitrogen was incorporated to ensure cooling of the samples. (2) We always evaporated the gold to completion to obtain reproducible results.

The average evaporation rates for a 1.27-cm length of gold were 0.303 ± 0.056 mg/s for pure gold and 0.307 ± 0.058 mg/s for gold with 1% copper. The average deposition rates were 0.144 ± 0.028 μg/cm² s

for pure gold and 0.160 ± 0.027 μg/cm² s for gold with 1% copper. These rates are somewhat lower than the rates used by others.[3,4,9] In this study we found that as the rate of evaporation was increased, less deposit was usually received at the sample palette. It is believed that the excess gold black deposited on surfaces closer to the filament.

4. Aging of Gold Black Films

The aging of the gold black films was done primarily in air. The films either were allowed to sit in the laboratory for a few days or were heated to some elevated temperature for a few hours immediately after the first measurements. The temperatures used for baking the films were 70, 90, and 120°C. We found that baking pure gold black films at 70°C had generally the same effect as aging at room temperature for a few days. The only real difference was that 70°C stabilized the films immediately, whereas room-temperature stabilization took a few days. During the aging process at 70°C the properties of the films changed. For example, the reflectance at long wavelengths (near 50 μm) increased from 5% to 15%. However, for films baked at 120°C, there was a much greater change in reflectance from 5% to ~75%. Harris[9] has stated that the addition of a small amount of another metal to form an alloy would largely inhibit this degradation. The first alloying metal chosen in this present study was palladium. It was selected because it has nearly the same vapor pressure at the same evaporation temperature as gold. However, it was soon discovered that palladium alloys with the tungsten filament, causing it to crack and burn out after one or two runs. Copper was then chosen and used with great success. Even at the higher temperatures of 120°C the gold–copper alloy films remained stable with little increase in reflectance. The usual amount of copper evaporated with the gold was 1%. A few deposits were also made with 3% copper. The results of the properties of alloyed gold blacks are discussed below.

During the aging studies it was observed that there was a statistical relationship between the relative humidity at the time of loading the vacuum system and the amount of degradation during aging, especially with pure gold black. An attempt was made to obtain a direct measure of this effect. Immediately after the deposition some samples were stored in vacuum, some at almost 100% relative humidity and some in laboratory air. However, no direct cause and effect could be discovered. Since these tests, made after the deposition, showed no relationship between aging and humidity, it appears that the degradation mentioned above must be a result of the variation of conditions during loading of the vacuum system or during the deposition. Other tests were tried, such as baking the vacuum system chamber, using an SiO getter, and using a liquid nitrogen cold trap. Nevertheless no direct relationship could be established. Figure 4 shows a distinct correlation between the reflectance of aged gold black and the relative humidity during loading. The straight line is a least-squares fit to the data with a correlation coefficient of 0.735. There is evidently some dependence of the aging on the relative humidity at the time of loading the vacuum system, although the mechanism is not clear.

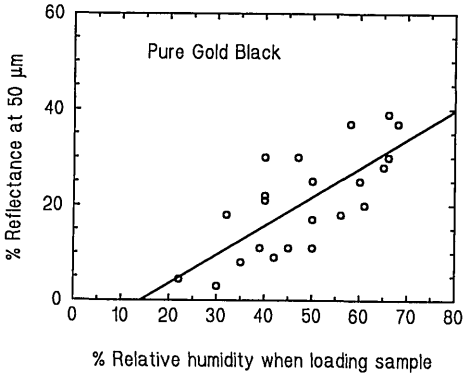

Fig. 4. Reflectance at 50 μm after aging occurs as a function of relative humidity at the time that samples are loaded into the vacuum system.

5. Electrical and Physical Properties

To understand better the properties of gold black, we measured before and after aging several parameters such as resistance, area density, and thickness. The details of these results are presented here. The optical properties were also measured, and these results are presented in Section 6.

The sample used to measure resistance was also used to determine the area density. A 22 × 22-mm cover glass, weighing ~180 mg, was coated with chromium/gold strips at opposite edges. The resistance was measured in units of ohms per square. The values for resistance measured immediately after the evaporation were twice as high as values measured after aging a few days. Also the resistance of gold black with 1% copper was ~1.3 times that of pure gold black. The resistance as a function of area density is plotted for pure gold black and gold black with 1% copper as shown in Figs. 5 and 6, respectively.

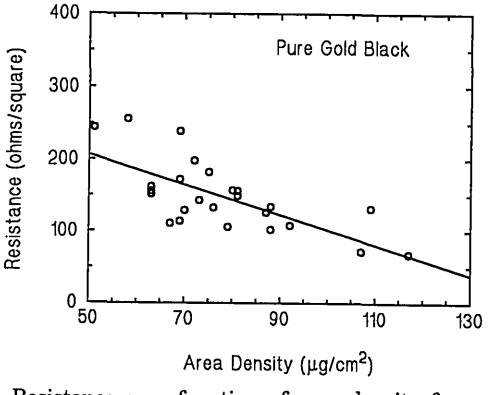

Fig. 5. Resistance as a function of area density for pure gold black.

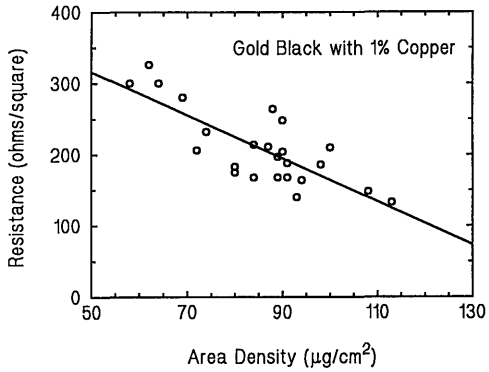

Fig. 6. Resistance as a function of area density for gold black with 1% copper.

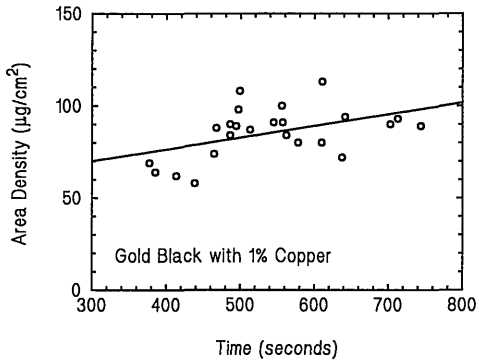

Fig. 8. Area density as a function of the deposition time for gold black with 1% copper.

The resistance decreased as the area density increased, as one would expect.

Before evaporation the area density–resistance sample was measured for mass to the nearest microgram with a Micro-Gram-Atic balance. After evaporation the sample was measured again. The difference in mass was then divided by the area coated with gold black. The area density for gold black with 1% copper was only slightly higher than that for pure gold black for the same deposition parameters. The volumetric density of the gold black was ~0.3% of the bulk density of gold. Figures 7 and 8 illustrate how the area density varied with evaporation time. For both pure gold black and gold black with 1% copper, the area density increased as the evaporation time increased.

We took thickness measurements using two approaches. One technique utilized a microscope to focus on the top and bottom of the film in transmission. The thickness was taken to be the difference in the two readings. The second approach deduced the thickness from fringes as measured on a spectrophotometer. This approach is discussed in detail in Section 6. Both approaches were in close agreement. The thickness increased as the area density increased as shown in Figs. 9 and 10. After the film aged a few days in air, the thickness decreased. This is in agreement with the fact that the resistance of the films decreases with aging. When the film thickness decreases, the gold black becomes less porous and more conductive.

Table 1 displays the average values for area density, resistance, and thickness before and after aging is performed for pure gold black and gold black with 1% and 3% copper. The gold was 0.091 cm in diameter and 1.27 cm long. The aging tended to produce a decrease in electrical resistivity and an increase in volumetric density. Table 2 displays the properties of gold black with 3% copper when various lengths of gold are used. The length of the gold varied from 1.27 to 2.54 cm. As the length increased the area density increased, the resistance decreased, and the thickness increased.

6. Optical Absorption

Most of the previous work on the optical absorption of gold black was done with the gold black deposited onto a thin membrane such as cellulose nitrate. We measured the transmittance and reflectance to find the amount of radiation absorbed. The specular and diffuse reflectance had been found to be low out to wavelengths as long as 15 μm.[6] Even at 100 μm the diffuse reflectance was <10%.[7] Therefore absorptance was assumed to be nearly equal to one minus the transmittance.

Since one of the applications that motivated this investigation required that the gold black be deposited onto a specular metal layer, it was decided to

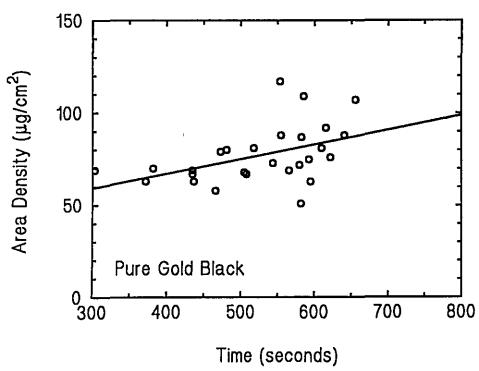

Fig. 7. Area density as a function of the deposition time for pure gold black.

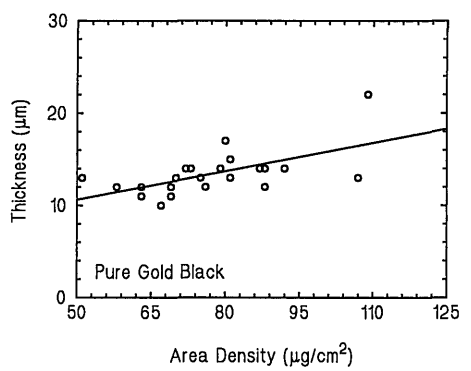

Fig. 9. Thickness as a function of area density for pure gold black.

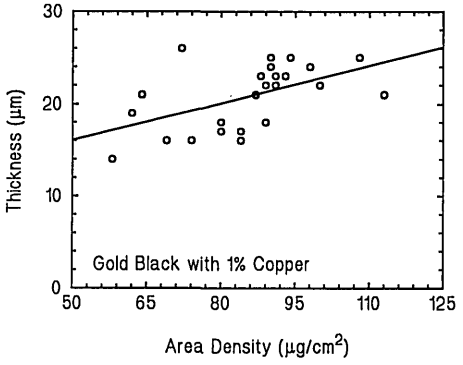

Fig. 10. Thickness as a function of area density for gold black with 1% copper.

deposit the gold black onto platinum-coated glass. Platinum was chosen because it is inert, has high reflectance in the IR, and is rather easy to deposit with an electron gun. The platinum was made to be ~100 nm thick to insure that it would be opaque in the IR. A thin chromium layer (3–5 nm thick) was deposited onto the glass just before we deposited the platinum to increase the platinum adhesion. The reflectance was measured in the wavelength region from 0.2 to 50 μm with Perkin-Elmer models 330 and 983 spectrophotometers. Since the platinum was opaque and the diffuse reflectance was considered to be low, based on information in the literature, the absorptance in this configuration was assumed to be one minus the reflectance.

In the wavelength region from 0.2 μm in the UV to 0.7 μm in the visible, the reflectance of gold black on platinum is typically <2%. From the visible to ~3 μm the reflectance gradually decreases to a very low value, <0.3%. In the region from 3 to ~8 μm the reflectance of freshly prepared gold black films on platinum remains very low. After the films aged in laboratory air for a day or two, the reflectance in the 3–8-μm region increases a few tenths of a percent. Baking fresh films in air at 70°C for 3 h has about the same effect. After this initial aging the films remain stable.

In the 8–50-μm wavelength region the reflectance of fresh films of gold black increases from the low value of 8 μm to ~5% at 50 μm. However, after aging occurs the reflectance is much more erratic, especially near 50 μm. An example of this is shown

Table 1. Average Values of Area Density, Thickness, and Resistance Before and After Aging for Pure Gold Black and Gold Black with 1% and 3% Copper

Coating	Area Density (μg/cm²)	Thickness (μm) Before Aging	Thickness (μm) After Aging	Resistance (Ω/square) Before Aging	Resistance (Ω/square) After Aging
Pure gold black	77	18	13	381	147
Gold black with 1% copper	85	27	21	457	209
Gold black with 3% copper	95	32	23	445	231

Table 2. Average Values of Area Density, Thickness, and Resistance Before and After Aging for Gold Black with 3% Copper and Varying Lengths of Gold

Length of Gold (cm)	Area Density (μg/cm²)	Thickness (μm) Before Aging	Thickness (μm) After Aging	Resistance (Ω/square) Before Aging	Resistance (Ω/square) After Aging
1.27	95	32	23	445	231
1.52	161	51	38	265	134
1.91	234	—	66	178	88
2.54	338	95	65	140	72

in Fig. 11, which gives the reflectance at 50 μm as a function of area density after aging occurs for a day in air. There is a great amount of scatter in the data with reflectances as high as 39% and as low as 3%. This is probably a result of uncontrollable variable factors such as relative humidity, microcracks in the filament, and contact resistance in the filament clamps. The solid line is a least-squares fit to the data. The correlation coefficient is low so that not much significance should be given to the slope. In Fig. 12 we show a plot of data after aging occurs. It is similar to Fig. 11, except here 1% of copper was included with the gold during deposition. Not only are the values much lower but there is much less scatter.

The reflectance of typical, aged, gold black films as a function of wavelength from 3 to 50 μm is shown in Fig. 13. The dashed curve represents pure gold black, and the solid curve represents gold black with 1% copper. The reflectance stays low for both films out to ~10 μm, then gradually increases. At the longer wavelengths, near 50 μm, the reflectance for pure gold black is nearly twice as high as for gold black with 1% copper.

It was learned from the Goddard Space Flight Center that some of its applications require high optical absorptance to wavelengths as long as 1000 μm. Some special samples of gold black were made that had 3% of copper and high area density (~174 μg/cm²). The samples were made this way to have increased stability and higher absorptance at the

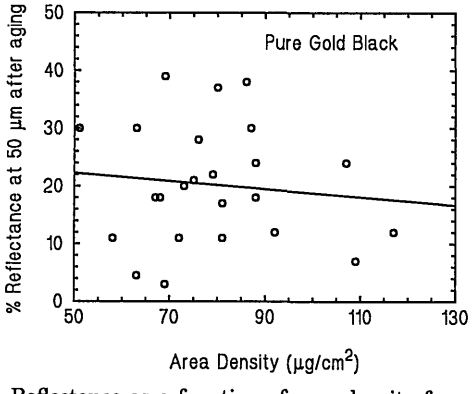

Fig. 11. Reflectance as a function of area density for pure gold black at a wavelength of 50 μm after aging in air occurs.

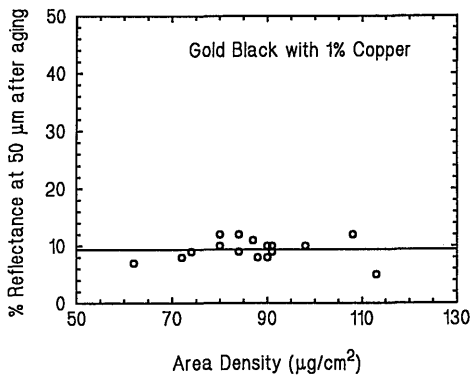

Fig. 12. Reflectance as a function of area density for gold black with 1% copper at a wavelength of 50 μm after aging in air occurs.

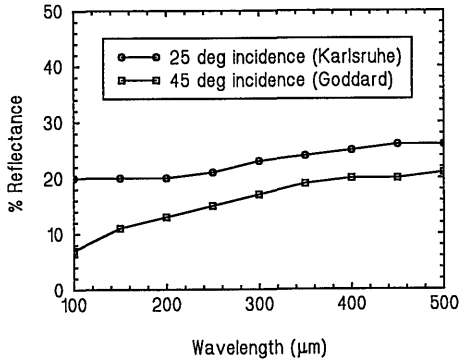

Fig. 14. Reflectance as a function of wavelength from 100 to 500 μm for gold black with 3% copper as measured at the Goddard Space Flight Center and the University of Karlsruhe.

longer wavelengths. These samples were sent to the Goddard Space Flight Center for measurement. The same samples were measured over the wavelength region from 100 to 500 μm at both the Goddard Space Flight Center in Maryland and the University of Karlsruhe in Germany. The measurements at Goddard were made at a 45-deg angle of incidence with a Nicolet Model 8000 Fourier transform spectrometer, a mercury arc source, a 25-μm-thick Mylar pellicle beam splitter, and an IR Laboratory liquid helium-cooled, doped, silicon bolometer. The sample chamber was at a pressure of 4 mbar. The measurements at Karlsruhe were made at a 25-deg angle of incidence with an IFS 113v Bruker Fourier transform spectrometer, a mercury vapor lamp source, and a Barnes liquid helium-cooled bolometer detector. A 25-μm-thick Mylar pellicle beam splitter was used for wavelengths below 200 μm, and a 50-μm-thick pellicle was used for the longer wavelengths. The sample chamber was at 3–4 mbar of pressure. Figure 14 shows the reflectance as a function of wavelength from 100 to 500 μm for both of these sets of measurements. Even though the thickness of the samples (~40 μm) is much smaller than the wavelength, the absorptance remains rather high.

Gold black coatings deposited onto a highly reflecting surface such as platinum exhibit patterns in reflectance versus a wavelength that is similar in appearance to interference fringes made by a single homogeneous weakly absorbing layer. These fringes have not been observed with gold black deposited onto thin membranes. These fringes are normally seen for all fresh gold black films, both pure and with copper, but they usually disappear on aging for pure gold black films. However, they can still be seen when 1% of copper has been included, as shown by the solid curve in Fig. 13. To determine whether the gold black patterns are an interference phenomenon, we made a greatly simplified computer simulation, ignoring scattering, to try to match the measured data. The simulated gold black was assumed to be a homogeneous layer on a highly reflecting metal surface.

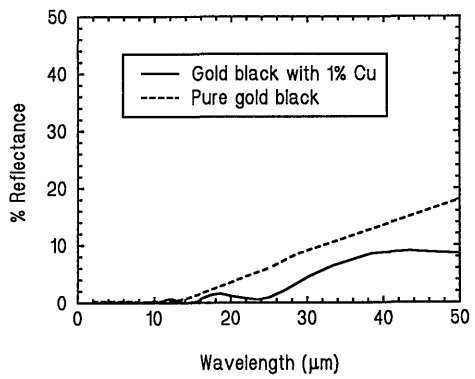

Fig. 13. Reflectance as a function of wavelength for a typical aged gold black film with and without 1% copper.

For a single nonabsorbing layer the thickness can be related to the wavelength through the following equation:

$$4 \times n \times t = m \times \lambda,$$

where n is the index of refraction, t is the layer thickness, m is the order number of the interference maximum or minimum, and λ is the wavelength of the maximum or minimum. (Note that the dimensions of t and λ must be the same.)

The order number m can be found from the wavelengths of the measured reflectance maxima and minima, and the thickness can then be calculated.

Some assumptions can be made about the simulation layer. When the gold black is thick compared with the wavelength, for example, 20 μm thick at a wavelength of 3 μm, the measured reflectance has a low value. This means that the reflectance at the gold black–air interface must be small. In addition the Maxwell–Garnett theory of the optical properties of aggregates[11] predicts that the real part of the index of refraction approaches one as the film becomes more and more porous (as is the case with gold black). This implies a value of one for n, the real part of the complex refractive index $(n - ik)$. If $n = 1$ interference effects can occur only if k is > 0 (for a film in air). At the longer wavelengths, where the maxima and minima are observed, the reflectance does not become

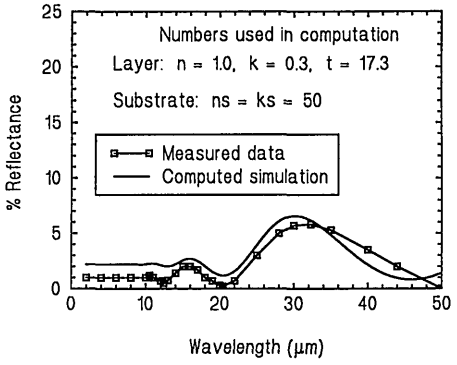

Fig. 15. Comparison of the reflectance of measured and computer-simulated gold black on a highly reflecting substrate as a function of wavelength for the best fit near 50 μm.

large. Therefore the value of k cannot be high. The simulated layer is thus chosen to have a real part of the refractive index equal to one and an imaginary part equal to a small number. To test whether a real gold black coating can be simulated by such a layer, we made a number of computations and compared them with measurements. The thickness of the measured coating, calculated from the above formula, was ~16 μm. A fairly good fit to the measured values was obtained for $n = 1$, $k = 0.3$ and $t = 17.3$ μm. The computed and experimental results are plotted in Fig. 15. When we consider the assumptions involved, the two curves are remarkably similar. Even the thickness used in the computations is close to that of the experimental layer.

Although the fit of the two curves is rather good, the reflectances at the short wavelengths differ. The measured value is 1%, while the computed value is ~2%. If the k had been chosen to be 0.2 rather than 0.3, the two values would agree. However, the reflectances at the longer wavelengths would not agree as well. Figure 16 shows a comparison of measured values with those computed for $k = 0.2$. It should not be surprising that the gold black would exhibit dispersion in its effective optical constants. Considering the gross simplification in the simulation, we found the agreement between computation and measurement to be surprisingly good. This gives support to interpreting the reflectance maxima and minima as an optical interference effect.

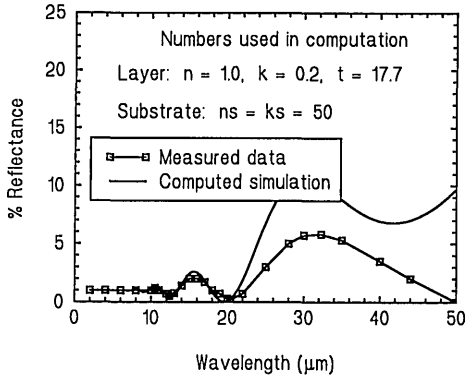

Fig. 16. Comparison of the reflectance of measured and computer-simulated gold black on a highly reflecting substrate as a function of wavelength for the best fit near 3 μm.

The measured value of reflectance near 3 μm for the sample just described was 1%. Most of the gold black samples were thicker and had reflectances closer to zero. This would not be consistent with a k value of 0.3 and points to the fact that scattering would have to be considered in any realistic model.

When we make reflectance measurements with gold black on platinum, the radiation must traverse the gold black twice, since the platinum is opaque. If the gold black were on a transparent low reflecting sample, most of the radiation would traverse the gold black only once and the transmittance squared should be approximately equal to the reflectance of gold black on platinum. To test this, we deposited gold black containing 1% copper onto KRS-5 (thallium–bromide–iodide). The sample material was chosen to be KRS-5 because it is transparent out to 40 μm and has a moderately low refractive index of 2.4, therefore a low reflectance. The measured values of fresh gold black films (no copper added) at a wavelength of 3 μm were as follows: a reflectance of ~0.2% for gold black on platinum and transmittance of 4.4% (corrected for the back surface reflectance of the KRS-5) for gold black on KRS-5. The value of 4.4% squared is 0.19%. This is in good agreement with 0.2%. In the region of 50 μm, however, there are the interference effects mentioned above, and the simple comparison of transmittance squared with reflectance is no longer valid. After aging occurred, the reflectance at 50 μm of the gold black on KRS-5 increased to 5% and the transmittance increased to 7%. This means that the absorptance remained high if it is assume that the diffuse reflectance was still low.

7. Delineation of Gold Black Films

Two methods have been used to delineate the gold black films. One method involved laser ablation, and the other used a stand-off mask during the evaporation process. Both have shown that it is possible to delineate gold black films.

The laser ablation technique was performed by Resonetics. A pulsed krypton fluoride excimer laser with a fluence of 900 mJ/cm² s was used. The pulse rate was 5 pulses/s with the duration of the exposure lasting <2 s. The laser beam exposed the black through a mask. The image was projected through a relay lens for a 10:1 reduction. The area where the film was removed was nonconducting, indicating that the film was completely ablated. A scanning electron micrograph of one of the patterns is shown in Fig. 17. The gold black film contained 1% copper, had an area density of 113 μg/cm², and was ~30 μm thick. The sample was chromium/gold on LF-5 glass.

Resonetics delineated four patterns on the chro-

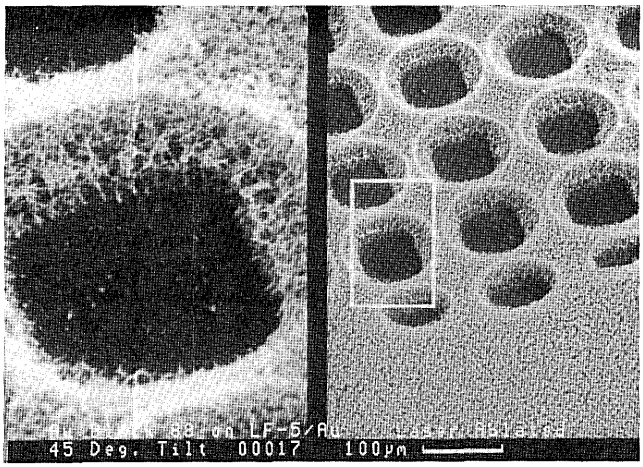

Fig. 17. Scanning electron micrograph of a laser-delineated gold black film.

mium/gold sample: holes, meandering lines, a fine grid, and open lines. All had sloped edges and looked grainy where the gold black had been removed. The smallest open area was 66 μm wide at the top surface of the film and 26 μm wide at the bottom. The smallest island was rounded to a point at the top and was 44 μm wide at the bottom. The island was only 16 μm thick, whereas the surrounding area was 30 μm thick. This reduction in thickness and the way the pattern's top surface rounded near the inside at the meander turns indicate that the film may have overheated and ablated or collapsed at the edges. Optimization of the ablation parameters would likely reduce or remove this effect.

The other delineation involved masking samples with a stand-off mask. The mask pattern consisted of four holes, ~800 μm in diameter. The holes were arranged in a square pattern and spaced 150 μm from one another. The samples were spaced 410 μm from the mask. Several delineations were made with various materials for the mask, sample, and electrical contact between them. A metal mask usually produced a pattern that was slightly larger than the hole dimensions by ~30 μm. A Teflon mask usually produced a pattern smaller than the hole opening by ~30 μm. It is not clear what caused this phenomenon, possibly an electrostatic charge buildup.

Another phenomenon that resulted from the stand-off mask patterns were lunes created on one side of the holes. The lunes pointed toward the center of the sample palette regardless of where the sample was placed on the palette during evaporation. Also the film was thicker in the lune area. This feature was not explored in detail but is noted for those who intend to delineate gold black films with stand-off masks.

Both delineations looked promising, especially when we consider that these were first attempts. With additional investigation, either of these methods could be optimized to produce a well-defined pattern.

8. Conclusions

A process has been described for the preparation of gold black films that have high optical absorptance out to wavelengths as long as 50 μm. Some preliminary measurements have been made to wavelengths as long as 500 μm. This extends optical measurements to longer wavelengths than has been reported by others. In previous work the gold black was usually deposited onto thin membranes such as cellulose nitrate. The gold black in the present study was deposited onto a highly reflecting surface to simulate certain detector applications where the surface to be coated is a highly reflecting metal. The absorptance of such coatings was found to be high from 0.2 μm in the UV to 50 μm in the far IR. The absorptance also remained moderately high at wavelengths as long as 500 μm. When pure gold was used, absorptance at wavelengths from 8 to 50 μm was found to decrease slightly with time during exposure to air. Baking for 3 h at 70°C had about the same effect as exposure to air at room temperature for a few days. However, baking at 120°C caused a large decrease in absorptance. The addition of copper to the gold during evaporation inhibited this degradation so that gold black films with 1% copper had high absorptance even after being baked at 120°C.

Other properties of the gold black that have been measured are sheet resistance, area density, and thickness. These properties changed with time, producing a decrease in electrical resistance and an increase in volumetric density. The changes are consistent with the corresponding decrease in optical absorptance.

Gold black films have been successfully delineated by means of laser ablation and by use of proximity masks.

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