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Determination of the Optical Constants of Thin Metalllic Films

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ABSTRACT

The current study was performed to determine the optical constants of thin metallic films with the help of ellipsometer. There are many theories like Murmann and Vasick theories which consider the reflection of light beam between the side boundaries. Thermal evaporation technique is used to prepare the thin films of bismuth and antimony. It is supposed to be more easier task to study the material in thin form rather than in the bulk form.

There are many applications of thin metallic films. These films can be used in optical devices such as lasers and beam-splitters. These films are used in electronic devices such as resistors, capacitors etc. Vaccum technology is used with the combination of thermal evaporation to prepare the thin metallic films. The current study highlights the method to determine the optical constants of thin metallic films.

1. Introduction

In the current study, the optical properties of thin films were studied with regard to wavelength in infra-red and ultra-violet area. Although, the optical constants were determined in the visible region. All dimensions of the thin film except the thickness were calculated with wavelengths 4348 A.U., 4790 A.U., 5085 A.U., 5461 A.U., 5790A.U and 5893 A.U.

It was observed that the resistance of thin films of Bithum with thickness less than 600 A.U. are not varied usually. This shows that the size of thin films are independent of the thickness. It was also observed that on decreasing the thickness of the film, the transmission of visible transmission tend to decrease with the wavelength between 4300 and 6000 A.U.

It was also found that there was maximum variation in transmission at the blue or red end of visible spectrum. Also, the thickness of film and wavelength of incident radiation are directly proportional to each other as the latter tends to increase on increasing the thickness. The structure and size of the thin film is used to get the maxima and minima of thickness of the film for certain values. A peculiar aggregated structure is found with the variation of thickness with q-factor for thin films.

Novel optical materials are continuously created and the interest in regard to their optical properties is mandatory. The context of thin films is especially important.

Ideally, the theoretical formalisms regarding the determination of the complex refractive index, (for absorbing materials), should be developed with a minimal number of approximations. It is then required to compute the intensity of the reflected and/or the transmitted light out of the sample as exactly as possible.

2. Determination of Optical Constants

Besides, in the case of the as-deposited film, exhibits an unusual behaviour. Indeed, for transparent materials the refractive index usually increases with decreasing wavelength, which is the reverse situation here. However, this unusual behaviour is theoretically obtainable from the Ketteler-Helmholtz dispersion relations when the bandwidth of the absorption band is very large. Actually, any loss mechanism can be associated with an effective "absorption" band.

Accordingly, being a diffusion process that might cover a large spectral range, light scattering form the surface or the volume of thin film can be described by means of a large bandwidth absorption band, especially at short wavelengths, as it is the case here in the UV-Vis. Thus, we can expect that this is the situation for the as-deposited thin film and that UV irradiation significantly reduces light scattering. This assumption is strongly supported by the large difference in Γ when comparing as-deposited and UV-exposed films. Since the surface roughness ("Box Statistics" in figures) is lower for irradiated film, we conjecture that it is the surface scattering that is reduced. In addition, it is worth noting that in this last case exhibit the usual and expected behaviour. This strongly suggests that a better oxidation of Bi is also achieved but apparently not completed as suggested from the higher than expected refractive index. This better oxidation could also explain the reduction of the volume scattering. Again and as an extrapolation, we could expect this to apply also in the case of heated films.

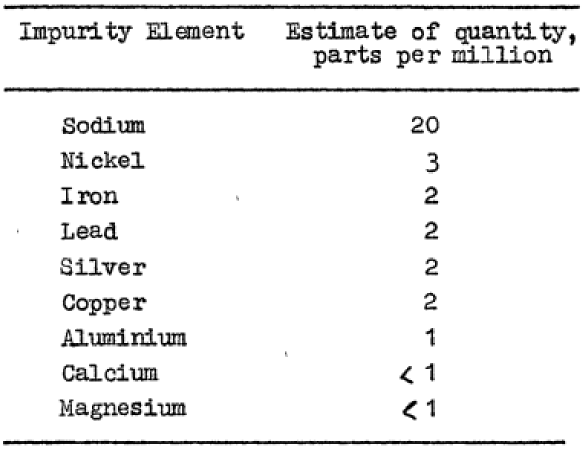
Besides, the evolution of the surface roughness in regard of the postdeposition processes is a key factor, depending on which process is used. Indeed, any heating process performed on thin films tends to increase their surface roughness, which in turn can have a dramatic consequence on their optical properties. We have then performed atomic force microscopy measurements on samples that have been irradiated or heated. It was shown that their respective quantitative roughness parameters are indeed smaller in the case of ultraviolet irradiation. Our results show that the use of ultraviolet irradiation is an interesting alternative to heating processes since it leads to less dramatic alteration of the film surface. This opens the way to additional treatments in order to obtain the best optical performances form thin films. Perspectives of further work include the study of the synergy between heating processes (in situ and/or ex situ) and irradiation. In addition, the relative contributions to light scattering from the surface and from the volume of thin films should also be further investigated.

3. Results

Accordingly and in order to get accurate empirical knowledge about numerous spectrophotometric methods have been developed. Here, we restrict our formalism to the case of a thin film of arbitrary absorptance, deposited on a thick absorbing substrate, which is however sufficiently transparent to allow the intensity of the transmitted light to be measured with sufficient accuracy.

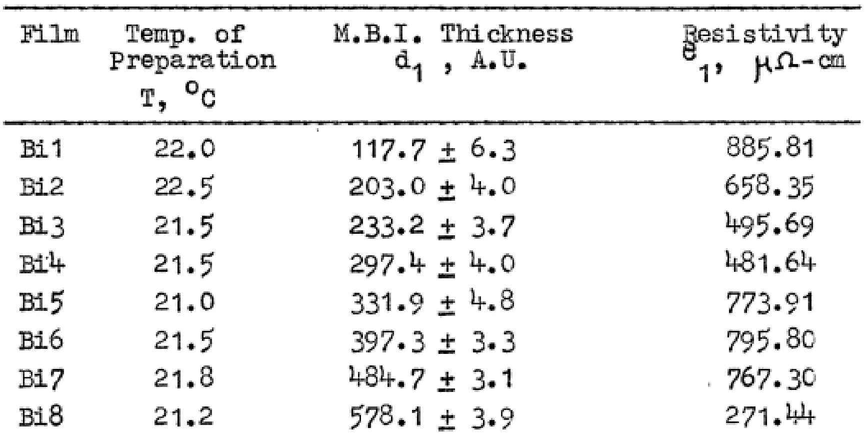
Furthermore, Bi thin films have been given considerable attention in the past decades due to a wide range of possible applications, which include laser mirrors, broadband interference filters, and ionic conductors. Bi is an important material, which possesses interesting properties such as large resistance against oxidation, high melting point (2,715°C), excellent thermal stability, and good ionic conductivity in the Y-stabilized cubic phase. For example, Bi thin film is a promising candidate to replace silicon dioxide as the gate dielectric in complementary metal-oxide-semiconductor technology.

Table 1: Purity of the metal used BISMUTH



Impurity Element	Estimate of quantity, parts per million
Sodium	20
Nickel	3
Iron	2
Lead	2
Silver	2
Copper	2
Aluminium	1
Calcium	< 1
Magnesium	< 1

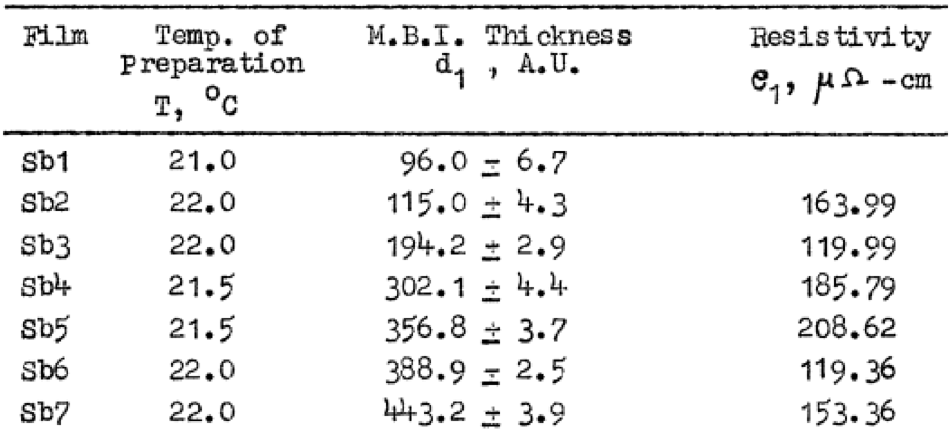
Table 2: Data for Bi films



Film	Temp. of Preparation T, °C	M.B.I. Thickness d_1 , A.U.	Resistivity ϱ_1, μΩ-cm
Bi1	22.0	117.7 ± 6.3	885.81
Bi2	22.5	203.0 ± 4.0	658.35
Bi3	21.5	233.2 ± 3.7	495.69
Bi4	21.5	297.4 ± 4.0	481.64
Bi5	21.0	331.9 ± 4.8	773.91
Bi6	21.5	397.3 ± 3.3	795.80
Bi7	21.8	484.7 ± 3.1	767.30
Bi8	21.2	578.1 ± 3.9	271.44

It is an electrical insulating material with a band gap of 5 eV and has potential use as an alternative material for storage capacitors in dynamic random access memories. In addition to its interesting electrical properties, Bi thin film also has highly attractive optical properties such as low absorption of light, high index of refraction, high transparency over a wide spectral range, and high field damage threshold and is therefore very attractive for laser optic applications. The properties of the film, however, highly depend on the deposition method chosen as well as the deposition conditions (substrate nature and temperature, partial gas pressure, and deposition rate). For this reason, the link between optical properties and microstructure has been widely investigated.

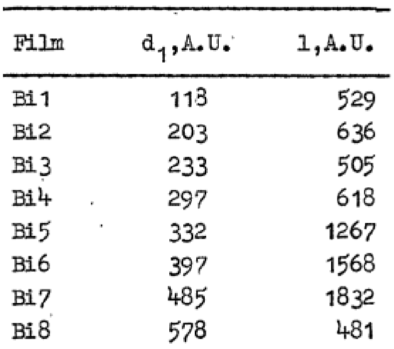
Table 3: Data for Sb films



Film	Temp. of Preparation T, °C	M.B.I. Thickness d_1 , A.U.	Resistivity ϱ_1, μΩ -cm
Sb1	21.0	96.0 ± 6.7	
Sb2	22.0	115.0 ± 4.3	163.99
Sb3	22.0	194.2 ± 2.9	119.99
Sb4	21.5	302.1 ± 4.4	185.79
Sb5	21.5	356.8 ± 3.7	208.62
Sb6	22.0	388.9 ± 2.5	119.36
Sb7	22.0	443.2 ± 3.9	153.36

Among the various fabrication techniques available to produce thin films, vacuum depositions techniques are the most often used. The main way to produce good samples of oxide films involves a reactive process, where the metal is evaporated or sputtered in a residual atmosphere containing oxygen. In our case, Bi thin films were obtained by DC reactive magnetron sputtering where argon was used as the sputtering gas in the presence of oxygen as the reactant. Sputtering deposition is a widely used technique which offers several advantages over other methods: high deposition rates; dense defect-free oxide films; not requiring high temperature; the fact that films have a composition close to that of the source material; the fact that high melting point materials are easily sputtered; sputtering usually leading to less contamination than evaporation methods; the fact that sputtered films have a good adhesion on the substrate; the fact that it can also be performed top-down. Due to its ability to reduce arcing during the reactive process, pulsed direct current magnetron sputtering is a valuable version of the sputtering technique.

Table 4: Mean free path of electrical carriers BISMUTH FILMS

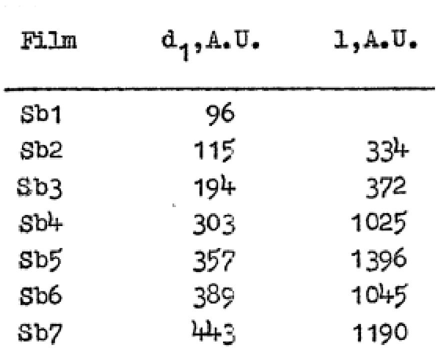


Film	d_1,A.U.	l,A.U.
Bi1	118	529
Bi2	203	636
Bi3	233	505
Bi4	297	618
Bi5	332	1267
Bi6	397	1568
Bi7	485	1832
Bi8	578	481

Postdeposition annealing of the sample is often necessary to releases voids incorporated during the deposition process which in turn favours the formation of more closely packed thin films leading to an increase in refractive index.

Postdeposition annealing is also used to complete the oxidation of the films. However, because subsidiary effects such as surface roughness modifications might come out in the process, it is important to take into account the surface morphology of the films, especially in the case of multilayer systems. The amount of energy brought into the material in such process is a key factor that leads to significant morphological differences.

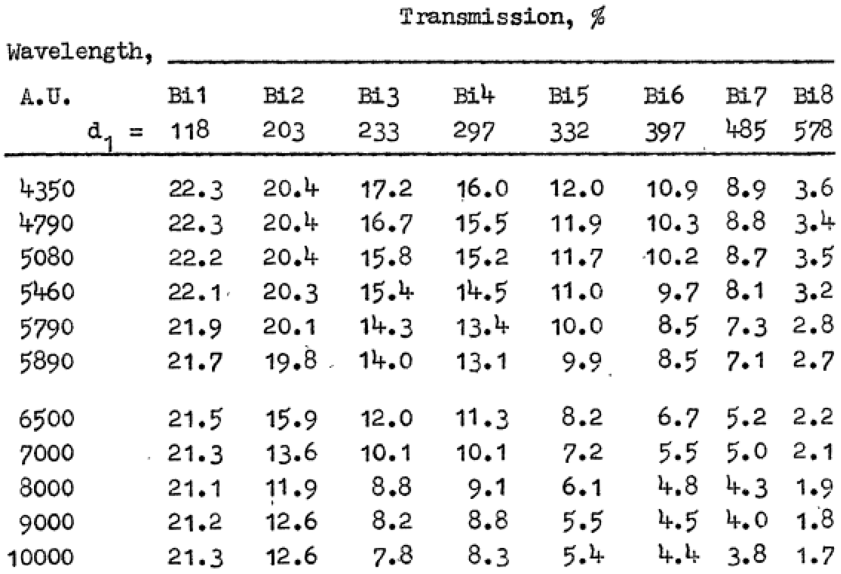
Table 5: Mean free path of electrical carriers AHTIMOHT HELMS



Film	d_1,A.U.	l,A.U.
Sb1	96	
Sb2	115	334
Sb3	194	372
Sb4	303	1025
Sb5	357	1396
Sb6	389	1045
Sb7	443	1190

Indeed, the actual heating process and its temporal evolution are significant. Other postdeposition processes that can be used to complete the oxidation of the films are worth being considered and could give very different outcomes. Photon-assisted oxidation has been reported to improve the quality of ultrathin (few tens of nanometres) oxide films.

Table 6: Measurement of Transmission



Wavelength,	Transmission, %							
A.U.	Bi1	Bi2	Bi3	Bi4	Bi5	Bi6	Bi7	Bi8
d_1 =	118	203	233	297	332	397	485	578
4350	22.3	20.4	17.2	16.0	12.0	10.9	8.9	3.6
4790	22.3	20.4	16.7	15.5	11.9	10.3	8.8	3.4
5080	22.2	20.4	15.8	15.2	11.7	10.2	8.7	3.5
5460	22.1	20.3	15.4	14.5	11.0	9.7	8.1	3.2
5790	21.9	20.1	14.3	13.4	10.0	8.5	7.3	2.8
5890	21.7	19.8	14.0	13.1	9.9	8.5	7.1	2.7
6500	21.5	15.9	12.0	11.3	8.2	6.7	5.2	2.2
7000	21.3	13.6	10.1	10.1	7.2	5.5	5.0	2.1
8000	21.1	11.9	8.8	9.1	6.1	4.8	4.3	1.9
9000	21.2	12.6	8.2	8.8	5.5	4.5	4.0	1.8
10000	21.3	12.6	7.8	8.3	5.4	4.4	3.8	1.7

4. Conclusion

The introduction of a spectral analysis method based on the Ketteler-Helmholtz dispersion relations is found useful to determine the optical properties of thin films. The case of zirconium oxide appears especially interesting. Indeed, we have studied the effect of postdeposition ultraviolet irradiation on the oxidation of Bi thin films deposited by direct-pulsed current reactive magnetron sputtering and have compared this effect with low temperature postdeposition heating on samples that were not completely oxidized.

We showed that the benefit of these processes in terms of improvement of the oxidation state of the films is very similar as can be seen by the increase of their respective transmittance spectrum. In addition, the spectral analysis method described in this paper leads to identifying unusual dispersion behaviour. We infer that such behaviour can be attributed to the presence of an effective “absorption” band, which is due to a light scattering process covering a large spectral range. It seems that UV irradiation significantly reduces surface light scattering.

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