R. PERIC[1], Z. KARASTOJKOVIC[2], M. JOVANOVIC[3], M. SRECKOVIC[4], Z. JANJUSEVIC[5], R. GAJIC[3]

Scientific paper
UDC:620.191.2/.7

Optical properties of gold alloy 585 monitored through amplitude diminutions at annealed and cold rolled strips with low deformations

The optical properties are determined and presented in an adequate references for common pure noble metals (Au, Ag, Cu, etc.) but not for almost their alloys. This was a reason for investigation of specific optical properties amplitude diminutions at gold alloy of 585 finess, as an often used alloy in jewelry. This alloy for jewel making in practice usually is composed from three - or four metals.

The jewels, as their nature need, ordinary must possess pretty high level of brilliance. Variuos metals will produce changes in optical properties of an alloy, indeed. Here are represented some ellipsometric measuring of tg(ψ) for annealed and cold rolled strips from golden alloy 585. Cold rolling is provided by height reduction of 10, 20 and 30%. Typical microstructures at annealed and cold rolled (30%) deformation were shown.

***Key words:** 585 gold alloy, ellipsometry, tg(ψ) values, microstructures of strips*

1. INTRODUCTION

In common considerations, optical properties of metals are regarded through the reflection or absorption of a light beam. The optical properties of noble metals are of an extremely importance, when those metals will be used in jewelry production. For almost pure noble metals (Au, Ag, Cu, Pd, Pd, etc.) the optical properties were pretty well examined [1-3] but not for their alloys [4-8]. Ellipsometry is a non-destructive characterization technique used for determine the principal optical constants, *(n)* and *(k)* indices, as real and imaginary components of refractive index, further for determination the ratio of amplitude dimunitions (ψ) and phase difference induced by the reflection (Δ) [6-7].

In golden jewel production many different technological operations should be used, main of those are: melting, alloying, casting, rolling, deep-drawing, welding, brazing and/or polishing [9÷10]. After alloying many properties of an alloy become quite different in accordance to the initial properties of pure metals, what is excellent known to metallurgists. The golden alloy used here is composed from min. 58,5% Au. This alloy (14kt) is one of the most popular in jewelry. The jewels, especially those made from noble metals, should possess a high level of brilliance. The shining properties frequently are judged individually on a descriptive manner as: good, proper, poor, well, etc., but those criteria are not based on scientific measuring(s).

2. ELLIPSOMETRY IN METAL STUDYING

The measuring of optical properties in metals does not represent a target in physical metallurgy, in the studying of diffraction behavior at a surface to be analyzed (Hill,Small), it is rather a matter of studying in other fields of physics, for example in solid state physics or similar (3,11). Ellipsometry became one usual technique for measuring the optical properties, in which is monitoring the interaction of incident light with material. In an appropriate literature could be found many applications of ellipsometry for thickness determination, crystallography, anisotropy, roughness, etc. The principal positions of needed equipments for providing the ellipsometric measurings are shown in Figure 1a).

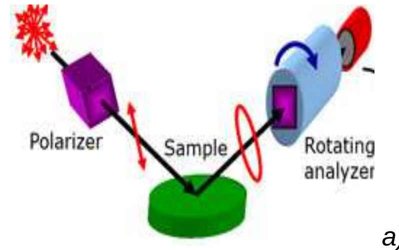
The ellipsometric measuring is based on using the linearly polarized light, as an incident beam. The reflected light beam is elliptically polarized in the s- and p-planes, see Figure 1b). The measure for elliptical polarization are parameters ψ and Δ, as could be seen from Figure 1b), and here will be monitored only ψ. The reflectance of pure noble metals, gold and silver as main components in the alloy, as the function of wavelength entire the visible spectra of light is shown in Figure 2a), according to literature data [7].

It could be said that reflectance represents "a kind of reflecting power" of investigated metal [9-11]. Reflectance and absorptivity for metals in the sum are equal to 1, because they are not transparent. It means that when the reflectance is high then the absorptivity must be low [9-11].

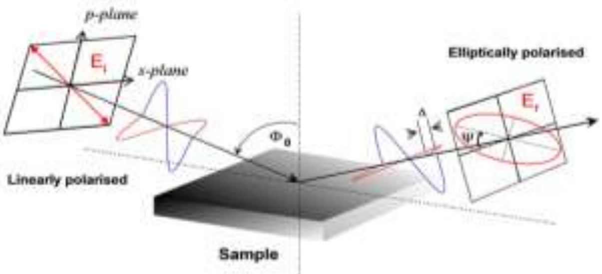
Author's address: [1]Perić&Perić, d.o.o., Požarevac, Dunavska 114, [2]Technical Colege, New Belgarde, Blvd. Dr Zorana Djindjića 152a, [3]Institute for Physics, University at Belgrade, Zemun, Pregrevica 118, [4]Electrotechnical Faculty, Beograd, Blvd. kralja Aleksandra 73, [5]Institute of Nuclear and Other Mineral Raw Materials, Beograd, Franše d 'Eperea 86, Serbia

Received for Publication: 14. 06. 2013.

Accepted for Publication: 11. 09. 2013.

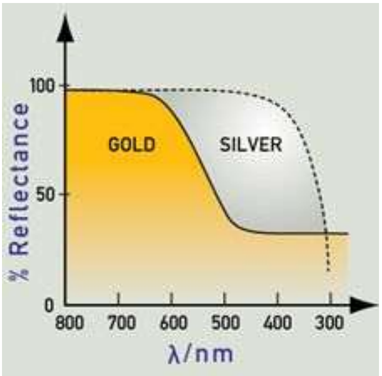


a)

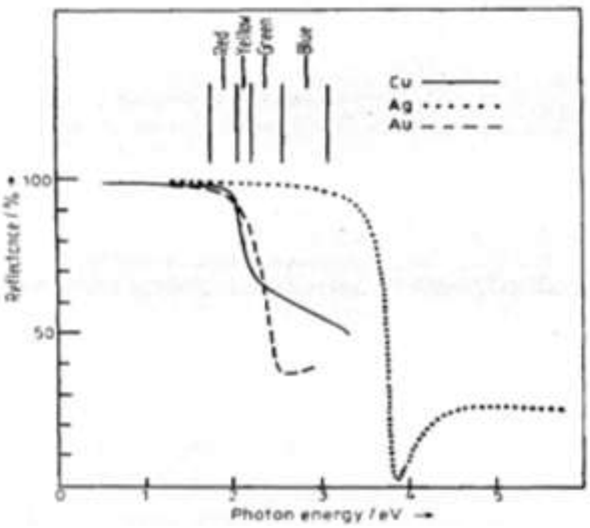


b)

Figure 1 - From known input of linearly polarized beam a) and definitions ψ and Δ for measuring at reflected elliptically polarized beam b)



a)



b)

Figure 2 - Trajectories of reflectance vs wavelength for gold and silver a) and reflectance vs photon energy of gold, silver and copper b) [7]

It is an exactly explanation for different colors of metals, Figure 2b), according to their energy, here in photons. The shape of reflecting power curve for gold, silver and copper is shifted according to the photon energy, and producing the variety in colors for every metal, as can be seen from Figure 2b).

3. SPECIMEN PREPARATION

This alloy is melted in a vacuum induction heated furnace from refined (99,99%) metals and casted in a protective atmosphere, containing the nitrogen gas [9,12]. Chemical composition of used golden alloy (14kt) was as follows: 58,%Au; 8,3%Ag; 25,7%Cu and 7,5%Zn. Cold rolling of golden strips is provided by height reductions of 10, 20 and 30%, to a final thickness of 0,5mm for all strips. One strip was fully annealed at 680^0C, 30min. Those reductions were chosen because a lot of semifinished products, in the shape of wire or strip, are obviously undergo to further shaping (by bending, piercing, etc.), when they might be damaged [12-14].

4. RESULTS AND DISCUSSION OF tan(Ψ) MEASURINGS

The ellipsometric measurements were performed on strips by using spectroscopic ellipsometer SOPRA GES5E IR, with the incident angle of 70^0, in the range of 300-800nm of electromagnetic spectrum. The obtained curves of tan(ψ) the visible range of light are represented in figs. 3-6. The value of tan(ψ) for specimen 1 is 0,63 at wavelength of 300nm, the maximum of 0,83 is reached at 560nm, and at 800nm the value of tan(ψ) is 0,78, see Figure 3.

After applying the cold deformation of 10%, specimen 2, the maximum value of tan(ψ) becomes lower and reaches the value of 0,757, Figure 4.

Trajectories for sample 3, deformed with 20%, are similar to previous, but the maximum further is lowered, the value of tan(ψ) is 0,757. All values for tan(ψ) are lowered in comparison to previous specimen, see Figure 3. and 4.

The highest applied deformation, here 30%, has produced similar behaviour for tan(ψ), Fig. 6, as in earlier cases. It could be seen that maximum value of tan(ψ) in all cases was reached at 560nm, as could be seen from figures 3-6.

Also, their inflection points for all curves of *tan(ψ) vs wavelentgth* for used gold strips have reached at 560 nm, and they were the same for all specimens.

In microstructure of an annealed (680 °C) specimen are present twins, known as annealing twins, Figure 7a). During cold rolling the crystal grains are elongated in the rolling direction, strips of 585 gold are shown in Figure 7b).

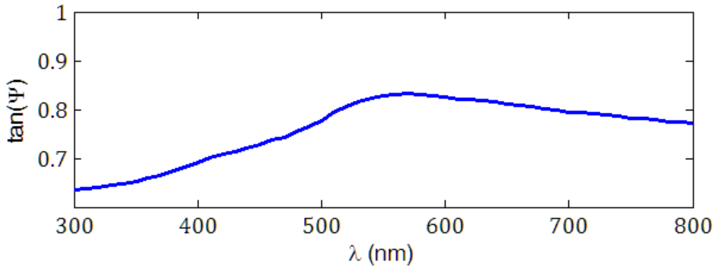


Figure 3 - Trajectories of tg(ψ) for gold 585 strip, annealed, specimen (1);

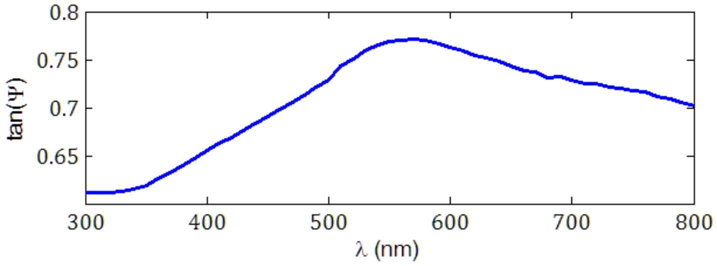


Figure 4 - Trajectories of tg(ψ) for gold 585 strip, a0% deformation, specimen (2)

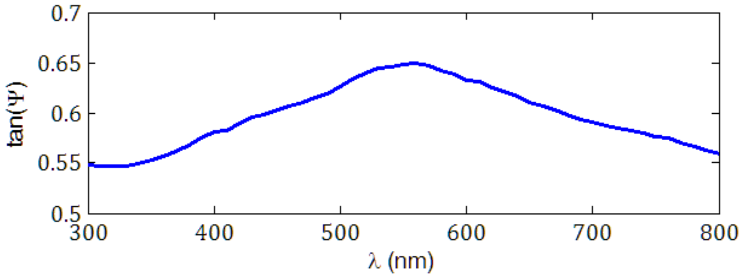


Figure 5 - Trajectories of tg(ψ) for gold 585 strip, 20% deformation, specimen (3)

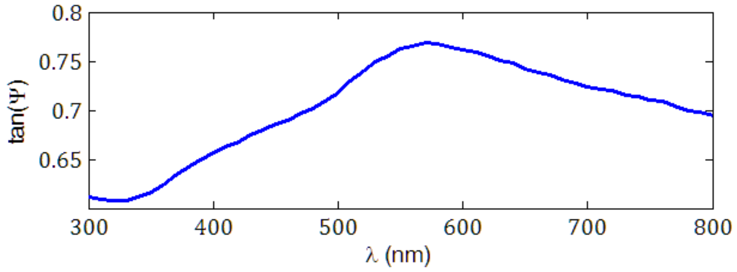


Figure 6 - Trajectories of tg(ψ) for gold 585 strip, 30% deformation, specimen (4)


a)


b)

Figure 7 - Microstructure of gold 585 strip: a) annealed at 680 ºC and b) cold deformed 30%

The close relationships between microstructure and amplitude diminutions still were not exactly established.

5. CONCLUSION

The optical properties and common constants of pure noble metals are fully examined, but not their alloys. Here is investigated 14kt gold, with 58,5% Au. Melting is provided in an induction furnace and casting in nitrogen protective atmosphere, for obtaining the clear surface. The strips were cold rolled by applying small deformations (10-30%), while one sample is annealed.

Those specimens were investigated at ellipsometer by using the incident angle of 70 ºC, in the range of 300 to 800 nm. The obtained results of amplitude diminution are shown in relation tan(ψ) *vs* wavelength. The maximum value of tan(ψ) was reached to be 0,83 at 560 nm - for annealed specimen, while the minimum value was 0,55 at 300 nm- for cold rolled specimen with reduction of 20%.

The obtained microstructures are as expected, for applied regime of annealing and cold rolling, and they can serve for further investigations.

Acknowledgement

Here represented results are provided by support from “Perić&Perić” Co, Požarevac, Serbia, and Laboratory for solid state physics and optics, Institute for Physics, Beograd-Zemun, Serbia, and we are grateful to them.

REFERENCES

[1] Sokolov, A.V. Optical Properties of Metals, in Russian, Moscow 1961, pp. 75-92; 142-152.

[2] A.M. Prohorov, I, Ursu, V.I. Konov, I.N. Mihalescu: Interaction of laser radiation with metals, in Russian, Moskva 1988, Nauka, pp. 74-96.

[3] G. Schulze: Metallphysik, Russian translation, Moskva 1971, MIR, pp. 366-371.

[4] M.A. Ordal, L.L. Long, et all, Applied optics, 22/1983/No 7, pp. 1099-1119.

[5] W. Hume-Rothery: Atomic Theory for Students of Metallurgy, London 1969, The Institute of Metals, pp. 259.

[6] H. G. Tompkins, A Users's Guide to Ellipsometry, Academic Press Inc, London (1993), pp. 24-48.

[7] R.T. Poole: The colour of the noble metals, Phys. Educ. 18/1983, pp. 279-284.

[8] V. Sedlaček: Non-ferrous metals and alloys, Amsterdam 1986, Elsevier, pp. 306-7, 388-391.

[9] R. Perić, Z. Karastojković, G. Đorđević: Prilog raspravi o kvalitetu šupljeg nakita od legure zlata 585, Kvalitet 8/2008/3-4, str. 65-67.

[10] R.E. Reed-Hill: Physical Metallurgy Principles, New York 1973, van Nostrand, pp. 38-59.

[11] R. J. Weiss: Solid state physics for metallurgists, Oxford 1963, Pergamon Press, pp. 222- 227.

[12] Karastojković, Z., Perić, R., Srećković, M., Janjušević, Z., Jakovljević, S., Kovačević, Z.: Metallurgy of gas and laser welding of thin parts made from 585 gold alloy, 10th National Conference of Metallurgy with International Participation, Varna – Bulgaria 2007, A 27.

[13] Karastojković, Z., Perić, R., Srećković, M. Janjušević, Z.: Uvodjene laserske tehnike u zlatarstvo, Beograd 2008, VII Savetovanje metalurga Srbije, Zbornik izvoda, pp.77.

[14] Perić, R., Karastojković, Z., Srećković, M., Janjušević, Z., Kovačević, Z.: Absorption layers in laser welding of silver & golden jewels, 40th International October Conference on Mining and Metallurgy, Soko Banja 2008, Proceedings Book, pp. 452-458.

IZVOD

OPTIČKE OSOBINE LEGURE ZLATA 585 PRAĆENE KROZ SKRAĆENJE AMPLITUDE U ŽARENIM I HLADNO VALJANIM TRAKAMA SA MALIM DEFORMACIJAMA

Optičke osobine su određene i prisutne u odgovarajućoj literaturi za uobičajene čiste plemenite metale (Au, Ag, Cu i dr.) ali ne i za većinu njihovih legura. To je bio razlog za ispitivanjem specifičnih optičkih osobina kao kašwewe amplitude u leguri zlata finoće 585, kao jedne često korišćene legure u zlatarstvu. Ova legura za izradu nakita u praksi se izrađuje sa tri- ili četiri metala.

Nakit, kako to njegova priroda zahteva, obično mora da poseduje prilično visok nivo sjajnosti. Različiti metali će, svakako, proizvesti promene u optičkim osobinama legure. Za praćenje ovih osobina su izvršena merenja pomeranja amplitude tg(ψ) svetlosti u opsegu talasnih dužina 300-800nm. Ovde su predstavljena neka elipsometrijska merenja tg(ψ) za odžarene i hladno valjane trake od legure zlata 585. Hladno valjane trake su izvedene sa redukcijama 10, 20 i 30%. Prikazane su tipične mikrostrukture za žareno i hladnovaljano stanje.

Ključne reči: *legura zlata 585, elipsometrija, vrednosti tg(ψ), mikrostruktura traka*

Originalni naučni rad
Primljeno za publikovanje: 14. 06. 2013.
Prihvaćeno za publikovanje: 11. 09. 2013.