Research of plasmon resonance in developed holographic photomaterials

N V Andreeva, T B Kuzmina and O V Andreeva

ITMO University, Saint Petersburg 197101, Russia

E-mail: andreevanv_3@mail.ru

Abstract. The research of aqueous suspensions of colloidal particles of silver obtained by photographic method was carried out, two optical methods were used: the standard photometric method and the method of dynamic light scattering. It is shown that in the researched preparations, which attenuation spectra in the visible region have a close form, distribution of the particles by sizes could vary considerably.

1. Introduction

Great interest to optics of metal nanoparticles that have arisen in recent decades is associated with the development of nanotechnologies and nanodiagnostics. This interest supports a rapidly evolving scientific field, called "Nanoplasmonics" [1], or "Plasmonics" [2]. Volume holograms on plasmon particles of silver represent the photoinduced periodic structures that demonstrate the practical use of plasmon resonance. The research of such structures is important for creation on their basis of new optical media with functional properties that surpass the capabilities of natural materials and traditional elements of optical devices and systems.

In the work the results of research of aqueous suspensions of colloidal particles of metallic silver obtained from the developed samples of high-resolution holographic photomaterials are presented. Silver particles in such suspensions could be considered isolated and during research we could evaluate their properties as properties of ensemble of isolated particles, which is impossible during research of patterns of the initial photomaterial.

2. Object and methods

The objects of research are holographic silver-halide photomaterials after exposure and development: holographic photoplates [3] and nanoporous silicate silver containing matrices Ag-NPM [4]-[5]. Developed photoplates (figure 1a) – silver particles distributed in gelatin matrice with a thickness of ≈ 10 μm, which is formed on a glass substrate. Developed samples AgNPM (figure 1b) – silver particles distributed in free volume of porous matrice with a thickness of ≈ 1 mm with the presence of gelatin (not more than 10% of sample weight).

Developed particles of metallic silver of colloidal structure, obtained in high-resolution photomaterials for holography, represent plasmon particles, which range of attenuation (plasmon resonance) has a maximum in the short-wave region of the spectrum (figure 2c). Maximums of spectra of attenuation of developed samples tend to have high values of optical density which are resistant to standard measurements on standard optical devices, especially in the case of samples on the basis of

nanoporous silicate matrices even during production of sufficiently thin samples with a thickness of about 300 μm (see figure 2c, curve 2).

To obtain the spectral characteristics of ensemble of isolated particles of developed silver were made preparations that have the ability to adjust the concentration of researched particles. On figure 2d the spectral characteristics of preparations of samples of photoplates and nanoporous recording media are shown (data obtained by the author taken from the report of SOI 1994).

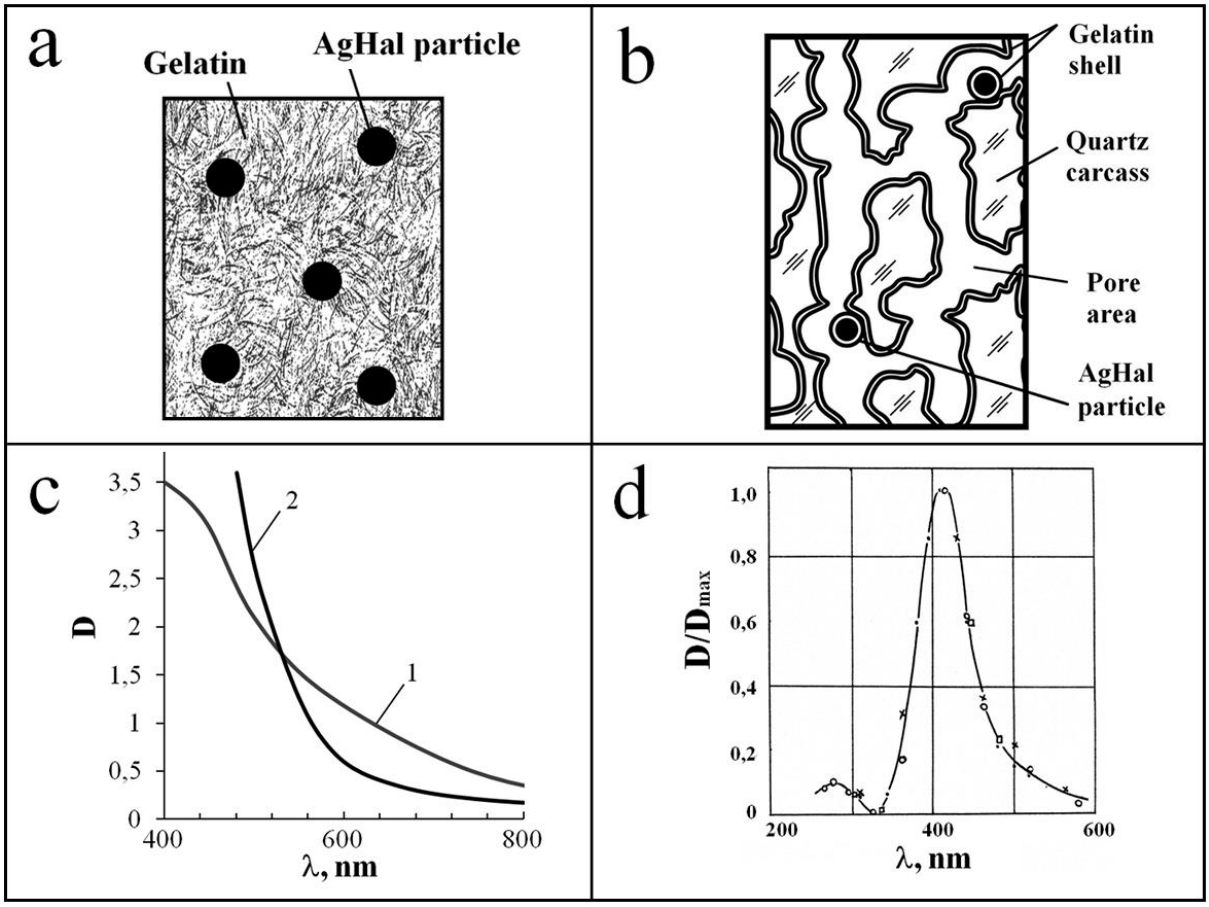

Figure 1. Schematic image of cross section of silver-halide photomaterial (a) and nanoporous silver-halide medium (b). c - spectra of attenuation of developed photoplate (curve 1) and AgNPM (curve 2), d - normalized spectra of attenuation of suspensions of particles of developed silver of these samples.

It should be noted that the average particle size of the prepared preparation could be higher than in initial samples due to the agglomeration of the smallest nanoparticles in the developement process of preparations as well as due to possible shell, which could be present on the particles of silver due to absorption of components of the mixture. For estimation the distribution of particles by sizes in the samples and for control of the state of preparations in parallel with the spectral measurements were carried out measurements of function of particles distribution by sizes using method of dynamic light scattering. Measurements of spectra of absorption were carried out on spectrophotometer Evolution 300 in the wavelength interval 300-800 nm. Estimation of the distribution of particles by sizes was carried out on device Horiba LB-550.

3. Experimental results

On figure 2 and in table 1 the results of measurements of parameters of preparations are shown. We could clearly see the difference in the distribution of particles by sizes of samples AgNPM and AgPP,

as well as changing of state of preparation AgPP during storage, while their spectra of attenuation differ not so much. For example, preparations (curves 1 and 2), which for D_{ch} (Q_{max}) differ in 7 times, in spectra of attenuation have not such big differences.

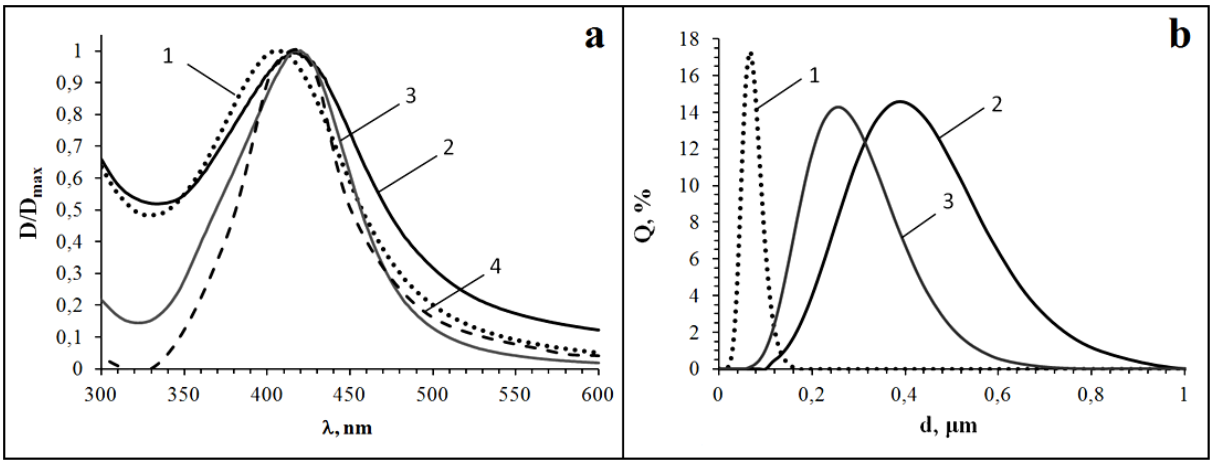

Figure 2. Spectra of attenuation (a) and the distribution of particles by sizes (b) of aqueous suspensions: AgNPM after 24 days (1), AgPP after 8 days (2) and 28 days (3), preparations of 1994 year (4, see figure 1d).

Table 1. Results of measurements of parameters of preparations.

№ of curve	Material	Time, days.	Spectral measurements		Distribution of particle sizes	
			$\lambda(D_{max})$, nm	$\Delta\lambda$, nm	D_{ch}, nm	ΔD, nm
1	AgNPM	24	407	116	50,7	60
2	AgPP	8	415	140	388,6	224
3	AgPP	28	417	88	258,6	340

4. Conclusions

In the work it was discovered that despite the coincidence of maximum values of optical density of researched suspensions, functions of distribution of silver particles by sizes obtained by method of dynamic scattering vary significantly. The size of developed silver particles in preparations AgNPM is several times less, than in preparations of photoplates PPH-03 – such assessments couldn't be done using only spectral measurements.

Thus, during research of developed silver nanoparticles with the plasmon resonance, the method of dynamic light scattering allows to do more accurately estimation in difference between parameters than spectrophotometric measurements do it.

References

[1] Klimov V V 2010 *Nanoplasmonics* (Moscow: Fizmatlit) 480 p
[2] Novotny L, Hecht B 2006 *Principles of nano-optics* (New York: Cambridge University Press) 541 p
[3] "Company SLAVICH", http://www.slavich.ru (accessed September 10, 2015).
[4] Andreeva O V, Obyknovennaya I E, Gavrilyuk E R, Paramonov A A, Kushnarenko A P 2005 *Journal of optical technology* **72 (12)** pp 916-922
[5] Andreeva O V, Bandyuk O V 2011 *Holograms - Recording Materials and Applications. Book 1* (INTECH Open Access Publisher) pp 45-70