The effest of alternating current on the process of silver nanoparticle formation in a polymer matrix

Sh. Amerkhanova[*], D. Belgibaeva[*], R. Shlyapov[*], M. Tatibaeva[**] and Sh. Yerzhanova[*]

[*] E. A. Buketov Karagandy State University,
Karagandy, Kazakhstan, amerkhanova_sh@mail.ru
**LLP «Technopark UniScienTech», Karagandy, Kazakhstan, vasli6689@mail.ru

ABSTRACT

Influence of an alternating current with various frequency from 500 to 5000 Hz on silver nanoparticles formation process in the presence of polyvinyl spirit is investigated. It is shown that the effect of alternating current frequency of 500 Hz leads to an increase of nanoparticles, and 5000 Hz contributes to the destruction of the agglomerates formed of smaller fragments. A scheme of the impact of AC on the formation of silver nanoparticles in the presence of polyvinyl alcohol

Keywords: silver nanoparticles, AC, polyvinyl alcohol, units

1. INTRODUCTION

Recently the interest to researching into nanoparticles has significantly increased. This is due to the occurrence of new perspective opportunities to use nanomaterials in many fields of science and technology, in particular, to produce effective and selective catalysts, to create elements of microelectronic and optical devices, to synthesize new materials [1]. The study [2] discusses a possibility of silver nanoparticle immobilization on the surface of silochrome and aminosilochrome, the indicated carriers having an expressed catalytic activity and selectivity towards organic unsaturated compounds. Moreover, the possibility to synthesize nanoparticles with thiocholesterol, which can be applied to the creation of optical and electro-optical devices, is considered as well [3]. On the other hand, nanoparticles represent the aggregates having various optical, electrical, magnetic, mechanical properties, the fact determining their heightened catalytic activity, thermal stability and reactionary ability. The above-noticed peculiarities can be realized in different ways; this can become the display of variability [4]. Thus, this study aimed at the nanostructure modification by alternating electric current and the evaluation of this effect on the process of silver nanoparticle formation in polyvinyl alcohol.

2. EXPERIMENTAL PART

Synthesis of silver nanoparticle was conducted by Carie-Lee's method. A 1:2 mix of citric acid and iron (II) sulphate processed by alternating current was added to a solution of silver nitrate and polyvinyl alcohol. The obtained solution was being intermingled for 1 hour, and then an optical density was measured. The following reagents were used in the research: polyvinyl alcohol (M_r = 172500 g/mole), citric acid, iron (II) sulphate heptahydrate, silver nitrate of "peculiarly pure" brand, bidistilled water. Molecular mass of polyvinyl alcohol was ascertained by ductility measuring [6]. UV spectra were acquired with the UV-1800.

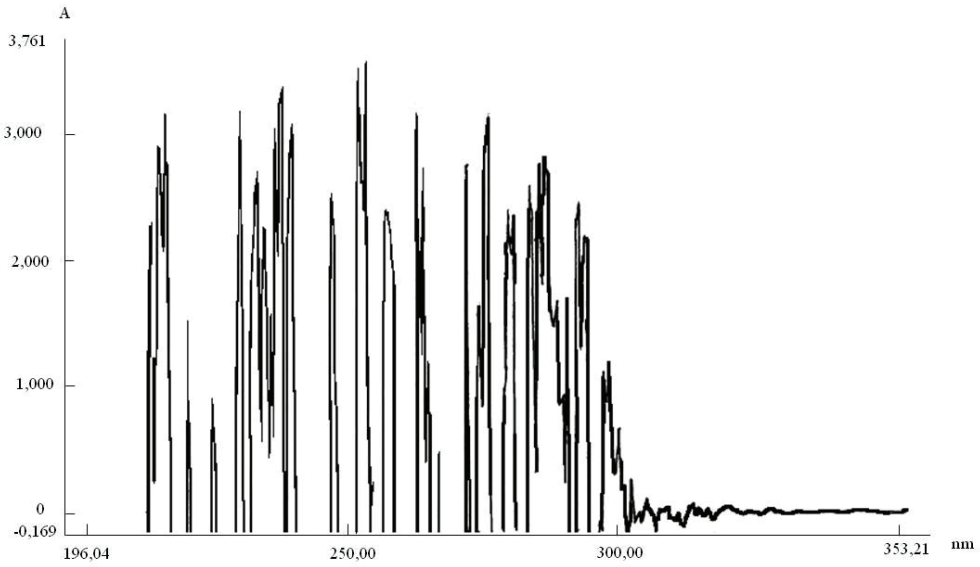
3. DISCUSSION OF RESULTS

Processing the samples with AC frequency of 500 hz for 60 min leads to the appearance of additional negative charge on silver nanoparticles, electrostatic interaction with positively charged particles and the appearance of larger associates, reducing the agregation-destruction period due to a more prolonged effect of alternating electric field [7]. Which can provide for an interchange of poles or charges in recombined particles of silver being a part of larger aggregate nucleus. Moreover, it is connected with the processes of destruction of larger fragments, polarization of fragments, which lose the ability to aggregate due to an acquisition of excessive negative charge.

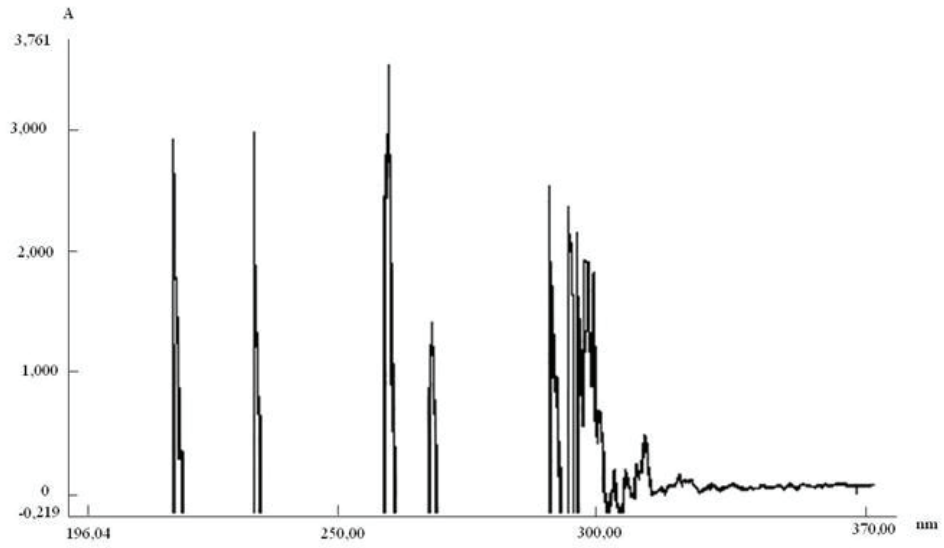
The above-mentioned peculiarities are confirmed in UV spectra. So, for the samples being processed for 60 min, a number of peaks increases, keeping the same interval of wavelengths, which allows judging about the increase in number of recombined particles of silver (Picture 1).

Processing the samples with AC frequency of 5000 hz for 60 min was conducted further. According to picture 1 the particle radius is reduced at the increase of time of exposure from 0 to 3 hours, from 24 to 120 hours, but it is increased in the interval from 3 to 48 hours. The indicated changes in particle radii can be connected with the intensivity increase in a process of oldening due to polymer macromolecule polarization, the intensification of interaction between charged units of macromolecules, and formation of more stable reticulated structures. The decrease of radius is conditioned on the destruction processes of aggregates being formed at the initial stages for the first period of time, and the increase due to the polarizing effect of alternating electric field, the joint effect of solvent release and formation of hydrogen bonds between single charged aggregates of silver nanoparticles.

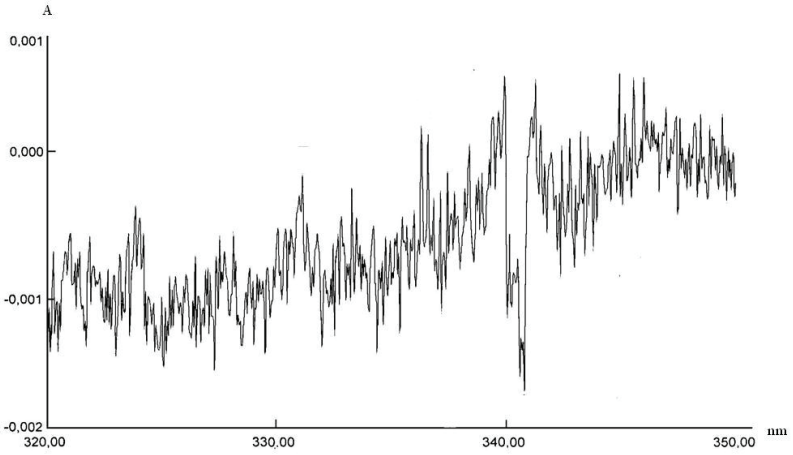
To confirm the results of calculations UV spectra of samples were acquired. It was shown that processing the samples with AC frequency of 5000 hz for 60 min leads to a sharp increase of peaks, keeping the same interval of wavelengths, which allows judging about the increase in number of recombined silver particles (Picture 2).



Picture 1: UV spectrum of PVS/Ag film sample processed by AC frequency of 500 hz for 60 min.



Picture 2: UV spectrum of PVS/Ag sample processed with AC frequency of 5000 hz for 20 min.

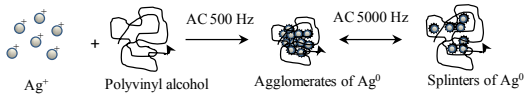


Picture 3: UV spectrum of argentiferous polymer film samples processed with AC frequency of 5000 hz for 60 min.

According to the data of spectral analysis of samples (Picture 2) the peaks responding to the recombined particles of silver, namely at the interval 250 – 340 nm are situated at a significant distance, i.e. it can be presumed that there's a formation of two different types of silver nanoparticles differentiated both in size and state of charge.

As it can be seen in picture 2, the intervals of time responding to aggregation-destruction periods are stretched, consequently, the process of changing the sizes of nanoparticles and their aggregates is complicated; this can be due to the fact that at such high frequency and length of exposure time, solvent molecules, polymer macromolecules don't have the same high energy and the extent of freedom needed for displacement, i.e. relaxation time needed to realize this process is incommensurably less than relaxation time for the indicated particles. Thus, the regions of maximum and minimum charge appear in molecules, which aggravate the formation of silver nanoparticles and leads to the appearance of compensation effect.

According to the data of Picture 3 the further increase of processing time to 60 min leads to the intensification of compensation processes due to the enlargement of a region influenced by alternating electric field. The result of this process is the destruction of macromolecular polymer fragments, formation of islet aggregates, slowing down the process of oldening, in other words, the indicated process promotes the growth of entropy. In this case silver particles formed at the initial stages are exposed to polarization-depolarization processes, which happen to be the reason of a more uniform distribution of nanoparticles both in a solution volume and size, i.e. a dynamic equilibrium occurs (picture 4).



Picture 4: Scheme of silver nanoparticle formation at processing with alternating electric current.

Thus, processing the samples with AC frequency of 5000 hz for 20, 40, and 60 min is the main factor affecting both the distribution of particles in a solution, their size, state of charge, and thermodynamic and kinetic stability; it is particularly revealed at low relaxation times of $10^{-4} – 10^{-6}$ s order, at which a special role is acquired by processes of hydration, namely, of the water exchange in the first and second hydrate shells formed both by silver nanoparticles and polyvinyl spirit macromolecules [8].

REFERENCES

[1] Kong Hyeyoung, Jang Jyongsik, *Antibacterial properties of novel poly methyl methacrylate nanofiber containing silver nanoparticles*, Langmuir. 24, №5, P. 2051-2056, 2008.

[2] Khokhlova T.D., Vlasenko Y.V., Khryaschekova D.N., Lanin S.N., Smirnov V.V. *Adsorption and gas-chromate-graphite properties of silochromes modified by silver*, MGU Herald, Series 2 Chemistry, Volume 52, № 2, P. 102-107, 2011.

[3] Belyaev A. A., Shabatina T.I., Sergeyev G.B. *Nano-sized silver aggregates with thiocholesterol*, MGU Herald, Series 2 Chemistry, Volume 50, № 4, P. 228-231, 2009.

[4] Melikhov I.V., Bozhevolnov V.Y. *Variability of nanosystems*, MGU Herald, Series 2 Chemistry, Volume 50, № 5, P. 297-302, 2009.

[5] Yershov B.G. *Nanoparticles of metals in water solutions: electronic, optic and catalytic properties* Russian chemical journal (journal of D.I. Mendeleev Russian Chemistry Society), T. XLV, № 3, P. 2001.
[6] Kurenkov V.F. *Practical work in polymer physics and chemistry*, Chemistry, 300, 1990.
[7]. *Austine Wood Comarow*, James Mann, *"Paintings in Polarized Light"*, Wasabi Publishing, 2005.
[8]. Bakeev M.I. *Hydration theory and electrolyte solution properties*, KarGU publishers, 221, 2007.