# Chapter 6

# The Effect of Metal Nanoparticles on Biological Systems

The following abbreviation is used in this chapter:
NPs— NanoParticles

The metal nanoparticles (NPs) are widely used in technical devices and for the action on biological systems (BS), in particular, in medicine. The main applications of metal NPs in medicine are targeted drug delivery, diagnosis, treatment, monitoring, and control of diseases. In spite of the extensive studies undertaken to establish the mechanism of the action of NPs, particularly metal NPs, on BS, it seems that many points remain unclear. Meanwhile, without a clear understanding of the processes underlying the biological effects of metal NPs, one can hardly hope to give well-founded recommendations for the safe application of metal NPs in medicine [71].

It is shown in this Chapter that many features of the effects of metal NPs on BS in the drug delivery and the treatment of diseases can be explained by the properties of spin supercurrent arising between the virtual photons created by quantum objects that constitute NPs, on the one hand, and the virtual photons created by quantum objects that constitute BS, on the other hand [10,72,73].

## 6.1. The Comparison of the Features of Effect of Metal Nanoparticles on Biological Systems with the Properties of Spin Supercurrent

1) As follows from recent studies, the medical effect of compound metal NPs on the cell of a biological organism is not determined in many cases by the action of the metal ions [71]. For example, with regard to the toxic effect of NPs such as AgNPs it cannot be reduced to the action of Ag+ ions in equivalent concentrations; this conclusion was made in the studies on the AgNP interaction with bacteria [71] and fish embryos [74]. Therefore, there are grounds to assume that the biological action of silver NPs can be realized through a different mechanism than that of Ag+ ions, that is, it is not due to electric interaction of ions [75].

Spin supercurrent has a nonmagnetic and nonelectric nature and consequently can be a process accomplishing biological action of NPs on BS.

2) The size of NPs is usually not higher than 100 nm.

According to property 7 of spin supercurrent (Chapter 1, Eq. [1.21]), the fact that NPs have a small size is of fundamental importance for effective interaction between the virtual photons created by quantum objects that constitute NPs, on the one hand, and BS, on the other.

3) There is a nonmonotonic dependence of the efficacy of the NPs' action on a BS on the size of NPs. The example of the nonmonotonic dependence of the toxic effect of silver NPs on *E. coli* on the NP size [71,76] is shown in Figure 6.1. It gives the dependence of the normalized toxicity rate $T_r / T_r^{'}$ ($T_r = T_r^{'}$ at $d = 9nm$) on the NP size *d*.

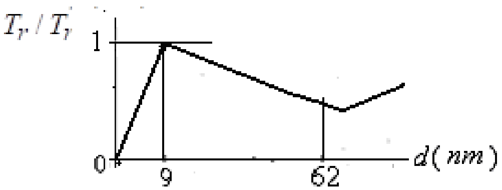


**Figure 6.1.** The type of dependence for the normalized toxicity rate $T_r / T_r^{'}$ ($T_r = T_r^{'}$ at $d = 9nm$) on the NP size *d*.

The nonmonotonic 'size-effect' dependence is analogous to the dependence of the spin supercurrent on the difference in precession angles of interacting virtual photons if the phase slippage effect takes place (see property 5 in Section 1.2, Figure 1.2).

4) The efficacy of NPs depends on their form. For example, in experiments on the action of AgNP on *E. coli* [71,77] it was found that the toxic action of AgNPs depended on their form: triangular particles were more active than spherical ones.

As shown in Section 9.1, Eq. (9.1), the special energy properties of the form of ambient bodies (cavity structures) are due to the emergence of spin supercurrents in them.

5) The medical action of NPs is determined by their intrinsic properties and does not depend significantly on the presence of a protective shell. For example, the following conclusion have been drawn by the researchers in terms of the medical effect of AgNP ([71]: 253): "Antimicrobial effect of AgNP is clearly expressed not only in water medium, but also in studies of solid materials with NPs deprived of their protective shell."

The independence of the action of NPs on a BS of the existence of the NPs' protective shells is similar to the property of spin supercurrent: the independence of both molecular and electromagnetic screening (property 6, section 1.2.).

6) There are two methods of drug targeting: active targeting using external physical factors and passive targeting where drug delivery is performed due to the properties of the medication and/or the drug carrier [78].

The magnetic field and heating can be external physical factors at active targeting. For example, hyperthermia in tumor cells seems to induce modifications in the cell surface receptor molecules and this means that tumor cells are more readily recognized by killer cells [79].

The features of passive adhesion of metal NPs, that is, when the drug delivery is performed due to the properties of the medication and/or the drug carrier, are explained by the properties of spin supercurrent. The use for targeting NPs of metals which are already contained in the cells (essentially, it is the 'kinetic paradox' considered in Section 2.1) under study should be looked upon as a search for methods that provide fulfillment of Condition (1.20). In other words, the metals whose NPs effectively "adhere" to certain organs have to be present in these organs before the introduction of NPs. For example, it is known [80] that the NPs of precious metals are used as drug carriers in passive targeting because silver is contained in the brain, liver, kidneys, and bones; and gold is found in the blood.

The passive adhesion of metal NPs can be performed by electric dipole-dipole interaction. In accordance with Eqs (1.14)–(1.15) and (1.18), the action of a spin supercurrent tends to equalize the precession frequencies, and the precession and deflection angles of the spins of virtual photons created by quantum objects constituting NPs, on the one hand, and those constituting BS, on the other hand. Then, while fulfilling Condition (1.20), the spins of these virtual photons ( $\mathbf{S}_1$ and $\mathbf{S}_2$ , respectively) can be oriented in the same direction, that is: $\mathbf{S}_1 \rightarrow\rightarrow \mathbf{S}_2$ . According to Eq. (1.7), electric dipole moments ( $\mathbf{d}_1$ and $\mathbf{d}_2$ , respectively) of these virtual photons will be oriented in the same direction as well:

$$\mathbf{d}_1 \rightarrow\rightarrow \mathbf{d}_2 . \qquad (6.1)$$

According to Condition (6.1), electric dipole-dipole attractive force $\mathbf{F}_V$ emerges between the virtual photons and respectively between quantum objects that created the virtual photons.

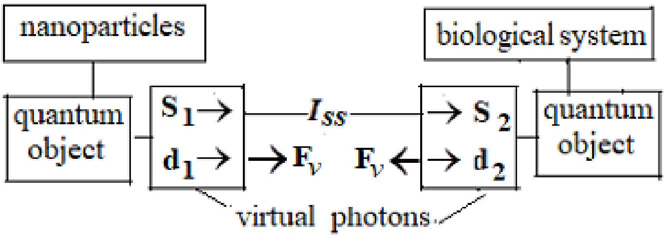


**Figure 6.2**. Schematic diagram of interaction of nanoparticles and a biological system. $\mathbf{S}_1$ and $\mathbf{S}_2$ are spins of virtual photons; $\mathbf{d}_1$ and $\mathbf{d}_2$ are electric dipole moments; $\mathbf{F}_V$ is an electric dipole-dipole attractive force between virtual photons; $I_{ss}$ is a spin supercurrent.

It should be noted that for successful passive adhesion of metal NPs, the use of Fe NPs is most desirable as they have "free" electrons' spins and, consequently, according to Eqs (1.9)-(1.10), "free" precessing spins of virtual photons created by those electrons. In this case a large number of these virtual photons will interact by means of spin supercurrent with virtual photons created by quantum objects of BS and form pairs for which Condition (6.1) is fulfilled. Thus, attractive force $\mathbf{F}_V$ can be great in this case.

7) It is an experimental fact that 3D NPs, which are spiral shaped, deform and even unwind the spiral when penetrating a DNA molecule. One example of such 3D NP is fullerene; computer simulations have shown that fullerenes, namely, spherical C60 molecules, are potentially dangerous to DNA molecules [81]. Another example of influence on a DNA molecule is dendrimer: 3D and higher generation dendrimers have a form which is similar to a sphere [82].

The observed results of action of 3D NPs can be a consequence of the action of spin supercurrent transferring the angular momentum.

## 6.2. Nanoparticles Against Viruses

The viruses consist of one of the types of nucleic acid (DNA-deoxyribonucleic acid or RNA-ribonucleic acid), that is viruses are quantum objects creating virtual photons. Thus, spin supercurrent can emerge between virtual photons created by quantum objects of viruses, on the one hand, and virtual photons created by quantum objects of other bodies, on the other hand.

The comparative analysis of characteristics of viruses and the properties of spin supercurrent shows that spin supercurrent can effectively influence viruses [73].

1) Viruses replicate inside the cell of all type of life forms, from animals and plants to microorganisms.

Spin supercurrent can emerge between virtual photons created by any quantum objects: electrically charged and neutral; magnetized and non-magnetized; constituting living organisms and non-living objects.

2) Viruses have a very small size equal to the one-hundredth the size of most bacteria.

According to property 7 of spin supercurrent, Eq. (1.21), the fact that viruses have a small size is of fundamental importance for the effective action of spin supercurrent on viruses.

3) Viruses are surrounded by a protective protein “coat”.

According to property 6 (Section 1.2) of spin supercurrent, the action of spin supercurrent is not shielded by electromagnetic and molecular screens.

4) Viruses have the shape from simple helical and icosahedral forms to more complex structures.

Spin supercurrent is a unique process because it transfers angular momentum. Consequently, spin supercurrent can change the viruses form if the current emerges, for example, between virtual photons created by viruses and virtual photons created by 3D NPs. The 3D NPs having spiral shape can deform and even unwind the spiral when penetrating a DNA or a RNA molecules.