Nanoparticle Interaction with Model Membranes

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Abstract

This talk describes the interaction mechanism of 3 classes of nanoparticles: SiO_2, ZnO and TiO_2 with biomembrane models. The particular model used was the ENNSATOX nanosensor which consisted of electrode supported phospholipid membranes on a microfabricated device in a flow cell[1]. Other membrane models of free standing phospholipid bilayers in vesicles and cell cultures were used to corroborate the results.

For amorphous SiO_2 at pH 7, particle size, geometrical and energetic considerations were the prime factors determining the particles' interaction with phospholipid membranes. The smaller the particle, the stronger the interaction which depended on the particle packing on the membrane surface. With free standing phospholipid membranes, SiO_2 particles < 30 nm in diameter adorbed on the membranes "freezing" the membrane structure. Larger SiO_2 particles destroyed the vesicle structure by causing the vesicle lipids to adsorb on the particle[1,2]. The interaction between particle and phospholipid appeared to be mainly instigated by van der Waals forces. The action of SiO_2 on cell cultures was shown to effect entry of SiO_2 into the cytoplasm due to their freezing effect on the biomembrane which led its consequent rupture.

ZnO nanoparticles differ from SiO_2 nanoparticles by showing a strong tendency to aggregate and to dissolve releasing Zn^{2+} ion[3]. Nonetheless using the ENNSATOX nanosensor it is possible to characterise the interactions between the ZnO particle and the phospholipid membrane before aggregation takes place and to see the effect of aggregation on the interaction. Moreover the influence of Zn^{2+} on the interaction can be separated from that due to the particle itself. It was shown that ZnO particle-membrane interaction is both inversely related to the primary size of the particle and to its state of aggregation. In addition coating the ZnO with $Zn_3(PO4)_2$ or fulvic acid decreased the interaction considerably.

Similar to ZnO, TiO_2 particles show a strong tendency to aggregate but can be stabilised by preserving in a low ionic strength solution of pH 2-3 where the particle carries a positive charge. Interaction of TiO_2 particles with phospholipid membranes also depends on particle size. Only particles of anatase of primary size < 10 nm were seen to interact strongly with the phospholipids. These results illustrate fundamental physical principles in the relationship between particle structure and their activity towards biomembranes and can be used to predict the biomembrane activity of different classes of nanoparticles.

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