Photocatalytic inactivation of bacteriophages using nanodispersed TiO_2

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TiO_2 photocatalysis has attracted great attention as a promising method of water and air cleaning [1,2] because highly-active radical species produced at TiO_2 surface under UV irradiation (hydroxyl radicals generated by photoholes from the TiO_2 valence band and superoxide ions formed due to interaction of photoelectrons from conduction band with molecular oxygen) can participate in the series of oxidation reactions resulting in the destruction of organic contaminants [2] that leads, in the limit, to their mineralization. Being strong oxidants, the reactive oxygen species generated by the TiO_2 photocatalytic reactions also cause various damages to microorganisms ensuring their rapid inactivation. Since the pioneer work of Matsunaga et al. [3] reported for the first time the microbiocide effect of the platinised TiO_2, research work on TiO_2-assisted photocatalytic killing has been intensively conducted on a wide spectrum of pathogenic microorganisms including bacteria, viruses, fungi and algae. These disinfection studies were carried out, on the one hand, to establish the basic photokilling mechanisms or to identify the effective disinfection factors [3,4] and, on the other hand, to investigate the disinfection kinetics for practical purposes [4,5]. They have revealed that the photocatalysis with TiO_2 shows much promise for the elimination of microorganisms in many applications especially in the areas where the use of chemical cleaning agents or biocides has proven to be ineffective or is restricted by regulations, e.g., in the pharmaceutical or food industry. However, while the mechanism of bacteria photokilling was studied in detail, the mechanism of inactivation of viruses still remains unclear.

In this work, the inactivation of bacteriophages BV-30 was studied. Nanodispersed TiO_2 photocatalyst shows high activity in photodeactivation of bacteriophages: the number of phages retaining the reproduction ability decreases by 33 times after 20-min of UV irradiation in the presence of TiO_2 nanoparticles. Figure 1 demonstrates that the attack of virions by active oxygen species produced at the photocatalyst surface results in the destruction of both phage capsid and phage tail, thus leading to virus degradation or preventing virus fastening onto the host cell, respectively.

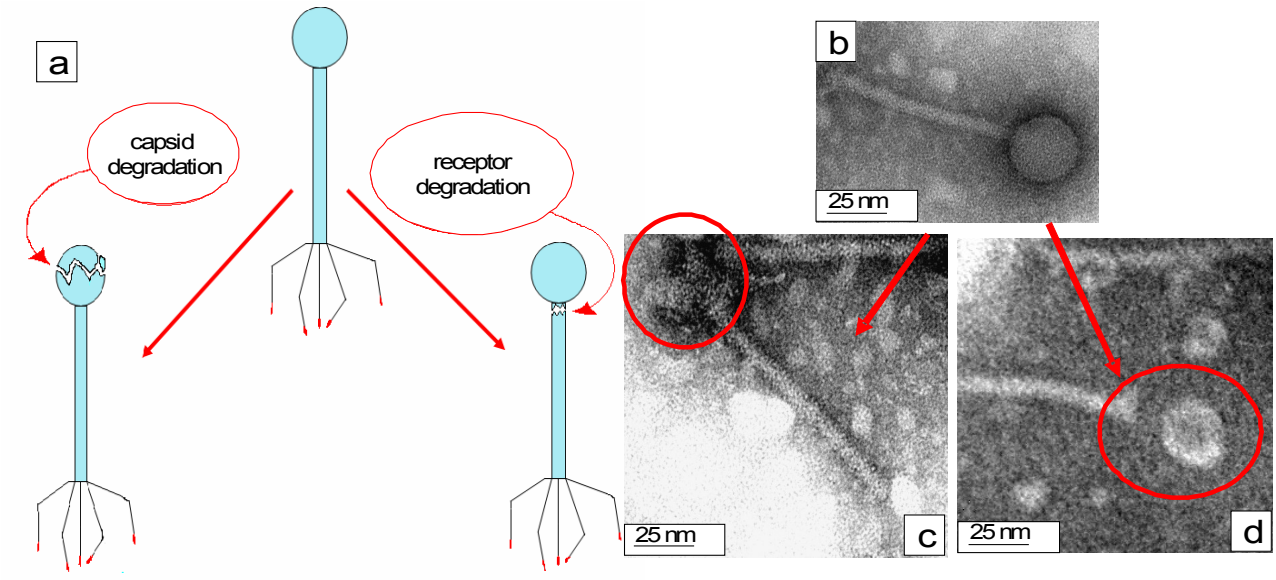

Fig. 1. (a) Schematic representation of phage deactivation. (b)TEM image of initial phage BV-30; (c,d) TEM images of phages BV-30 after UV irradiation in the presence of nano-TiO_2.

It has been shown previously [4] TiO_2-assested photocatalytic reactions cause great metabolic changes in bacteria even under the sub-lethal doses of UV irradiation. Our experiments has evidenced that lactate bacteria *L. lactis* containing DNA of temperate bacteriophage, being exposed to UV irradiation in the presence of nano-TiO_2, exhibit opening accompanied by release of mature phages in the surrounding medium; contrastingly, the irradiation of lactic bacteria with the same dose in the presence of non-photoactive nano-SiO_2 does not cause the breaking of the cellular membrane and the cell lysis. On this basis, the highly effective photocatalytic method permitting to reveal the lysogenic lactic bacteria can be developed.

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