NEW GENERATION ANTIMICROBIAL COATINGS BASED ON SILVER NANOPARTICLE-DISPERSED HYPERBRANCHED POLYGLYCEROLS CONTAINING MULTICHROMOPHORIC GROUPS

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INTRODUCTION

Nanoscience and nanotechnology has emerged as one of the promising areas of multidisciplinary science. Nanotechnology is an emerging technology seeking to exploit distinct technological advances of controlling the structure of materials at a reduced dimensional scale approaching individual molecules and their organized aggregates or supramolecular structures. Nanotechnology makes use of materials and systems at the scale of the atom: the nano-meter. By taking advantage of quantum-level properties, it allows for unprecedented control of the material world, at the nanoscale, providing the means by which system and materials can be built with exacting specifications and characteristics. Nanotechnology involves the tailoring of materials at atomic level to attain unique properties, which can be suitably manipulated for the desired applications. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production.

Nanotechnology is expected to open new avenues to fight and prevent disease using atomic scale tailoring of materials. The study of bactericidal nanomaterials is particularly timely considering the recent increase of new resistant strains of bacteria to the most potent antibiotics. The development of new resistant strains of bacteria to current antibiotics has become a serious problem in public health; therefore, there is a strong incentive to develop new bactericides. This makes current research in bactericidal nanomaterials particularly timely.

Dendrimers are synthetic, complex, and spherical molecules with very well defined chemical structures first synthesized in the early 1980s. These nanomaterials are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can be tailored to perform specific chemical functions. This property could also be useful for catalysis. Dendrimers show some significantly improved physical and chemical properties compared to traditional polymers. Also, because three-dimensional dendrimers contain interior cavities into which other molecules could be placed, they may be useful for drug delivery. Dendrimers have been applied in *invitro* diagnostics for heart muscle damage, tested as contrast agents for medical resonance imaging, have been used as photocross-linkable “glue” to seal large corneal lacerations in ophthalmic surgery, topical microbicide with activity against herpes simplex virus infection and HIV-1, used in drug delivery, in targeting tumour cells, in gene therapy, and in boron neutron capture therapy for cancer treatment. The dendrimer is built from an initiator core in sequential shells, called generations. The internal cavity of the “dendritic box” encapsulates guest molecules.

P. aeruginosa is a gram-negative bacterium, has become a major opportunistic human pathogen and the leading cause of nosocomial infections in cancer, transplantation, burn, and cystic fibrosis patients. These infections are impossible to eradicate in part due to its renowned intrinsic resistance to a wide spectrum of structurally and functionally diverse antibiotics. To effectively treat the bacterial infections and prevent bacteria from developing multidrug resistance (MDR), the main strategy is to fully understand MDR mechanisms and carefully design and screen more efficacious new antibiotics.

Silver ions have been known to be very effective against microorganisms and also to be non-toxic and environmentally friendly. Polymer coated functionalized noble metal nanoparticles have recently emerged as an active field of research due to many novel properties of these materials. Hyperbranched polyglycerol (HPG) is a novel biocompatible polymer that can be obtained by cationic or anionic ring-opening multibranching polymerization (ROMBP) of glycidol. In addition to its excellent biocompatibility, these polymers offer possibilities for further functionalisation due to its polyfunctionality.

Silver is an important commercially available metal and its nanoparticles are superior to other nanosized metal particles for their antimicrobial effects and optical and catalytic properties. However their stability is a serious problem and matrices with polar terminal groups like amine or hydroxyl groups are usually used for their stabilization. HPGs possess large number of peripheral hydroxyl groups and thus can be used for the stabilization of nanoparticles. Here we report the synthesis of nanoparticle dispersed HPG and its antibacterial activity on *P. aeruginosa*.

OBJECTIVES

- *To Synthesise metal nanoparticles such as Ag-NP by novel reduction methods*
- *To synthesise metal nanoparticle-dispersed dendritic polymers with extreme stability, solubility, and coating ability.*
- *To study the antimicrobial, especially, the antibacterial properties of the newly developed systems against various bacterial strains.*

RESULTS AND DISCUSSION

Silver nanoparticles and the nanoparticle dispersed HPGs were characterized by Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and UV-visible spectroscopy. The UV visible spectrum of the silver nanoparticle was recorded by dissolving the nanoparticles in hexane. In the UV visible spectrum, the maximum absorbing wavelength was in the visible region around λ_{max} 402 nm. It belongs to the characteristic Surface Plasmon Resonance band of silver nanoparticles.

The Surface Plasmon Resonance of silver nanoparticles depends on the size and shape of the particles. For nonspherical particles the absorption spectra consists of more than one SPR bands. Here we got only a single SPR band in the visible region. This observation suggests that the particles are spherical in shape. This spherical shape was again confirmed by SEM and TEM analysis. The UV-visible spectrum of nanoparticle encapsulated HPG was recorded by dissolving the product in hexane. In the UV-visible spectrum, there is a strong absorption peak at 408 nm characteristic of silver nanoparticles.

The scanning electron microscopic studies were conducted to investigate the surface morphology of silver nanoparticles and the distribution of the silver nanoparticles in the polymer matrix. It is evident from the SEM analysis that the nanoparticles are spherical in shape. It also indicates that there is no change in the size or shape of the nanoparticles upon encapsulation and the particles are well distributed in the polymer matrix. The TEM analysis of silver nanoparticles was conducted to probe the internal structure of the nanoparticle to get an access to the morphological fine structure. It is found that the nanoparticles are 8 nm in size, spherical in shape and have narrow size distribution.

Antimicrobial Studies

The antibacterial activity of silver nanoparticles encapsulated HPG was investigated on *P. aeruginosa*. The diameter of inhibition zone (in millimeters) around the nanosilver encapsulated HPG against test strain was found to be 15mm. In a control experiment HPG was also tested for their antibacterial activity. It was found that HPG is totally inactive towards *P. aeruginosa*. The size of bacterial colonies grown on plates was significantly reduced by the action of silver nanoparticles encapsulated HPG. The studies show that these particles have an excellent biocidal effect and effectiveness in reducing bacterial growth for practical applications such as the formulation of various biocidal materials. The bacteria was tested at two different concentrations of nanoparticle encapsulated HPG in order to observe the effect of concentration on bacterial growth. It is found that the activity is concentration dependent and the moderately concentrated solution shows high activity against the bacteria. This striking antibacterial activity makes this system efficient core material for various industrial applications. The antibacterial properties are associated with the slow oxidation of silver nanoparticles. Due to their small size, silver nanoparticles are capable of penetrating through the cell membrane. Inside the bacteria, they interact with the DNA and as a result, DNA loses its ability for replication and this ultimately leads to cell death. The bacterial activity was also tested against *Staphylococcus aureus, Escherichia coli,* and *Klebsiella pneumoniae*. The results confirmed that the treated *E. coli* and *Staphylococcus aureus* cells were damaged , showing formation of “pits” in the cell wall of the bacteria, while the silver nanoparticles were found to accumulate in the bacterial membrane. A membrane with such morphology exhibits a significant increase in permeability, resulting in death of the cell. These nontoxic nanomaterials, which can be prepared in a simple and cost-effective manner, may be suitable for the formulation of new types of bactericidal materials. The results are summarized in the following table.

Table. Results of Antibacterial Studies

Sl.No	Bacterial Strain tested	**I**	**II**	**III**	**IV**	**Mean**
1	*P. aeruginosa*	15	15	15	15	15
2	*Escherichia coli*	12	13	13	12	12.5
3	*Staphylococcus aureus*	19	19	19	19	19
4	*Klebsiella pneumoniae*	Resistant	Resistant	Resistant	Resistant	Resistant

CONCLUSION

Nanotechnology is the creation of functional materials, devices and systems, through the understanding and control of matter at dimensions in the nanometer scale length (1-100 nm), where new functionalities and properties of matter are observed and harnessed for a broad range of applications. It is expected that nanotechnology will be developed at several levels: materials, devices and systems. The nanomaterials level is the most advanced at present, both in scientific knowledge and in commercial applications. A decade ago, nanoparticles were studied because of their size-dependent physical and chemical properties. Now they have entered a commercial exploration period.

Nanoparticles are uniquely important because of their interesting and unexpected properties. Nanosized materials display different physical, chemical, electrical, magnetic and optical properties compared to bulk materials and hence offer great opportunities to harness them for new development. It is expected, that nanoparticle will have a huge impact in developments in new technologies in many fields including electronics, agriculture, environmental sciences and medicine in the coming years.

Further, nanotechnology was also expanded extensively to other fields of interest due to the novel properties of nanomaterials discovered and to be discovered. Nanotechnology offers important new tools expected to have a great impact on many areas in medical technology. It provides extraordinary opportunities not only to improve materials and medical devices but also to create new “smart” devices and technologies where existing and more conventional technologies may be reaching their limits. Nanotechnology has the potential to make significant contributions to disease detection, diagnosis, therapy, and prevention. Further advances are needed in order to turn the concept of nanoparticle technology into a realistic practical application as the next generation of drug delivery system. The present study gave important results on the stability, coating ability, solubility and excellent antibacterial activity of a newly developed Ag-NP HPG(dendritic) system.

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