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Antibacterial Effects of Silver Doped Polyethyleneglycol Based Polyamidoamine Side Chain Dendritic Polyurethane

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Antibacterial activity was imparted with polyamidoamine (PAMAM) side chain dendritic polyurethane (SCDPU-PEG) by doping of silver particles. Antibacterial activities of both the polyurethane (SCDPU-PEG) and its silver doped structures were investigated against Escherichia coli bacteria. The silver doped polymeric structures were found to exhibit antibacterial activity while the polymer without silver loading showed no antibacterial activity. Formation of silver doped side chain dendritic polymers was investigated from the UV-vis plasmon absorption band of silver particles.

Keywords polyamidoamine (PAMAM), dendritic polyurethane (SCDPU-PEG), polyethylene glycol, antibacterial

Introduction

Polyamidoamine (PAMAM) dendrimers (1–3) having biocompatibility and unique architectural benefits have recently attracted increasing interest as backbones for the development of several biologic materials. In particular, there is considerable current interest in the development and use of dendronized polymers/side chain dendritic polymers (SCDPs) for biomimetic applications. In this context, we have recently reported (4) a series of PAMAM side chain dendritic polyurethanes for their ultimate application in the biomedical field. Moreover, due to the increasing demand in hygienic living conditions, antimicrobial polymers (5) are of great interest. Therefore, achieving the antibacterial PAMAM based dendritic polyurethanes is an important goal in their use for prevention of biomaterials related infections. We have recently reported (6) the antibacterial activity of polyamidoamine side chain dendritic polyurethane (SCDPU) architecture, as well as its silver doped composite structures. This paper reports the antibacterial activity of our recently developed (4c) polyethyleneglycol embedded side chain dendritic polyurethane (SCDPU-PEG) and its complexes with metal ions, especially the silver ion.

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Experimental

Materials

PEG-based PAMAM side chain dendritic polyurethane (SCDPU-PEG) was synthesized as described previously (4c). Silver nitrate, sodium borohydride, nutrient agar and other reagents were used as received.

Preparation of Silver Doped (Ag^{+}/Ag^{0}) Polymers of SCDPU-PEG

The synthesis procedure of silver doped polymers is similar to that reported procedures (6–8). The SCDPU-PEG (1) encapsulated silver particles were synthesized in aDMSO: H_2O (1:1) solution containing an equal volume of SCDPU-PEG (1.69×10^{-3} M) and $AgNO_3$ (3.68×10^{-2} M). After allowing the solution to equilibrate for 20 min, $NaBH_4$ was added to reduce the silver ions. The reduction of silver ions was checked by a Shimadzu UV-VIS spectrophotometer.

Antibacterial Assessment

The antibacterial activities of SCDPU-PEG and its silver doped products were evaluated against *Escherichia coli* bacteria using a nutrient agar method according to our previously reported procedure (6). The evaluated plates were then seeded with *Escherichia coli* bacteria. 20 μL of each of the prepared sample solutions was taken in each of the Whatman paper discs (6.5 mm dia.). The discs loaded with samples were planted onto the agar plates. All the plates were incubated at 37°C for 18 h, and the zone of inhibition around sample-loaded discs was measured.

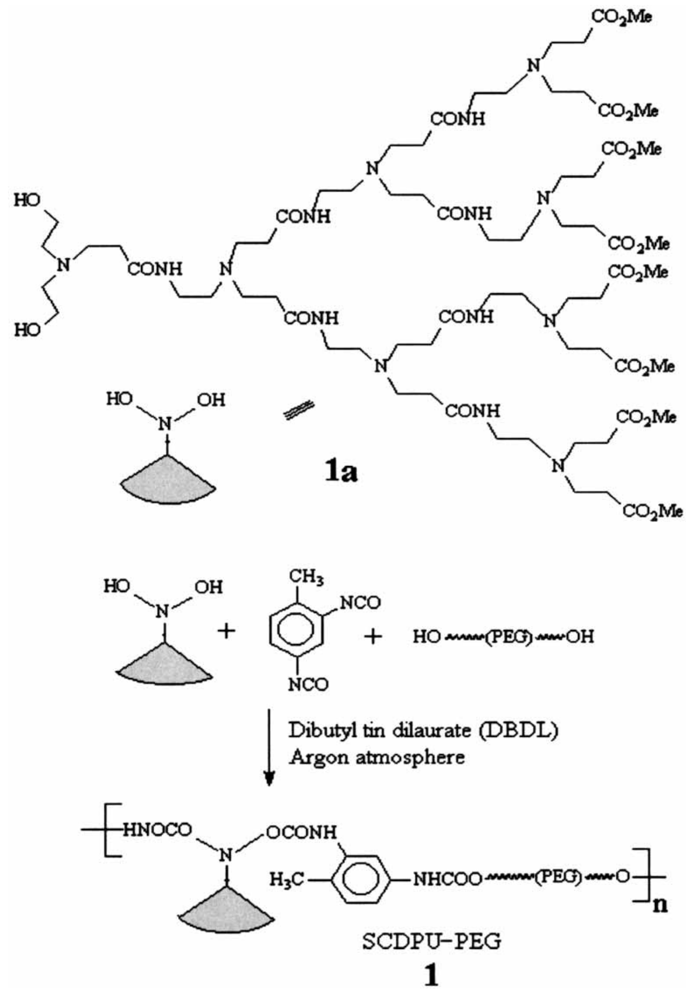
Results and Discussion

Synthesis

In our previous report (4, 6) we have developed PAMAM side chain dendritic polyurethane and studied the cytotoxicity, as well as antibacterial activity. Recently, we logically extended our approach to the synthesis of novel PAMAM side chain dendritic polyurethane architecture **1** incorporating PEG units in order to amplify its biocompatibility to some extent. The synthetic strategy that was elaborated in the recent report (4c) for the preparation of **1** is outlined in Scheme 1.

Characterization of Ag^{+}/Ag^{0} Doped Polymers (SCDPU-PEG)

The characteristics of the resulting silver doped composites derived from SCDPU-PEG **1** were estimated on the basis of UV-vis spectroscopic measurement. Polyurethane **1** provided the effective polymeric chelating agent to Ag^{+} ions. On addition of $NaBH_4$ into the solutions, silver particles were formed resulting in the immediate change in solutions color from light yellow to orange. Before reduction, a solution of Ag^{+} ion doped polyurethane exhibits no absorptions in the UV-vis spectra due to the d^{10} configuration of silver ions. However, zero-valent silvers are known to have intense plasmon absorption bands in the visible region. After reduction, the absorption spectra of the silver particles passivated by **1** (Figure 1) display strong absorption bands at



Scheme 1.

around 394 nm with a shoulder at 540 nm attributing to the surface plasmon absorption of silver colloids.

Antibacterial Assessment

In the field of biomedical polymeric materials, infections associated with the biomaterials represent a significant challenge to develop antimicrobial surfaces for more wide spread applications of medical implants. In this context, silver doped materials exhibit effective antibacterial properties (5–8). In a recent study, we have observed that the loading of silver particles into the PAMAM dendron alters significantly its antibacterial activity. Therefore, in this paper we have explored the anti bacterial activities of SCDPU-PEG and SCDPU-PEG-silver composites (SCDPU-PEG-[$(Ag^+)_x$], SCDPU-PEG-[$(Ag^0)_x$]) against *Escherichia coli* bacteria. A control experiment was conducted with only DMSO:H_2O (1:1) to verify the effect of its use during study. Moreover,

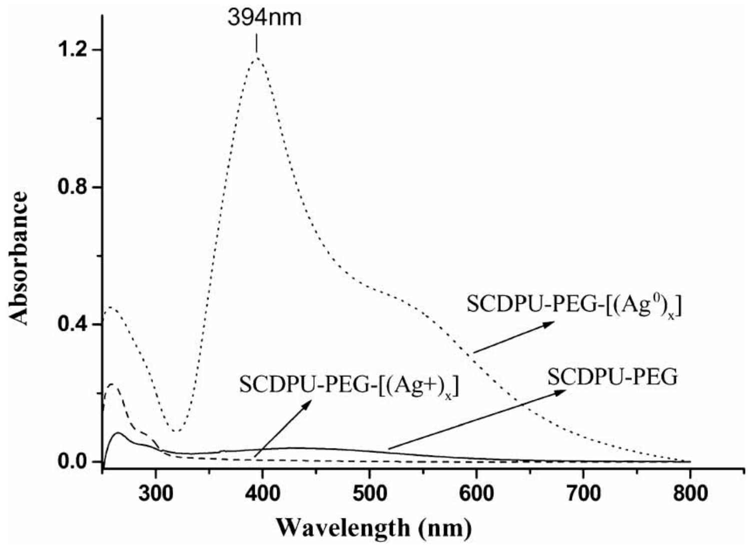


Figure 1. UV-vis spectra of SCDPU-PEG and its silver doped composites (SCDPU-PEG-[$(Ag^{+})_x$], SCDPU-PEG-[$(Ag^{0})_x$]).

a known antibiotic, like amoxicillin, was also used for confirmation of the study of antibacterial activity against *E. coli* bacteria.

From the data shown in Table 1, it was concluded that polydendron **1** showed no inhibitory effect. However, the silver (Ag^{+}/Ag^{0}) doped polydendron exhibited a inhibitory effect towards the test bacteria on a solid agar medium on incubation for 18 h although no significant difference in the total area of zone of inhibition was observed amongst the silver loaded samples.

Figure 2 shows the growth inhibitory effect of **1** and its silver doped materials e.g, SCDPU-PEG-[$(Ag^{+})_x$], SCDPU-PEG-[$(Ag^{0})_x$]. The results obtained showed that the polydendron **1** only have antibacterial activity when associated in a silver complex. The oxidation state of the silver in the complex is immaterial. These observations are in agreement with those reported in our previous paper (6). It is thus obvious from the results that both Ag^{+} and Ag^{0} play an important role in providing effective protection of SCDPU-PEG from bacterial attack.

Table 1
Diameters of Inhibition zones against *Escherichia coli* bacteria

Samples	Inhibition zones (mm)
SCDPU-PEG	0
SCDPU-PEG-[$(Ag^{+})_x$]	11.5
SCDPU-PEG-[$(Ag^{0})_x$]	11

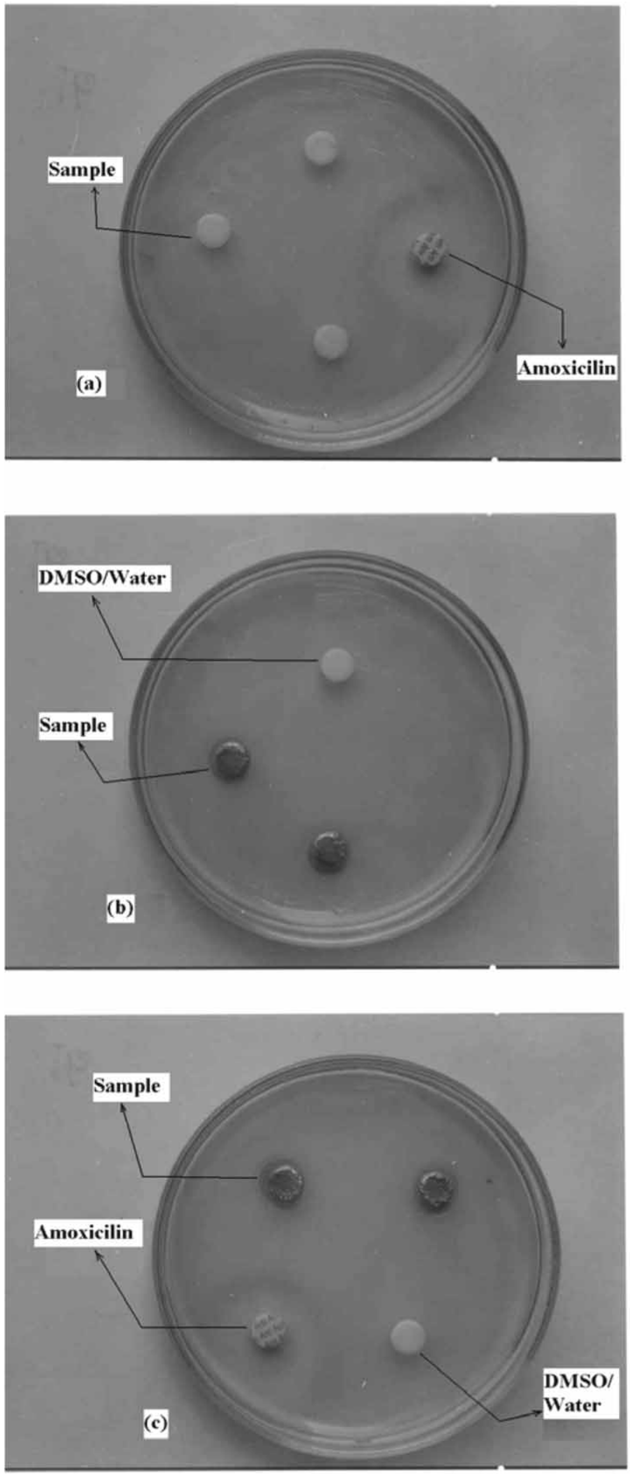


Figure 2. Bacterial adherence to polymer samples kept in contact with *E. coli* bacteria (a) SCDPU-PEG, (b) SCDPU-PEG-[$(Ag^{+})_x$], (c) SCDPU-PEG-[$(Ag^{0})_x$]

Conclusions

Thus, the primary evaluation of the antibacterial properties of PEG based polydendron and its silver based composites like SCDPU-PEG-$[(Ag^{+})_x]$, SCDPU-PEG-$[(Ag^{0})_x]$ has been achieved *in vitro* against *E. coli.* Silver doped materials only exhibited the antibacterial effects. Thus, the antibacterial characteristics of SCDPU-PEG, as well as their silver doped composites, might be of interest to meet the specific demand in hygienic living conditions. Further studies are under progress.

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