Synchrotron X-ray radiation was used to synthesis Ag and Au nanoparticles, and simultaneous diffusion of them in Polycarbonate (PC) films. The diffusion of nanoparticles were characterized by Rutherford back scattering, X-ray diffraction, Scanning electron microscopy, UV-Visible spectroscopy, Fourier transform infrared spectroscopy. From these techniques, it is confirmed the diffusion of face-centered cubic structured silver and gold nanoparticles on the surface of Polycarbonate after irradiation. The results of anti-biofilm activity of the synthesized Ag-PC and Au-PC matrix demonstrated its bacterial growth inhibition ability. The results indicate the potential to produce an Ag-PC and Au-PC matrix for various applications in medical and food industries by Synchrotron X-ray radiation assisted method.
4.1 Introduction

Synchrotron radiation is the radiation which occurs when charged particles are accelerated in a curved path or orbit. Fundamentally, if charged particle which moves in a curved path or is accelerated/decelerated in a straight line path will emit electromagnetic radiation. Various names are given to this kind of radiation in different application contexts. In the application to the circular particle accelerators like synchrotrons, where charged particles are accelerated to ultra high speeds, the radiation is referred to as synchrotron radiation [1]. A synchrotron source is basically a source of electromagnetic radiation. Synchrotron radiation is produced by storage rings and particle accelerators, typically accelerating electrons. Once the high energy electron beam is generated, it is directed into bending magnets and insertion devices in storage rings. These supply the strong magnetic fields perpendicular to the beam which is needed to convert high energy electrons into photons [2].

Synchrotron radiations have major applications in condensed matter physics, materials science, and biology. Many experiments are being carried out using synchrotron radiations which involve probing the structure of matter from the nanometer level of electronic structure to the micrometer level for medical imaging. Synchrotron radiation possesses high intensity, tunable wavelength, collimation, and polarization can be used at beamlines which are designed for specific kinds of experiments. The high intensity and penetrating power of synchrotron X-rays enables experiments to be performed inside irradiation chambers designed for specific environments. Samples may be heated/cooled, or exposed to gas/liquid or high pressure environments [3].

Among various approaches to synthesis of metal-polymer nanocomposites, the radiation-chemical reduction of metal ions was found to be a promising tool due to the feasibility of controlling the generation of reducing agents and reduction rate. In our earlier work, the mechanism of the radiation-induced reduction of metal ions and formation of metal nanoparticles was studied in detail. It is worth mentioning that the cited works were carried out with γ-irradiation [4], [5]. Meanwhile, according to the literature survey, the applications of X-ray radiation for reduction of metal ions are still rather limited. Vladimir I. Feldman et al. [6] reported that, pioneering work of X-ray radiation assisted reduction was carried out by Muller et al.[7]. They have
introduced this method for surface treatment of a Langmuir monolayer leading to the formation of nanostructured films. Vladimir I. Feldman et al. themselves used X-ray assisted synthesis method for the formation of metal nanoparticles from interpolyelectrolyte complexes with copper and silver ions [6]. Plasmonic nanostructures were synthesized using monochromatic X-rays for photovoltaic applications [8]. Further, the irradiation with soft X-rays were used for surface reduction of noble metal ions embedded in a polymer medium resulting in the formation of metal nanoparticles [9]. Similarly, it has been shown that white X-ray radiation (bremsstrahlung) was successfully used for effective reduction of metal ions and preparation of nanocomposites from interpolyelectrolyte films in the swollen state [10].

In the present study, irradiation has been carried out using synchrotron X-rays beam of energy upto 40 keV at beamline used for materials science experiments (imaging beamline, 2.5 GeV storage ring energy and 135 mA maximum current), Indus-2, RRCAT (Indore) INDIA. The photon flux was $6.9 \times 10^7$ ph/s at energy 20 keV [11].

4.2 Experimental details and characterizations

Appropriate amount of AgNO$_3$ and HAuCl$_4$ powder was dissolved in 100 ml of double distilled water in separate bottles. The mixture was stirred continuously for 30 min at room temperature. PVP and CTAB were added to the Ag and Au solution respectively and kept for further stirring. For irradiation purpose, glass bottles were taken and each bottle was filled with 10 ml of Ag/Au solution. In every bottle Polycarbonate (Lexan, C$_{16}$H$_{14}$O$_3$, thickness – 200 µm) film of size (1.5 x 1.5) cm$^2$ were immersed. These bottles were exposed to 40 keV synchrotron X-rays for the period of 15 min (27126 mAs), 30 min (54255 mAs), 45 min (108510 mAs) and 60 min (217020 mAs). These were named as Dose 1, Dose 2, Dose 3 and Dose 4 respectively. PC samples were removed from the bottle, washed with copious amount of distilled water and dried at room temperature.

The surface plasma resonance of gold was studied by UV-Visible spectroscopy of model JASCO, V-670 UV-Visible spectrophotometer by taking PC as a reference in the wavelength range 300-700 nm. The diffusion of Au in PC was estimated by Rutherford Backscattering (RBS) technique using helium ions of energy 2 MeV. XRD diffractograms were recorded in the 2θ range (10-80°) using a Bruker
AXS D8 Advance X-ray diffractometer with CuK\textsubscript{\alpha} radiation at a wavelength of 1.5406 Å. The surface morphology and atomic percentage of gold for all the samples was studied using SEM of model JEOL JSM 6390LV attached with electron diffusion spectroscopy (EDS). FTIR spectroscopy was carried out for all the samples using JASCO V-670 FTIR spectrophotometer. The positron lifetime measurements were made at room temperature with two BaF\textsubscript{2} scintillators, coupled to XP2020Q photomultipliers using a fast–fast coincidence system with a time resolution of 220 psec, to record the start and stop events. The lifetime spectra, containing at least 10\textsuperscript{6} counts, were analysed using the PAT-fit program. For the CDBS measurements a high purity Germanium (HPGe) energy sensitive detector, with 1.1 keV full width at half maximum (FWHM) resolution, enabled the linear momentum to be measured. The source-sample sandwich was placed 20 cm away from the detector to avoid any increase in the background detection due to 3-\gamma annihilation. Around 10\textsuperscript{6}-10\textsuperscript{7} counts were collected under each Doppler Broadened 511 keV \gamma-ray spectrum.

**4.3 Results and discussion**

**4.3.1 Rutherford backscattering spectroscopy**

The content of Ag and Au particle in the polycarbonate matrix and their depth profile were determined from the RBS spectra measured with the 2 MeV \textsuperscript{4}He beam (0° incidence angle, 165° laboratory scattering angle), and the back scattered particles were detected with a surface barrier detector. Depth profile of the incorporated Ag and Au atoms were determined by a simple channel by channel method taking into account the energy dependence of the alpha particle stopping power, calculated for pristine polymers using the data base from the SRIM code (Ziegler et al., 2010). The RBS spectra of PC, Ag-PC and Au-PC samples are as shown in figure 4.1. In the figure 4.1(a), the peak edge at the channel \~1725 corresponds to silver and in the figure 4.1(b), the peak edge at the channel \~1837 corresponds to gold content. This indicates the diffusion of silver and gold nanoparticles inside the PC matrix. The depth of distribution of silver nanoparticles in PC at the highest X-ray dose (217020 mAs) is found to be 0.55 \textmu m while for the gold nanoparticles at the highest dose it is \~0.38 \textmu m.
The surface plasmon resonance of AgNPs in PC was studied using UV-Visible spectroscopic study and absorbance spectrum is shown in figure 4.2(a). At a low dose, a small peak at around 420 nm appears which corresponds to Ag. The absorbance of this peak increases with increase X-ray dose and also it shift towards lower wavelength region, i.e. blue shift. Similar kind of variation has been observed in our earlier studies using X-ray irradiation. This indicates that the particle size decreases with increase in X-ray dose.
Similarly, UV-Visible absorption spectra for Au-PC matrix irradiated by different X-ray doses are shown in figure 4.2(b). It can be observed from figure that the Au-PC showed main absorption edge at 585 nm. The absorbance of this peak increases with increase X-ray dose and also it shift towards lower wavelength region, i.e. blue shift. The intensity of this peak increases with increase in dose indicating the increase in concentration of gold particles inside PC. While, the blue shift indicate the decrease in particle size of gold.

![UV-Visible absorption spectra for Au-PC matrix](image)

Figure 4.2: UV-Visible absorption spectra (a) silver nanoparticles diffused PC and (b) gold nanoparticles diffused PC at different doses.
4.3.3 X-ray diffractogram (XRD)

XRD patterns for silver and gold diffused PC are shown in figure 4.3. Figure 4.3(a) shows spectra of samples after irradiating PC in silver solution at increase in dose, indicates a main sharp peak at $2\theta \sim 38.20^\circ$ with index (111) and small peaks at $2\theta \sim 44.52^\circ$, $64.61^\circ$, $77.50^\circ$ with index (200), (220), (311) respectively, which corresponds to silver nanoparticles and the structure of these silver nanoparticles is face centred cubic (JCPDS file no. 04.0784). Figure 4.3(b) shows spectra of Au-PC samples with increase in dose, indicates a main sharp peak at $2\theta \sim 38.29^\circ$ with index (111) and small peaks at $2\theta \sim 44.56^\circ$, $64.65^\circ$, $77.68^\circ$ with index (200), (220), (311) respectively, which corresponds to gold nanoparticles and the structure of these gold nanoparticles is also FCC (JCPDS file no. 04.0784). In addition, figures 4.3(a) and 4.3(b) also show the increase in intensity and broadening of XRD peaks indicating the diffusion of more silver/gold particles and the average size of the particles decreases with increase in X-ray dose. The particle size of silver and gold nanoparticles irradiated at highest dose is found to be 70 nm and 90 nm respectively.
4.3.4 Scanning electron microscopy (SEM)

Figure 4.4 shows the SEM images of the Ag-PC and Au-PC samples. It is found from SEM images, for both the cases that the particle size of Ag and Au nanoparticles decreases with increase in synchrotron X-ray dose. The atomic percentage of Ag and Au in all samples are measured using EDS and is found to increase with increase in X-ray dose. The nanoparticles formed on the surface are considerably larger than the nanoparticles formed and diffused in the subsurface region of the PC matrix. Hence, there is an obvious difference in the size of the nanoparticles observed in the SEM images and the nanoparticles size calculated from the XRD data. In case of Ag-PC samples, the average particle size of nanoparticles irradiated at lower doses is in the range of 100-120 nm and this goes on decreasing with increasing in dose. For the highest dose it is ∼80 nm. Similarly for Au-PC samples the average particle size decreases from 150 nm to 100 nm.
4.3.5 FTIR spectroscopy

To investigate the origin of interaction between silver and gold nanoparticles with chemical groups in the PC matrix, FTIR measurements of pristine PC and synchrotron X-ray irradiated PC in silver/gold solution were measured and is as shown in figure 4.5. As seen from the spectra, all of them exhibit the characteristic signature of vibrations of benzene ring, –CH₂– and asymmetric vibrations of CH₃ at 1505 cm⁻¹, 1014 cm⁻¹ and 2968 cm⁻¹ respectively [12][13]. The peaks present between the wave numbers 1150 cm⁻¹ to 1220 cm⁻¹ are due to C–O–C vibrations (aromatic). It
is clearly observed that, there is change in the intensities of all these bands. This clearly indicates the scissioning of the corresponding bonds on X-ray exposure of PC. A peak at 1602 cm\(^{-1}\) is assigned to the stretching band of C–O and is observed shifting from 1602 cm\(^{-1}\) to 1645 cm\(^{-1}\) for Ag-PC samples and to 1650 cm\(^{-1}\) for Au-PC samples. These shifts identify that the oxygen ion pair in –C–O– participates in the interaction and is main interaction between surface of Ag/Au nanoparticles and PC chains [13]. At 3260 cm\(^{-1}\), a broad band present in case of pristine and X-ray irradiated samples, which is due to O–H bonds. Sinha et al. [12] reported that, phenolic groups (-OH groups) are formed in PC after irradiation. Also, this may be due to the presence of water molecules adsorbed on the surface of PC surface [13].

![Figure 4.5: FTIR spectra of (a) silver nanoparticles diffused PC and (b) gold nanoparticles diffused PC at different doses.](image)
4.3.6 Positron annihilation lifetime spectroscopy

Initial studies using Positron Annihilation Lifetime Spectroscopy (PALS) sought the microstructural changes caused by different doses of X-ray irradiation assisted in-situ diffusion of AgNPs and AuNPs in PC. In order to get detailed information, we have carried out PAS measurements for pristine PC i.e. irradiated without silver/gold solution at the same synchrotron X-rays doses. In this study, same protocol which we had used in our earlier studies was used to analyse the data. The obtained lifetime spectra are resolved into three-lifetime components \( \tau_1 \), \( \tau_2 \) and \( \tau_3 \) using Positron Annihilation Lifetime Spectroscopy fit program with variances \( \chi^2 \) of fits \( \approx 1 \) and with respective intensities \( I_1 \), \( I_2 \) and \( I_3 \). The shortest lifetime \( \tau_1 \) with intensity \( I_1 \) is attributed to annihilation of para-positronium (p-Ps) and free positron. The lifetime component \( \tau_2 \) with intensity \( I_2 \) is the contribution due to the positrons trapped at the defects present in the crystalline regions or trapped at the crystalline-amorphous interface regions. The longest-lived component \( \tau_3 \) with intensity \( I_3 \) is due to the pickoff annihilation of the ortho-positronium (o-Ps) from the free volume sites present mainly in the amorphous regions of the polymer matrix [14]. The long life component \( \tau_3 \) of o-Ps respond very sensitively to the size and the distribution of the free volumes as Ps atoms are preferentially trapped in holes of atomic dimensions.

The average free volume hole size \( (V_f) \), the fractional free volume or the free-volume \( F_V \) and the obtained values of parameters \( \tau_3 \), \( I_3 \) and \( V_f \) are tabulated for X-ray irradiated PC without and with silver/gold solution are given in Table 4.1, 4.2 and 4.3 respectively.

From Table 4.1, we can observe that values of \( \tau_3 \), \( I_3 \) and \( F_V \) for X-ray irradiated PC decreases with increase in X-ray irradiation dose. The decrease in \( I_3 \) and \( F_V \) is associated with decrease in the concentration of free-volume holes [15], as a consequence of cross-linking process in the polymer matrix [16] and could be due to the formation of free radicals and cross linking of these free radicals with residual polymer [17]. Further the decrease in \( \tau_3 \) could be due to chemical reaction of these free radicals with positronium. In the cross-linked state the polymer chains are expected to have closer packing resulting in the decrease of sizes of the free volume holes which is evident from the decrease in the \( \tau_3 \) values.
Table 4.1: PAS results of the Synchrotron X-ray irradiated pristine polycarbonate samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>$I_3$ ± 0.22(%)</th>
<th>$\tau_3$ ± 0.0082(ns)</th>
<th>$R$ (Å)</th>
<th>$V_f$ ± 0.7(Å$^3$)</th>
<th>$F_V$ ± 0.03(%)</th>
<th>$S$ ± 0.00016</th>
<th>$W$ ± 0.00001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>32.13</td>
<td>2.131</td>
<td>2.966</td>
<td>109.74</td>
<td>6.35</td>
<td>0.5155</td>
<td>0.00342</td>
</tr>
<tr>
<td>Dose 1</td>
<td>31.28</td>
<td>2.092</td>
<td>2.932</td>
<td>105.58</td>
<td>5.94</td>
<td>0.5124</td>
<td>0.00354</td>
</tr>
<tr>
<td>Dose 2</td>
<td>30.38</td>
<td>2.058</td>
<td>2.902</td>
<td>102.37</td>
<td>5.59</td>
<td>0.5113</td>
<td>0.00363</td>
</tr>
<tr>
<td>Dose 3</td>
<td>28.98</td>
<td>2.034</td>
<td>2.880</td>
<td>100.06</td>
<td>5.22</td>
<td>0.5104</td>
<td>0.00368</td>
</tr>
<tr>
<td>Dose 4</td>
<td>27.52</td>
<td>2.019</td>
<td>2.866</td>
<td>98.61</td>
<td>4.88</td>
<td>0.5099</td>
<td>0.00371</td>
</tr>
</tbody>
</table>

Table 4.2: PAS results of the Synchrotron X-ray prepared Ag-polycarbonate samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>$I_3$ ± 0.22(%)</th>
<th>$\tau_3$ ± 0.0082(ns)</th>
<th>$R$ (Å)</th>
<th>$V_f$ ± 0.7(Å$^3$)</th>
<th>$F_V$ ± 0.03(%)</th>
<th>$S$ ± 0.00016</th>
<th>$W$ ± 0.00001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>32.13</td>
<td>2.131</td>
<td>2.966</td>
<td>109.74</td>
<td>6.35</td>
<td>0.5155</td>
<td>0.00342</td>
</tr>
<tr>
<td>Dose 1</td>
<td>32.01</td>
<td>2.117</td>
<td>2.954</td>
<td>107.97</td>
<td>6.22</td>
<td>0.5137</td>
<td>0.00349</td>
</tr>
<tr>
<td>Dose 2</td>
<td>31.44</td>
<td>2.092</td>
<td>2.932</td>
<td>105.57</td>
<td>5.97</td>
<td>0.5119</td>
<td>0.00354</td>
</tr>
<tr>
<td>Dose 3</td>
<td>30.04</td>
<td>2.063</td>
<td>2.906</td>
<td>102.79</td>
<td>5.56</td>
<td>0.5109</td>
<td>0.00361</td>
</tr>
<tr>
<td>Dose 4</td>
<td>28.89</td>
<td>2.032</td>
<td>2.878</td>
<td>99.85</td>
<td>5.19</td>
<td>0.5104</td>
<td>0.00366</td>
</tr>
</tbody>
</table>

Table 4.3: PAS results of the Synchrotron X-ray prepared Au-polycarbonate samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>$I_3$ ± 0.22(%)</th>
<th>$\tau_3$ ± 0.0082(ns)</th>
<th>$R$ (Å)</th>
<th>$V_f$ ± 0.7(Å$^3$)</th>
<th>$F_V$ ± 0.03(%)</th>
<th>$S$ ± 0.00016</th>
<th>$W$ ± 0.00001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>32.13</td>
<td>2.131</td>
<td>2.966</td>
<td>109.74</td>
<td>6.35</td>
<td>0.5155</td>
<td>0.00342</td>
</tr>
<tr>
<td>Dose 1</td>
<td>31.88</td>
<td>2.107</td>
<td>2.945</td>
<td>106.99</td>
<td>6.14</td>
<td>0.5131</td>
<td>0.00352</td>
</tr>
<tr>
<td>Dose 2</td>
<td>31.01</td>
<td>2.081</td>
<td>2.922</td>
<td>104.50</td>
<td>5.83</td>
<td>0.5119</td>
<td>0.00359</td>
</tr>
<tr>
<td>Dose 3</td>
<td>29.93</td>
<td>2.049</td>
<td>2.894</td>
<td>101.53</td>
<td>5.47</td>
<td>0.5108</td>
<td>0.00365</td>
</tr>
<tr>
<td>Dose 4</td>
<td>28.01</td>
<td>2.026</td>
<td>2.873</td>
<td>99.33</td>
<td>5.01</td>
<td>0.5102</td>
<td>0.00369</td>
</tr>
</tbody>
</table>

Similar to X-ray irradiation of pristine PC, when the PC samples were irradiated in silver and gold solution, the $\tau_3$, $I_3$ (Table 4.2 and 4.3) and $F_V$ (Figure 4.6 and 4.7) values decreased gradually. The decrease in $\tau_3$, $I_3$ and $F_V$ for this set of samples can be explained as discussed earlier. Due to irradiation, cross-linking occurs and results in close packing of polymer chains thereby decreasing the average free volume size and number density of free volume sites; hence $I_3$ decrease is observed and consequently $F_V$ also decreases. However, the decrease in $\tau_3$, $I_3$ and $F_V$ is less compared to that of X-ray irradiated PC. This may be due to the diffusion of AgNPs and AuNPs in to the free volume holes. These nanoparticles may diffuse into
the free volume holes results in the less decrease of $\tau_3$, $I_3$ and $F_V$ compared to that of X-rayirradiated PC. This is also supported by RBS results.

Figure 4.6 (c-d) and 4.7 (c-d) shows the change in the $S$ and $W$ parameters for Ag and Au doped PC respectively, calculated from the Doppler Broadening spectrum. As can be seen from the figures, the line shape parameter $S$ decreases whereas $W$ increases with increasing dose. This result is consistent with the RBS and XRD results which show increase in the diffusion of Ag particles into the polymer matrix as the irradiation dose increased. As the diffusion of nanoparticles into PC matrix increases the overall crystalline region of the sample increases. Thus with increase in dosage the crystallinity of the sample increases which results in reduction in free-volume size (i.e. amorphous region). This interpretation is in agreement with the PAS results given in Table 4.2 and 4.3.

![Figure 4.6](image)

Figure 4.6 : Variation of the (a) fractional free volume (b) average free volume size (c) $S$-parameter and (d) $W$-parameter of pristine and Ag-PC samples as a function of dose.

The shape of the DB spectrum is determined by the momentum distribution of electrons with which the positron interacts—i.e., valence or core—and the type of atom donating the electron. If the annihilation occurs in a large open volume site such as a defect in a crystalline material or free volume in amorphous material (polymer), the
fraction of low momentum conduction and valence electrons (represented by the $S$-parameter) participating in the process increases relative to the fraction of high momentum core electrons (represented by the $W$-parameter). Thus, a defect-rich/higher free volume material will have a narrower electron momentum distribution than would a defect free material. Similar to the gamma irradiated samples, in the present study for the X-ray irradiated Ag-PC/Au-PC samples, as the dosage increases the free volume size decreases and the observed increase in $W$ parameter and reduction in $S$ parameter are in complete agreement.

![Graphs showing variation of fractional free volume, average free volume size, S-parameter, and W-parameter](image)

Figure 4.7: Variation of the (a) fractional free volume (b) average free volume size (c) $S$-parameter and (d) $W$-parameter of pristine and Au-PC samples as a function of dose.

### 4.3.7 Testing of biofilm formation

The biofilm formation by *Salmonella typhi* on PC films, X-ray irradiated Au-PC and Ag-PC films were carried out. The test culture of *S. typhi* was grown for 24 hours at 37°C. A fresh culture was inoculated into the sterile petri plates containing 20 ml of sterile nutrient broth medium embedded with PC films. The plates without irradiated PC films were considered as control. The plates with Au-PC and Ag-PC films irradiated for 15, 30, 45 and 60 minutes (Dose 1 to Dose 4) were considered as
test. The biofilm formation on PC films, X-ray irradiated Au-PC and Ag-PC films were studied by using a scanning electron microscopy (SEM). The bacterial sample preparation for SEM examination was performed by using the protocol reported by Bankar et al., 2009 [18].

The PC used in these studies is a biocompatible polymer with low water absorption. These materials are easily sterilized and commonly used in medical equipments [19]. This material has ability to prevent biofilm formation on the medical devices and thus, plays important role in the prevention of infections and health issues [20]. It was seen that polymer is also compounded with different organic and inorganic biocides has antimicrobial property against several human pathogens [21]. Prevention of biofilm formation by pathogens has an importance in pathogenicity. It is known that bacterial biofilm is difficult to eradicate. The bacterial cells are protected from environment and antimicrobial agents when they are embedded in biofilms [22]. In the present study, anti-biofilm efficacy of Au and Ag diffused PC films was evaluated against the pathogenic strain of S. typhi. The biofilm was formed on control i.e. pristine PC films. Earlier Chelvam et al., have studied in detail the ability of S. typhi for biofilm formation [23].

Figure 4.8 shows a wide range of morphological differences in biofilm architectures of S. typhi. The obtained results are in well agreement with a previous report [24]. This figure shows the SEM images of S. typhi cells grown as biofilm on control PC and on Au-PC and Ag-PC samples irradiated at Dose 1 to Dose 4 (tests). The biofilm was very well established on control PC film and considered to be 100%. It was observed that that biofilm reduction (%) increased with increasing irradiation time. The biofilm formation was inhibited ≈ 30% at Dose 1 for Au-PC sample. Further, the biofilm was inhibited about 70, 90 and 95% for Dose 2, Dose 3 and Dose 4 for Au-PC films respectively. Figure 4.9 shows that the biofilm formation was 100% inhibited on Ag-PC samples for 15, 30, 45 and 60 minutes of irradiation i.e. for all the doses. This may be due to the populated clusters of the silver nanoparticles on the surface region of the PC matrix.

It was well known that PC has hydrophobic properties with a low energy surface. Moreover, incorporation of gold/silver nanoparticles in the Au/Ag-PC samples making the surface more hydrophilic. This is helping in the reduction of the formation of biofilm. Among all metal ions, silver is best for its antimicrobial properties [25]. Similar kind of study was carried out systematically earlier to study
the antimicrobial activity of Au/Ag metal [18], [26]. The positive charges of Au/Ag attracts towards negative charged bacterial cell surfaces. Further, they can damage the cell membrane and results into the cell death. They may also cause a serious problem to DNA, RNA and protein synthesis of bacterial cells [27],[28].

Figure 4.8: Biofilm formation by *S. typhi* on (a) PC films without irradiation (b-e) Au-PC samples with dose 1 to dose 4

Figure 4.9: Biofilm formation by *S. typhi* on (a) PC films without irradiation (b-e) Ag-PC samples with dose 1 to dose 4
4.4 Conclusion

Here, in this chapter we extended the study of radiation assisted nanocomposite synthesis method by using synchrotron X-rays. Ag-PC and Au-PC sample were prepared by an easy and cost effective method of X-rays irradiation by the similar approach. RBS results showed the diffusion of Ag and Au in PC down to a depth of 0.55 and 0.38 µm respectively. The surface plasmon resonance of the AgNPs/AuNPs decreased with increase in dose indicating the decrease in the particle size of Ag/Au which is also corroborated by SEM results. XRD results revealed that the diffused AgNPs/AuNPs have FCC structure. The effect of X-ray radiation with varying dosage on PC and Ag-PC/Au-PC samples has been studied through Positron Annihilation Spectroscopy. The observed reduction in lifetime parameters is due to the cross linking of chains and diffusion of Ag/Au nanoparticle into the amorphous region of the polymer matrix. These results were further supported by the line shape parameters S and W. The anti-biofilm against S. typhi on the surface of PC increased with increasing X-ray dose and Ag/Au content in the polymer matrix. This activity is observed due to Ag/Au metal’s toxicity towards cells of S. typhi.
References

[1] “http://hyperphysics.phy-astr.gsu.edu/hbase/Particles/synchrotron.html.”.


