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Topological and morphological analysis of gamma rays irradiated chitosan-poly (vinyl alcohol) blends using atomic force microscopy

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ABSTRACT

In the present communication, binary blends of poly (vinyl alcohol) (PVA) and chitosan (CS) were prepared by solution cast method and the roughness parameters of PVA, native CS and CS-PVA blend films were determined using atomic force microscopy (AFM). Moreover, the changes in the morphology of the samples were also investigated after irradiation of gamma rays at absorbed dose of 1 Mrad and 10 Mrad for the scanning areas of 5×5 μm^2, 10×10 μm^2 and 20×20 μm^2. Amplitude, statistical and spatial parameters, including line, 3D and 2D image profiles of the experimental surfaces were examined and compared to un-irradiated samples. For gamma irradiated CS-PVA blends the larger waviness over the surface was found as compared to un-irradiated CS-PVA blends but the values of average roughness for both the films were found almost same. The coefficient of skewness was positive for gamma irradiated CS-PVA blends which revealed the presence of more peaks than valleys on the blend surfaces.

1. Introduction

Developing new biocompatible materials has emerged as an interdisciplinary area of research where materials science and biomedical fields overlap to design well architectured molecular assemblies of great potential finding a wide spectrum of biomedical applications ranging from drug delivery systems to artificial implants. Among several approaches of fabricating biocompatible materials, high energy radiations e.g. gamma rays, has been the most effective strategy in medical and pharmaceutical domains (Shahabi et al., 2014). The ultimate properties of the irradiated films depend greatly on the nature and structure of target materials as well as the dose of the radiation used. Some of the observed changes may be related to the formation of clusters due to cross-linking, chain scission and formation of new chemical linkages or breaking up of chemical bonds (Katare et al., 2014). Exposure to gamma radiation results in an enhanced cross-linking of the polymer networks and affects surface morphology by rearrangement of macromolecular chains by inter-molecular forces.

Chitosan (CS) is a natural polysaccharide biopolymer which is mainly used in wound healing agent as a cream, dressing excipient, and skin adhesive (Chhatri et al., 2011; Paul and Sharma, 2004; Silva et al., 2008). Blending of CS with synthetic polymers like poly (vinyl alcohol) (PVA) imparts desirable characteristics to the resulting material for numerous biomedical and environmental applications (El-Hefian et al., 2013). It is reported that blending of CS with PVA enhances not only its biocompatibility but also hydrophilicity and mechanical properties of the film in comparison to the native CS polymer film (Parida et al., 2011; Azizi et al., 2014). The biocompatible nature of CS and good film forming property of PVA offer possibilities of designing blends of these two polymers that may find applications in the areas like wound healing, burn dressing matrices and other biomedical applications. Since morphology of the surfaces also plays a key role in determining blood compatible nature of the material, it is desirable to investigate the topographical and morphological investigation of a blend of the CS and PVA. A further enhancement in blood compatibility may also be brought about by irradiation of the blend with gamma rays.

Nouman and coworkers described the impact of biological responses e.g. cytotoxicity, inflammation, thrombosis etc. with body tissues when they contact with different surfaces of the experimental samples (Nouman et al., 2016). Good adhesion of the red blood cells and good cohesions of the platelets have been reported by the due modifications in the surface morphology of the films (Albu et al., 2011). Similarly the surface modification of magnesium alloy was found to improve the blood compatibility of the material (Pan et al., 2017).

The treatment of the AFM data and analysis are the basic requirements while studying topography of a film surface (Konovalova et al.,

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Table 1
Topological parameters of the experimental samples.

	Untreated Native CS			**Untreated CS (0.5%) + PVA**			**Untreated CS (2%) + PVA**		
Scanning area (in µm²)	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**
Average Roughness (in nm)	26.7 ± 1.1	38.8 ± 1.2	44.4 ± 1.3	6.8 ± 0.3	7 ± 0.4	7.2 ± 0.3	5 ± 0.15	10.7 ± 0.32	12.9 ± 0.51
Root Mean Square (in nm)	33.9 ± 1.1	48 ± 2	54.7 ± 1.7	9.5 ± 0.4	10.3 ± 0.3	10.7 ± 0.4	6.7 ± 0.3	16.1 ± 0.64	19.5 ± 0.8
Surface skewness	−0.17 ± 0.07	−0.1 ± 0.06	−0.2 ± 0.07	1.5 ± 0.06	1.8 ± 0.08	2.3 ± 0.1	0.9 ± 0.04	1.4 ± 0.05	2 ± 0.09
Coefficient of kurtosis	0.03 ± 0.007	−0.12 ± 0.05	−0.32 ± 0.01	3.7 ± 0.11	5.1 ± 0.15	7.7 ± 0.32	2.8 ± 0.09	4.6 ± 0.21	6.1 ± 0.3
Entropy	10.3 ± 0.3	10.8 ± 0.32	11 ± 0.4	8.4 ± 0.28	8.5 ± 0.28	8.4 ± 0.28	8 ± 0.23	9.1 ± 0.29	9.2 ± 0.3
	1 Mrad radiated Native CS			**1 Mrad radiated CS (0.5%) + PVA**			**1 Mrad radiated CS (2%) + PVA**		
Scanning area (in µm²)	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**
Average Roughness (in nm)	16.5 ± 0.65	17.6 ± 0.8	21.5 ± 0.8	8.1 ± 0.26	14 ± 0.54	18 ± 0.8	8.7 ± 0.28	11 ± 0.32	14.5 ± 0.53
Root Mean Square (in nm)	21.1 ± 0.77	22.2 ± 0.8	28 ± 0.9	11.5 ± 0.33	22 ± 0.87	27 ± 1.02	11.9 ± 0.34	14.9 ± 0.53	22.2 ± 0.88
Surface skewness	0.25 ± 0.01	0.46 ± 0.02	0.48 ± 0.02	1 ± 0.04	2 ± 0.08	2 ± 0.06	0.8 ± 0.03	1.2 ± 0.04	3 ± 0.08
Coefficient of kurtosis	0.4 ± 0.02	0.3 ± 0.02	1.4 ± 0.04	3.9 ± 0.11	8.1 ± 0.34	6.3 ± 0.3	2 ± 0.08	2.5 ± 0.08	9.5 ± 0.3
Entropy	9.8 ± 0.32	9.9 ± 0.32	10.2 ± 0.34	8.8 ± 0.28	9.5 ± 0.34	9.8 ± 0.4	8.9 ± 0.28	9.13 ± 0.3	9.4 ± 0.33
	10 Mrad radiated Native CS			**10 Mrad radiated CS (0.5%) + PVA**			**10 Mrad radiated CS (2%) + PVA**		
Scanning area (in µm²)	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**	**5 × 5**	**10 × 10**	**20 × 20**
Average Roughness (in nm)	5.6 ± 0.16	9 ± 0.28	14.9 ± 0.53	7 ± 0.28	8.3 ± 0.26	9.5 ± 0.33	5 ± 0.15	7.8 ± 0.32	13.4 ± 0.51
Root Mean Square (in nm)	8.1 ± 0.24	13.1 ± 0.5	23.6 ± 1	9.1 ± 0.3	10.7 ± 0.31	12.8 ± 0.5	9 ± 0.3	12.4 ± 0.48	22.6 ± 0.9
Surface skewness	0.85 ± 0.03	1.5 ± 0.04	1.53 ± 0.04	0.93 ± 0.04	0.8 ± 0.03	1.4 ± 0.04	2.1 ± 0.06	2 ± 0.06	1.3 ± 0.05
Coefficient of kurtosis	2.7 ± 0.1	5.6 ± 0.17	13.6 ± 0.54	2.7 ± 0.1	1.3 ± 0.04	4.6 ± 0.2	12.3 ± 0.48	6.6 ± 0.3	17.9 ± 0.7
Entropy	8.3 ± 0.27	8.9 ± 0.21	9.5 ± 0.34	8.5 ± 0.28	8.8 ± 0.28	8.9 ± 0.28	7.9 ± 0.21	8.6 ± 0.26	9.3 ± 0.33

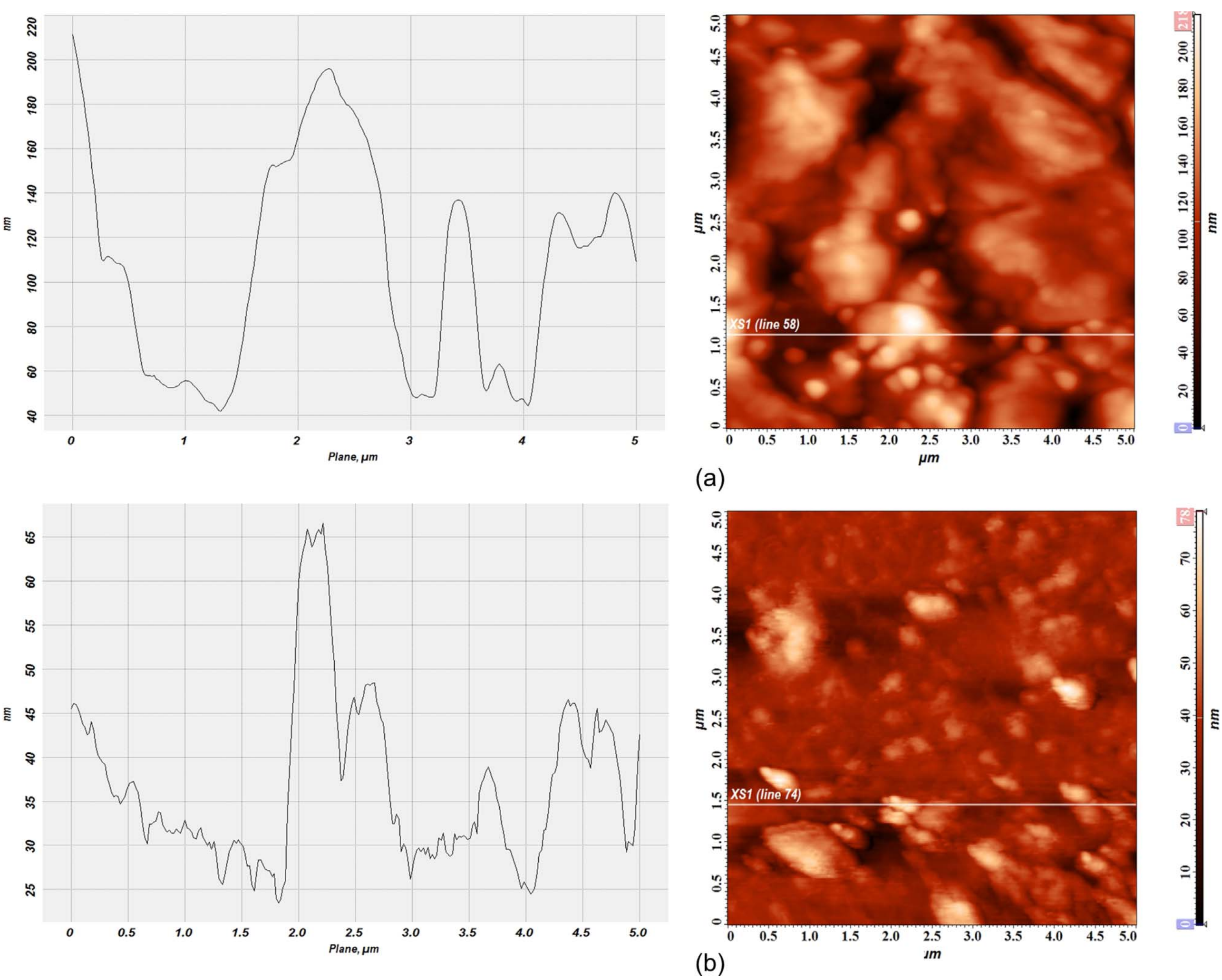

Fig. 1. Line profile images showing waviness of (a) Un-irradiated CS with scanning area 5×5 µm^2 (b) Irradiated CS with scanning area 5×5 µm^2 (10 Mrad).

2013; Cohen et al., 1994). The roughness parameters such as root mean square value (R_{rms}), average roughness and average heights are the few parameters that explain the cluster distribution or phase separation of different molecules in 3D (Krajcar et al., 2014; Azevedo et al., 2013). It also determines the surface growth behavior of the films. Furthermore, asymmetry, flatness and distribution of height can