Structure and mechanical properties of PVA – PEG – TiO_2 hydrogel composites cross-linked by electron irradiation

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Introduction

Hydrogels are three-dimensional hydrophilic polymer networks that can absorb and store significant amounts of water and biological fluids. They are widely used in the medical and pharmaceutical industries. Ionizing radiation is favored for crosslinking hydrogels, improving their mechanical characteristics and resistance to high temperatures. Hydrogel filling with TiO_2 particles is of interest due to their photocatalytic properties. Comprehensive characterization, including structural studies, is necessary to understand the hydrogel's properties, including its mechanical aspects.

Synthesis

The synthesis process involves dissolving PVA 17-99 and PEG-6000 in water, both with continuous stirring. The PEG solution is then added to the PVA solution and stirred for 10 minutes.

Next, TiO_2 particles with a 320 nm diameter are added to the PVA-PEG solution in different quantities (1%, 0.1%, and 0.01% of the mass of dry matter). The resulting solutions form gels that are refrigerated at 4°C for 4 days. After cooling, the gels are irradiated with electrons (4 MeV, 33 kGy).

Results and discussions

Particle size

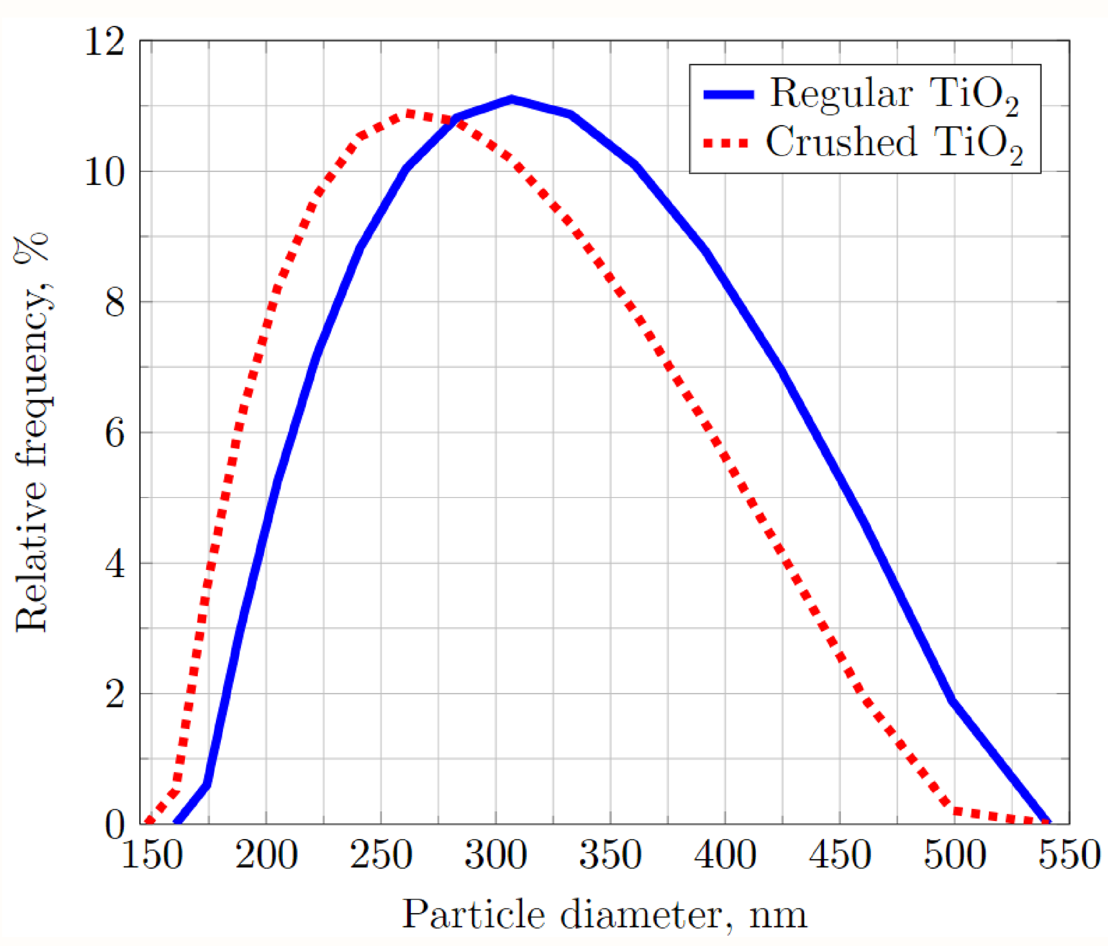

Figure 1: Dependence of the relative frequency distribution of TiO_2 particles on their diameter.

The size of the particles and their distribution were determined by the DLS method.

Non-crushed TiO_2 had an average diameter of 370 nm, while crushed particles had an average diameter of 320 nm. The polydispersity index, reflecting heterogeneity, was 12% for unground TiO_2 and 9% for ground particles.

Microscopic images

Figure 2 displays electron scanning microscope photographs of a polymer matrix sample with 1 wt.% TiO_2.

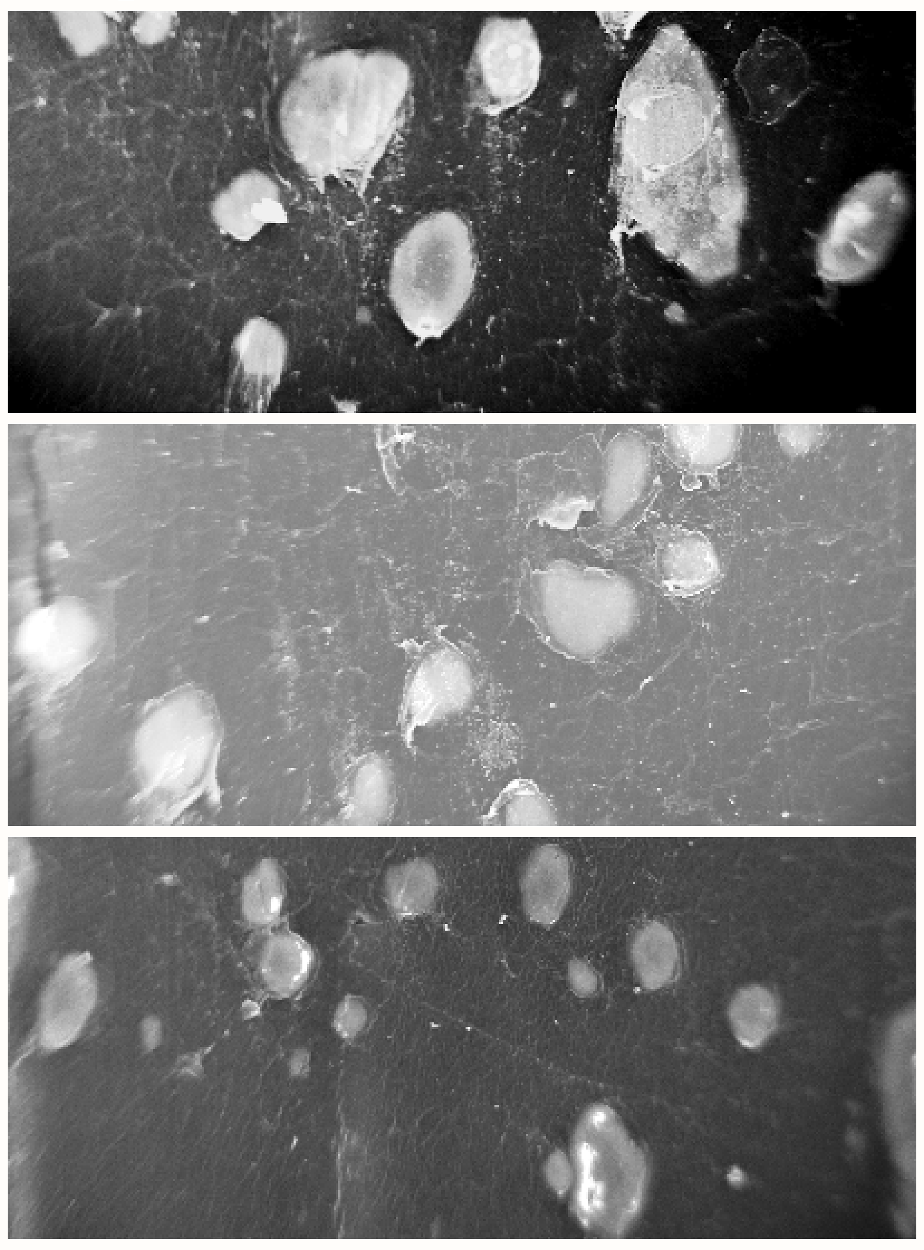

Figure 2: Photographs of a sample containing 1 wt.% TiO_2, magnified at 300 times.

X-ray Structural Analysis

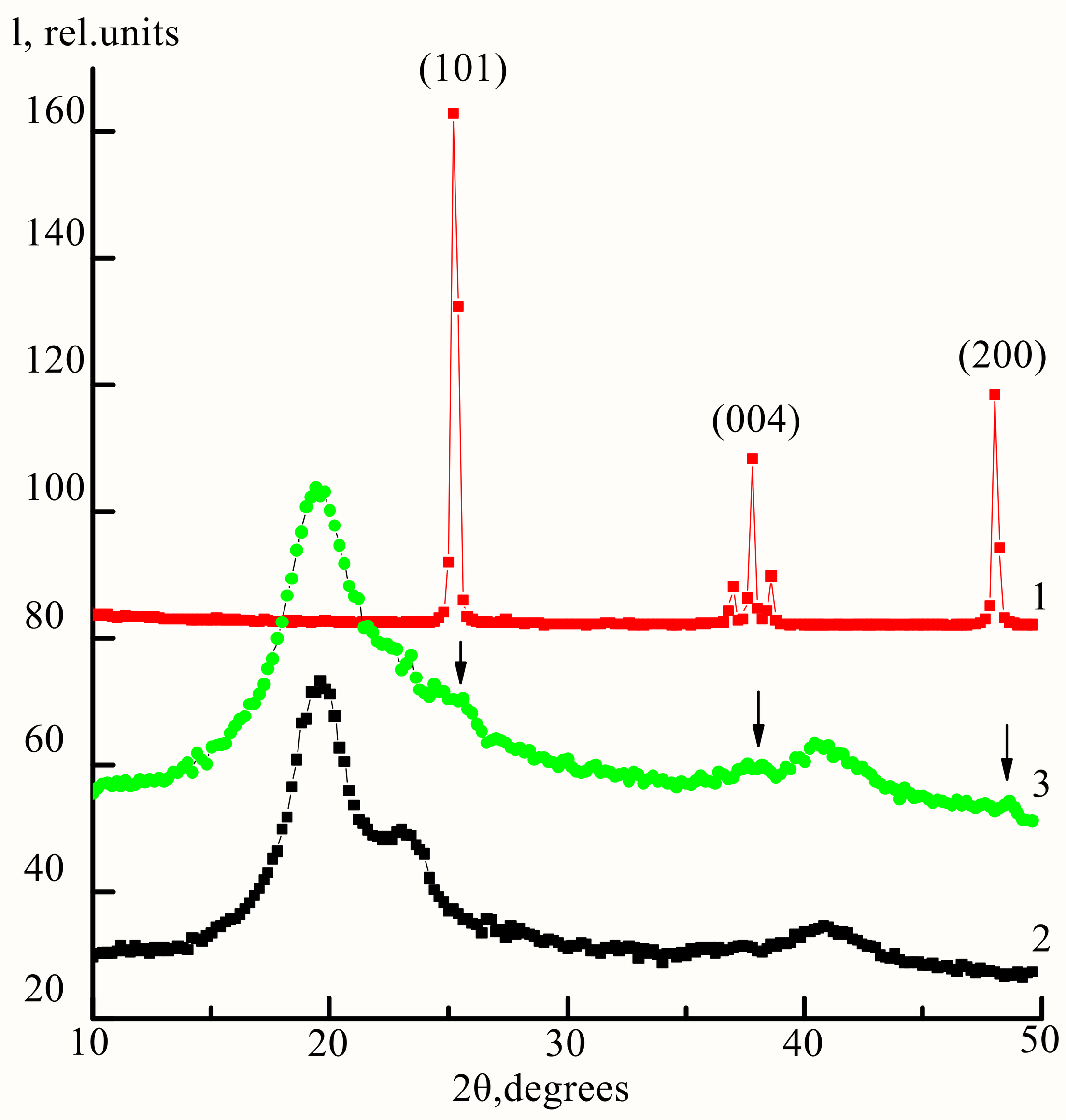

Figure 3: X-ray diffraction patterns of TiO_2 powder (1), PVA–PEG (2), and PVA–PEG-TiO_2(3) samples irradiated with electrons

X-ray studies of the initial powder TiO_2 revealed an anatase crystal structure with characteristic peaks (101), (004), and (200) observed in the diffractogram (Fig. 3, curve 1).

The diffraction pattern of a PVA–PEG sample containing 1 wt.% TiO_2 also displayed peaks corresponding to TiO_2. However, these peaks showed a slight shift in angular position compared to the original powder (3, curve 3, indicated by an arrow). This suggests a possible interaction between the PVA–PEG polymer matrix and TiO_2 particles.

Tensile properties

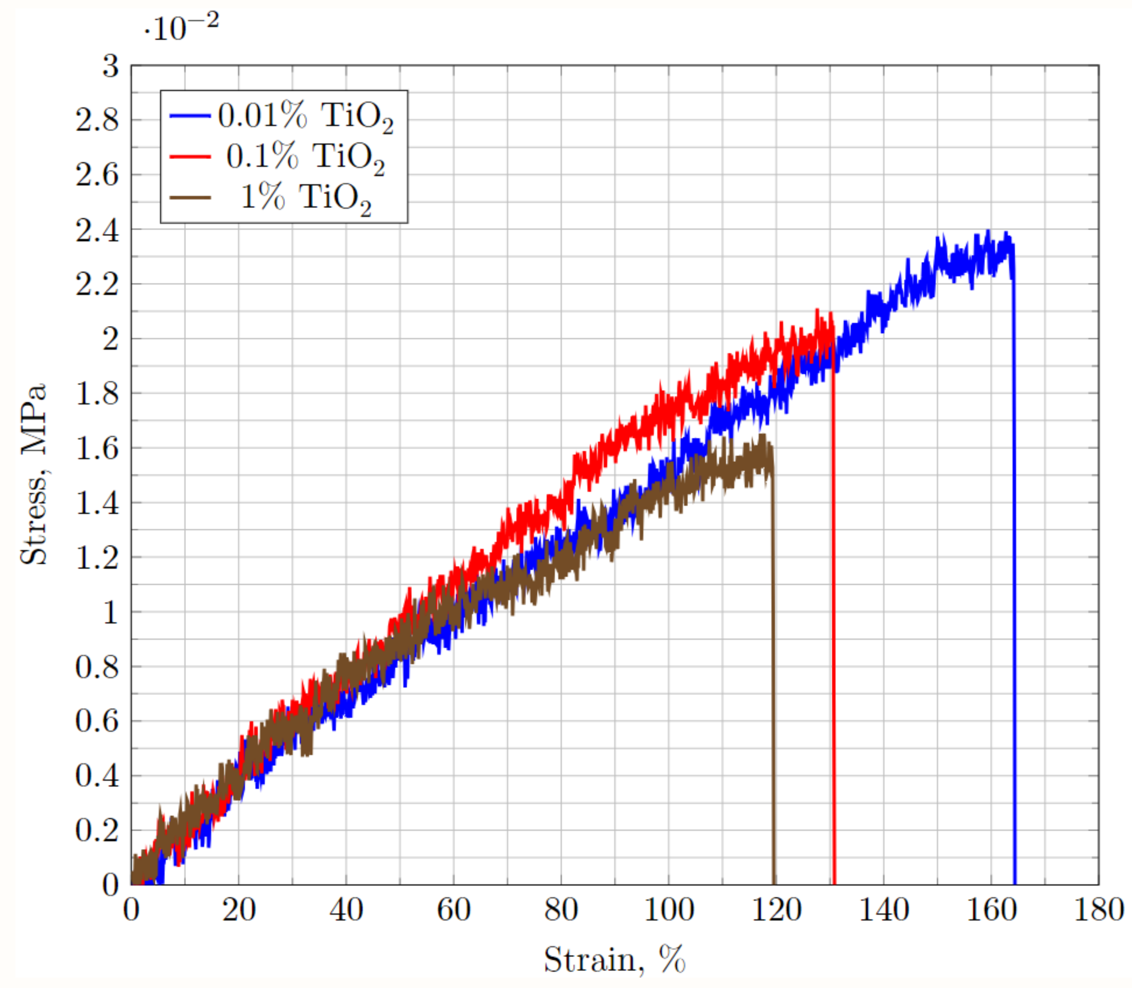

Figure 4: Stress-strain curve for samples with different concentrations of TiO_2.

0.01% TiO_2	0.1% TiO_2	1% TiO_2
∼ 164%	∼ 131%	∼ 120%
$16,2 \pm 0,5$ kPa	$20,2 \pm 0,4$ kPa	$23,2 \pm 0,5$ kPa

Tensile tests reveal that as the concentration of TiO_2 increases, both tensile strength and maximum elongation to break decrease. This suggests that TiO_2 particles act as defects in the polymer network, affecting its mechanical properties.

Bactericidal effect

a) b)

Figure 5: Bactericidal effect study of TiO_2 1% samples: a – *Escherichia coli*; b – *Staphylococcus aureus*.

The lack of a zone without microorganisms indicates the absence of antimicrobial activity, possibly due to the relatively large size of TiO_2 particles (320 nm) used in the hydrogel synthesis.

Summary and conclusions

TiO_2 particles size (320 nm) were measured for synthesis, and microscopic photographs of their distribution in the hydrogel were obtained. X-ray structural studies suggest a potential interaction between TiO_2 and the PVA-PEG polymer matrix. TiO_2 particles act as defects, decreasing the hydrogel's mechanical properties. The sample with 1 wt.% TiO_2 showed no antimicrobial activity.