such diverse fields as material science, meteorology, ecology, urban landscapes, economics and finance, soil sciences, and medical imaging. Papadopoulos and co. [11] working at the pore–particle scale, describe the use of the slit island method with image analysis to calculate fractal dimensions of soil pore perimeters.

A basic principle to estimate fractal dimension is based on the concept of self-similarity. The property of self-similarity implies that the form of an object is invariant with respect to scale. In other words, a strictly self-similar object can be th[illegible]d of an infinite n[illegible]e f[illegible] a bounded set A in Euclidea[illegible]x c[illegible]t A in a grey image is given by: $D = \lim_{n \to \infty} \frac{\log [illegible]}{\log(1/r [illegible])}$ [illegible] d[illegible]e number of boxes of side length $r = 2^n$, $n = 1, 2, 3, 4...$ (t[illegible]f d[illegible] copies of A in the scale[illegible]

2. Experimental details

N[illegible]w matrices based on collagen and chitosan biopolymers hydrogels doped with silver nanoparticles were obtained and characterized. Chitosan (a natural polymer derived from chitin with a degree of deacetylation of 85%) and collagen have been used for the preparation of the membrane. Gel of collagen with native structure, extracted from bovine skin, at pH 2.[illegible] was obtained from National Institute of Research and Development for Textile and Leather, Bucharest, Romania. Collagen/Chitosan membranes were doped with silver nanoparticles and prepared by lyophilization. Both chitosan and silver nanoparticles have been added to collagen membranes and matrices to achieve a better antibacterial activity. The fabricated membranes were coated with gold and viewed in high vacuum under an SEM (Hitachi S-2600 N). Using digitized SEM images of the membrane surface of collagen/chitosan, fractal dimensions were measured. The box counting method was used for the fractal analysis of grayscale images using the [illegible] analysis software written by H. Sasaki [12].

3. [illegible]

V[illegible] of collagen/chitosan mixtures were pre[illegible]s m[illegible] Collagen/chitosan porous [illegible]d by lyophilization and morphology observed by Scanning Electron Microscopy (SEM) (Figure 1). SEM analyses of these collagen membranes indicate that a microporous architecture was created by modulating the processing of the membrane. SEM micrographs also indicated good homogeneity between these two materials. SEM analysis of the surface of the samples highlighted the presence of superficial irregularities and protuberances which confer certain porosity to the matrices. Fractal analysis based on micrographs electronic microscopy SEM showed nanostructure features with self-similar properties on a large scale. Fractal dimensions calculated from SEM image analysis represented realistic values from approximately 2.50 to 2.38. A decrease in fractal dimension with increase in chitosan concentration is expected and observed. Using digitized images of the surface of the three membranes which have been prepared with different ratio between components, fractal dimension was calculated by the method of box-counting of grayscale with fractal analysis software. The fractal nature of the surface was revealed for this membranes and was obtained fractal dimensions of 2.50 for collagen: chitosan (1:0); 2.39 for collagen: chitosan (2:1); 2.38 for collagen: chitosan (1:1). Modification collagen matrix with chitosan decreases the fractal dimensionality revealing change complexity of hybrid material surface.

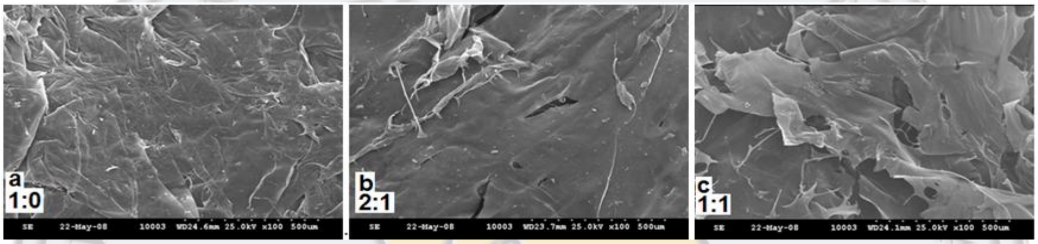

Figure 1. Views by SEM
a) collagen: chitosan (1:0); b) collagen: chitosan (2:1); c) collagen: chitosan (1:1).

We have seen modification of the fractal dimension of the TEM images of silver nanoparticles prepared by chemical reduction with sodium citrate using different $AgNO_3$ concentrations which control the aggregation processes. At the beginning an increase in $AgNO_3$ from 1×10^{-3} M $AgNO_3$ to 3×10^{-3} M $AgNO_3$ increased fractal dimensions from 2.59 to 2.70 corresponding to the presence aggregates of silver nanoparticles. The fractal dimension increases with the size and the complexity of the aggregate having a more compact morphology. Values approaching 3 for a three dimensional indicates a high degree of compaction whilst values approaching 1 indicates a very loose and open structure.

4. Conclusions

In this work we pointed out the importance of the concept of fractal structure of the fractal structure concept in physical characterization of materials. Fractal dimensions of the studied materials were found to be in the range of $2 < D < 3$. Fractal analysis based on micrographs electronic microscopy SEM images shows nanostructure features with self-similar properties on a large scale. The porosity of collagen matrix can be controlled by chitosan content; as the content of chitosan was increased, the fractal dimension decreased. Scanning electron microscopy indicated that the addition of chitosan greatly influences structure and change collagen fibres cross-linking, reinforcing the structure and increasing pore size.

Materials with a higher fractal dimension are less porous than those with a lower fractal dimension. New methods of investigation and a new method to determine the fractal dimension for biomaterials are necessary in the future in order to understand how the porosity of these organic materials is connected to the fractal dimension.

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