# SEM STUDY OF THE MORPHOLOGY OF EXTRACTED UHMWPE

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**ABSTRACT**
Ultra high molecular weight polyethylene (UHMWPE) is the preferred interposition biomaterial for orthopedic prostheses. Its microstructure, based on the extremely high molecular weight, leads to optimal mechanical properties. High energy irradiation may cause chain scission and/or crosslinking of polymers. Samples of UHMWPE were γ-irradiated and afterwards the soluble part (short chains molecules) was extracted by Soxhlet method using xylene as solvent. The insoluble part (crosslinked part) was etched by permanganic solution to reveal its morphology. SEM images of the insoluble part samples show variations in the surface texture as well as degradation, which are probably caused by the irradiation effects (chain scission and oxidative degradation) as well as the action of the solvent and etching. Finally, some samples show a well-defined spherulitic structure.

**Keywords**: UHMWPE, spherulite, extraction, etching.

## INTRODUCTION

Good mechanical properties such as high wear and fatigue resistances, fracture toughness along with a low friction coefficient and high biocompatibility make UHMWPE a perfect candidate for use in orthopedic prostheses to articulate against metallic alloys or ceramics [1]. The microstructure of UHMWPE consists of an amorphous region, with entangled long molecular chains and a crystalline region with thin lamellae. Moreover, Tie molecules that interconnect the regions by crossing the amorphous region from one lamella to the other and the entanglements in the amorphous phase are responsible for the excellent mechanical properties of this material [2].

The objective of the present work was to investigate, in UHMWPE, the surface morphology and the degradation caused by γ-irradiation followed by Soxhlet extraction using scanning electron microscopy (SEM) [3–5].

## MATERIALS AND METHODS

A commercial grade (UTEC2540) of UHMWPE (Polialden Petroquímica, Brazil), density = 0.93 and MW ≈ 2,500,000 was received as compression molded square plates. γ-irradiation was performed in a $^{60}$Co commercial radiation equipment with operating dose rate of 2.5 kGy/h, at room temperature in air, to the following integrated doses: 500, 750, 1750 kGy. The soluble part of the samples has extracted by solvent (Xylene) using the Soxhlet method. Peramagnic etching [6] was applied to reveal the microstructure of the materials. The samples were sputter-coated with gold and examined by scanning electron microscopy (SEM), model JSM 5800LV JEOL.

## RESULTS AND DISCUSSION

SEM images of the as received samples (extracted and etched) in Figures 1.a and 1.b shows a ridged layered structure, and some small spherical particles.

In Figs. 2a. and 2.b of the 500 kGy irradiated UHMWPE, the morphology is characterized by spherulitic texture analogous to the way under which the primary particles are combined to form large agglomerates [7]. A good analogy is that of a cauliflower, since the hierarchy of particles and sub-particles resembles the hierarchy of florets in the head of this vegetable [8].

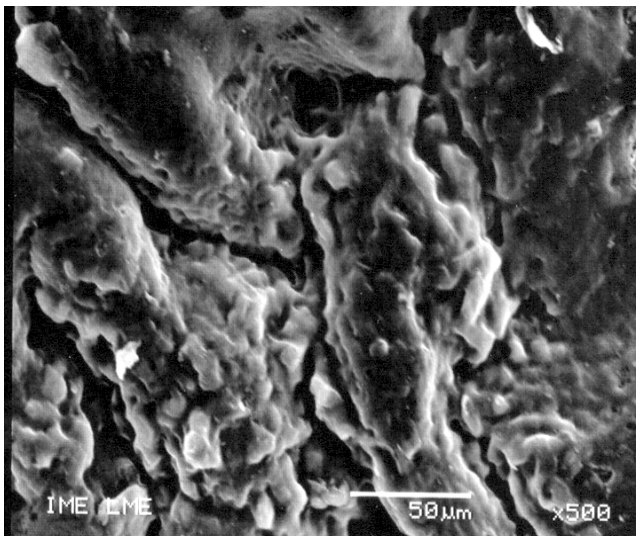


Fig. 1.a. UHMWPE as received after extracted and etched, no spherulites are seen (magnification x500).

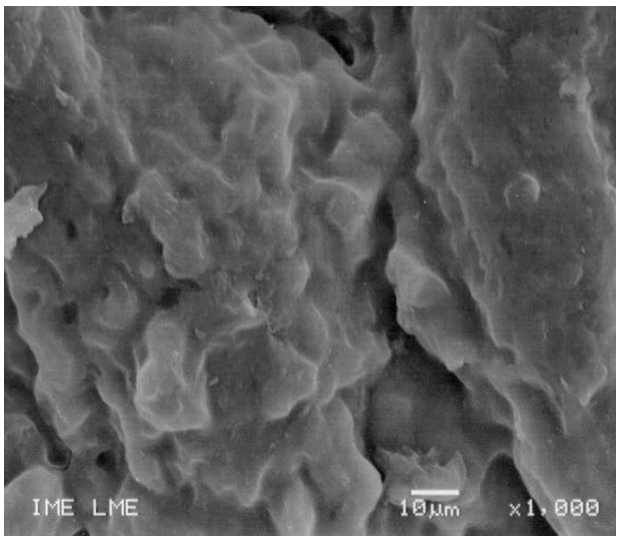


Fig. 1.b. UHMWPE as received after extracted and etched showing layered structure (magnification x1000).

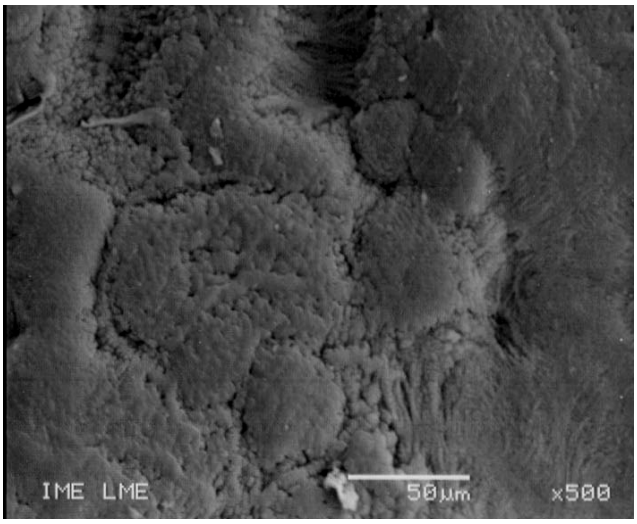


Fig. 2.a. "Cauliflower" structure-like of the 500 kGy irradiated UHMWPE (magnification x500).

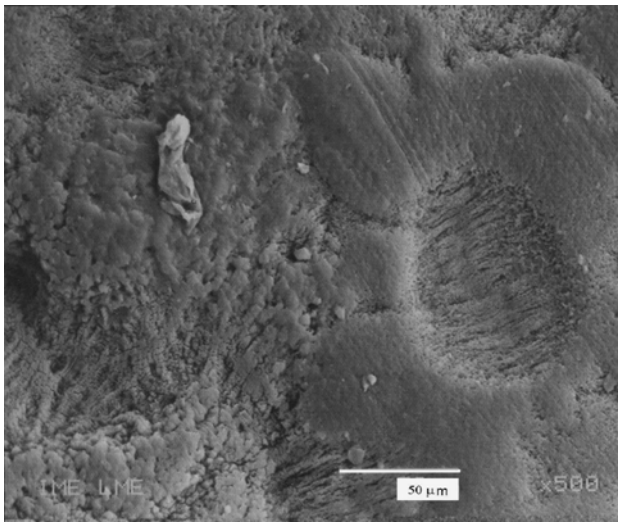


Fig. 2.b. Spherulite structure in the 500 kGy UHMWPE (magnification x500).

Figure 2-b shows details that could be associated to spherulitic structures, however, to confirm this TEM studies should be carried out.

Figures 3.a and 3.b, of the 750 kGy irradiated samples, show a surface patterning which has never been reported for UHMWPE morphology; it consists of spherical particles, probably spherulites that are organized in the cauliflower hierarchy. Figures 4-a, b, and c of the high dose (1750 kGy) irradiated UHMWPE show an eroded surface and a spherulite-like structure. Here the boundaries were strongly picked out by etching: the development of "black-lines" may be, due to the etching solution being able to physically penetrate between the spherulites. The boundaries between particles may act as defects that lead to crack initiation, particle detachment and consequently to the degradation of the samples [9,–11].

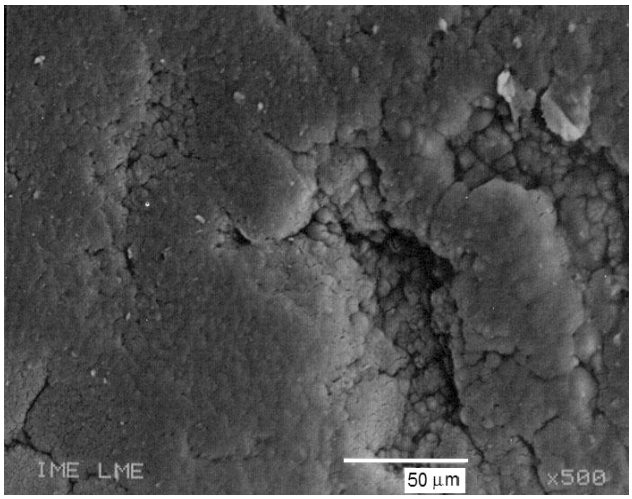


Fig. 3.a. Structure resembling "cauliflower" in the 750 kGy UHMWPE (magnification x500).

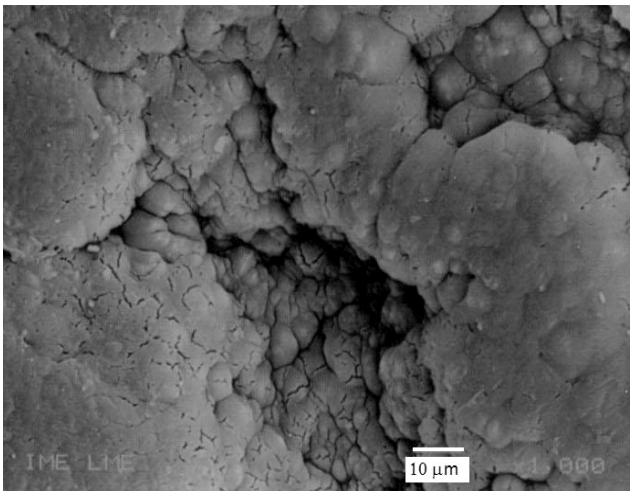


Fig. 3.b. Voids between the particles (probably due to degradation) in the 750 kGy UHMWPE (magnification x1000).

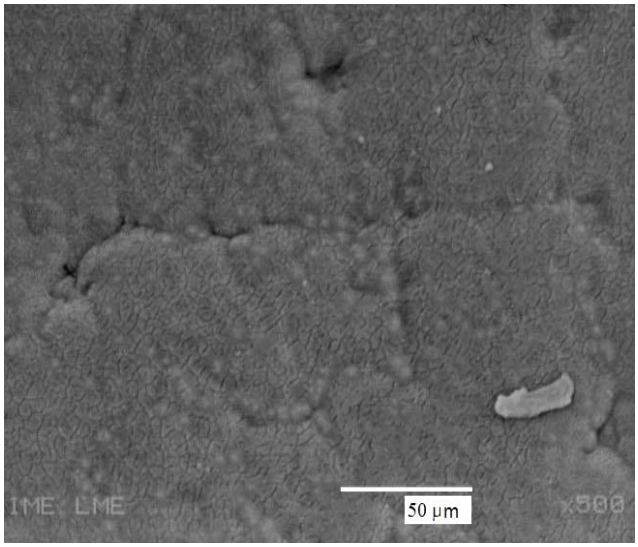


Fig. 4.a. High dose (1750 kGy) irradiated UHMWPE showing some voids between "cauliflowers" (magnification x500).

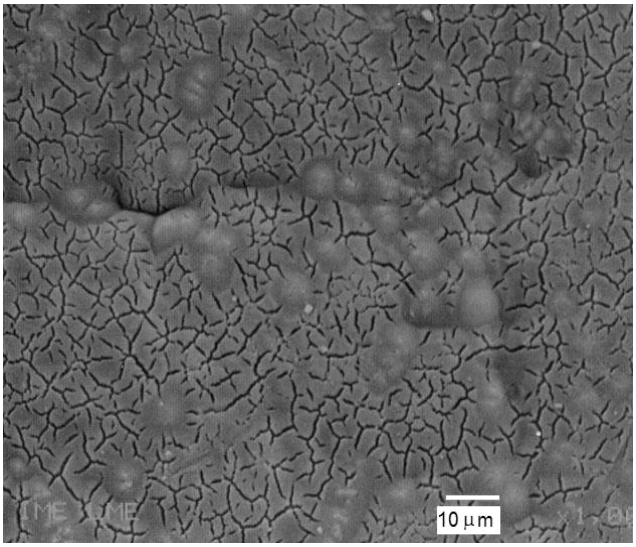


Fig. 4.b. More details of the 1750 kGy UHMWPE structure showing spherical particles, voids and internal cracking, possibly due to combined degradation by solvent extraction and etching (magnification x1000).

**CONCLUSIONS**

In all the irradiated, extracted, and etched samples, the SEM technique has been successful in revealing the variations, not only in the spherulitic texture, but also in the degree of consolidation of particles with their neighbors. The observation of the irradiated samples, as compared with the as received ones, reveals the occurrence of different topographic features; this may suggest that chain scission and oxidative degradation caused by γ-irradiation at high doses and the chemical degradation produced by solvent and chemicals used in the etching process modify the UHMWPE structure.

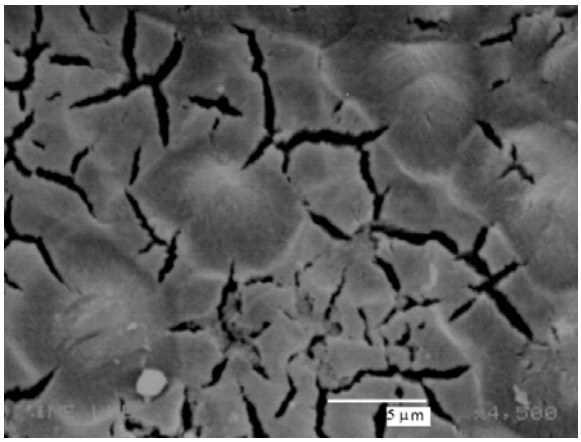


Fig. 4.c. Details of the internal cracking, and The rounded particles are spherulites, resembles the one in Fig. 2.b (magnification x4.500).

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