

## **POLYETHYLENE CRYSTALLINE STRUCTURE DIFFERENCES IN UHMWPE RAM EXTRUDED ROD**

*Mariann Kollár<sup>1</sup>, Gabriella Zsoldos<sup>1</sup>, Imre Kállai<sup>1</sup>*

*<sup>1</sup>University of Miskolc, Institute of Ceramics and Polymer Engineering*

### **1. INTRODUCTION**

Ultra-high-molecular-weight polyethylene (UHMWPE) is a subset of the thermoplastic polyethylene. Also known as high-modulus polyethylene, (HMPE), or high-performance polyethylene (HPPE), it has extremely long chains, with a molecular mass usually between 2 and 6 million Daltons. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions. This results in a very tough material, with the highest impact strength of any thermoplastic presently made.

UHMWPE is a odorless, tasteless, and nontoxic material. It is highly resistant to corrosive chemicals except oxidizing acids; has extremely low moisture absorption and a very low coefficient of friction; is self-lubricating (see boundary lubrication); and is highly resistant to abrasion, in some forms being 15 times more resistant to abrasion than carbon steel.

When disease, trauma, or overuse cause natural joints to fail, they can be replaced by artificial ones to regain function and offset debilitating pain. Most often, artificial joints contain one or more metallic components integrated with bone, and a polymer component that promotes easy movement.

The polymer must be biocompatible and tough enough to handle the loads imposed on the joint by normal life activities. It must also resist wear and mechanical damage, and have excellent lubricity, among other properties. This article discusses properties of RAM extruded ultra-high-molecular-weight polyethylene (UHMWPE).

### **2. RAM EXTRUSION**

Polymer Industries uses a ram extrusion process for the manufacture of UHMWPE rod, tubing, and profiles. UHMW powder is gravity fed into a chamber and a hydraulic ram pushes the powder from this chamber into the die. The die is the shape of the desired product, a certain diameter rod, a certain OD and ID tube, or a profile shape. Heaters are employed on the outside of the die to heat the plastic and form it into the shape of the die. The hydraulic ram moves back and forth continuously feeding the powder into the die. As the material comes out of the die, it travels the length of the conveyor where it is cut to length. Ram extrusion does not shear, homogenize the material that is being manufactured as does single or multiple screw extrusion which employs rotating screw/s to move the material. It moves the material by hydraulically pushing it through the die which is the desired

shape of the end product. UHMW-PE, which becomes gelatinous when it melts instead of being a fluid like melt, can only be extruded with this or a similar process [1].

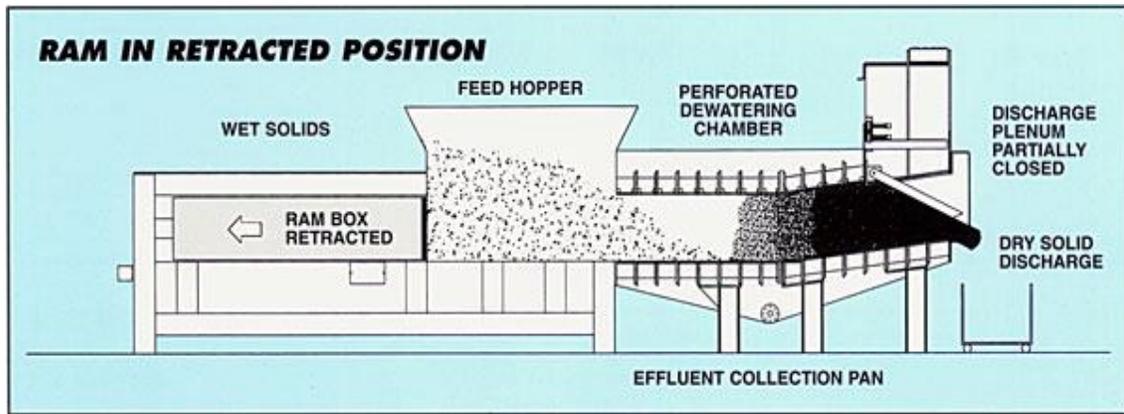


Figure 1. RAM extrusion

### 3. MATERIALS AND METHODS

During the study we have examined two types of samples. Sample one a RAM extruded UHMWPE rod for medical usage, and sample two a RAM extruded UHMWPE rod for industrial purpose. The difference between the two samples was the finishing treatment - the cooling method. In case of the medical usage rod the cooling method was carried out under strictly controlled conditions.

At first we cut thin disks from the extruded polymer rods.



Figure. 1. Prepared UHMWPE discs (smaller  $\varnothing$ -medical, larger  $\varnothing$ -industrial)

The spectra of UHMWPE disks were recorded using a Bruker Tensor 27 Fourier Transformed InfraRed (FTIR) spectrometer equipped with total reflectance (ATR) cell. IR curves were recorded in the range of 600-4000  $\text{cm}^{-1}$ , 64 scans with a resolution of 4  $\text{cm}^{-1}$ .

#### 4. CONCLUSIONS

The polyethylene is characterized by strong bands at about 2920  $\text{cm}^{-1}$  (C–H stretching vibrations) and at 1460  $\text{cm}^{-1}$  (C–H deformation vibrations) and a band of average intensity (usually a doublet) at about 725  $\text{cm}^{-1}$ . If a polymer is hyper-branched, an additional band appears at about 1380  $\text{cm}^{-1}$  and 1365  $\text{cm}^{-1}$ . Due to a different degree of polyethylene crystallinity, the bands at 1460  $\text{cm}^{-1}$  and 720  $\text{cm}^{-1}$  might be separated; then additional bands appear at about 1470  $\text{cm}^{-1}$  and 730  $\text{cm}^{-1}$ . The spectral bands corresponding to the bending vibrations: 1474 and 730  $\text{cm}^{-1}$  (crystalline phase) and 1464 and 720  $\text{cm}^{-1}$  (amorphous phase) [2].

Consequently FTIR absorption peaks show the structure of the UHMWPE. After ram extrusion some inhomogeneity remains in the structure of the polymer rod. It can be problematic during application because it can cause inhomogeneity in the mechanical properties also. It appears also visibly as deformation of the disc during and after cutting.

The best way to follow the flows stresses in the rods is to determine the crystalline and amorphous phases using 1474 and 730  $\text{cm}^{-1}$  (crystalline phase) and 1464 and 720  $\text{cm}^{-1}$  (amorphous phase) bands.

The studies demonstrated that the medical purpose UHMWPE rods had a uniform structural distribution because of the finishing treatment. The industrial grade UHMWPE rods cooled in freely after leaving the machine therefore the structure contains much more inhomogeneity.

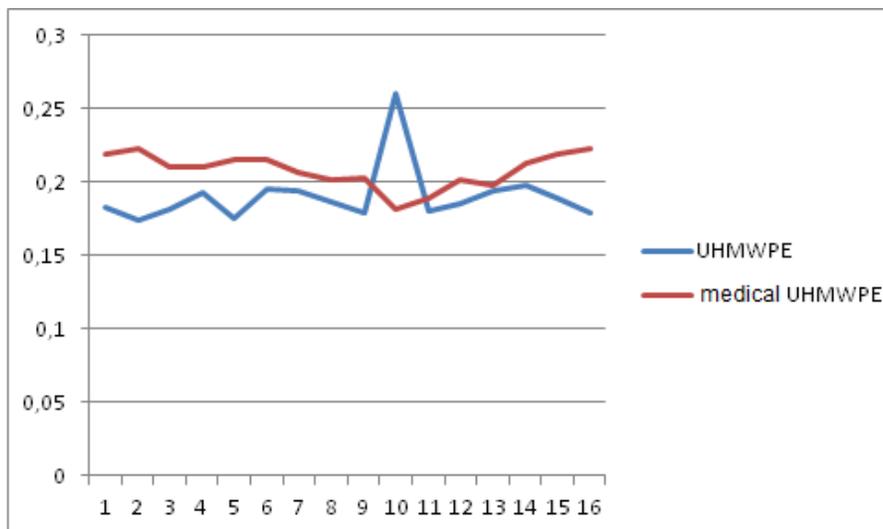


Figure 2. Absorption peaks  $730\text{ cm}^{-1}$  in industrial and medical UHMWPE

## 5. ACKNOWLEDGMENTS

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