MOLECULAR MOBILITY IN NEAR-SURFACE NANO-LAYERS OF ULTRA-HIGH-MOLECULAR-WEIGHT POLYETHYLENE AS REVEALED BY THERMOLUMINESCENCe ACTIVATED BY LOW-TEMPERATURE PLASMA

L.P. MYASNIKOVA, O.YU. SOLOV’EVA, K.A. DANILOVA, V. A. PREOBRAZHENSKII, V. I. SIKLITSKIJI, A.O. POZDNYAKOV, A. K. GLADKOV

1Ioffe Institute, St. Petersburg, Russia
2OOO Connector, Optics, St. Petersburg, Russia
3JSC Scientific Production Enterprise “Radar MMS”, St. Petersburg, Russia

e-mail: liu2000@mail.ru

It is known that the behavior of bulk materials depends dramatically on the properties of surface and near-surface layers. This work is concerned with a study of molecular mobility in the near-surface nano-layers of the ultra-high molecular weight polyethylene (UHMWPE) reactor powders (RP) and its change after compaction at room temperature and subsequent sintering at the higher temperature close but lower than melting temperature.

Interest in these characteristics is caused by currently actively developing non-solvent (dry) methods for processing UHMWPE into high-performance fibers, alternative to gel technology using a large amount of solvents. Mechanically coherent film obtained by compaction/sintering is a precursor for subsequent orientation hardening (orientation drawing), which makes it possible to obtain high-strength high-modulus fibers. The precursor should not break prematurely along the weak grain boundaries before reaching the ultimate draw ratio.

Obviously, the properties of the surface of the powder particles play a key role in the formation of strong intergrain boundaries. The molecular mobility of the near-surface layers was studied by thermoluminescence method using self-made device Nanoluminograph, patented in Russia and USA [1-2]. The surface of the investigated samples was activated by low temperature, low power high-frequency (HF 13.36 MHz) plasma of Ar gas discharge at 77K. When experiments are carried out in given conditions (the consumed energy $W = 0.004 \text{ Wt/cm}^3$, activation time 1 sec, Ar pressure is $10^{-1}$ torr, reduced strength is $E/P \sim 2 \cdot 10^3 \text{ Vcm}^{-1}\text{MPa}$, electron energy is $E_e \approx 50-100 \text{ eV}$) the thickness of the analyzed surface layer $d$ is about 5-10 nm. It was recognized that the peaks on glow curves (the dependence of thermoluminescence intensity on temperature) are associated with recombination of the stabilized charge carriers in the temperature range of relaxation transitions in polymers due to releasing molecular mobility in the immediate vicinity of the charge traps, which can be of various nature and depth [3-4].

The glow curves were recorded by Nanoluminograph for UHMWPE powders, compacted and sintered samples. As an example, the powder and compact glow curves are presented in Fig. 1A. The complicate profile of glow curves implies the overlapping of a number of different elementary relaxation processes. Profile curve analysis using the Fityk program allows us to obtain information about possible elementary relaxation processes (Fig. 1B and 1C). The change in molecular mobility (defreezing molecular motion in the temperature range of relaxation processes) after compaction and sintering will be discussed.

Fig.1. Powder glow curve (black) and compact powder glow curve (red) (A); decomposition of the compact glow curve (B); decomposition of the powder glow curve (C)

REFERENCES


