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Comparative analysis of instrumented indentation hardness and viscoelastic behavior of different polymers after gamma radiation

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Abstract – Irradiation of polymers can induce crosslink or chain scission. In this work it is investigated by instrumented indentation the modification of hardness and viscoelastic behavior of four different polymers submitted to gamma irradiation. Hardness and elastic modulus were determined by nanoindentation with a Berkovich indenter. The viscoelastic behavior was investigated with nanoindentation with a spherical tip. The investigated polymers were ultra high density polyethylene, polycarbonate, low density polyethylene and a polyurethane adhesive derivate from castor oil. The gamma radiation doses vary from 1 kGy to 100 kGy. UHDPE, PC and LDPE show decrease in hardness with gamma radiation. The hardness of polyurethane adhesive does not vary significantly with gamma radiation.

Gamma irradiation is a common process to sterilize polymers for medical applications. Doses of 25 kGy are typical for some applications. In this work instrumented indentation is employed to investigate the modifications in mechanical properties of different polymers submitted to gamma irradiation. The investigated polymers were ultra high density polyethylene (UHDPE), polycarbonate (PC), low density polyethylene (LDPE) and a polyurethane adhesive (PU) derivate from castor oil. The gamma radiation doses vary from 1 kGy to 100 kGy. Mechanical properties of irradiated surfaces were measured by instrumented indentation. Hardness and elastic modulus were determined from standard load versus displacements curves generated by a Nanoindenter XP with a Berkovich indenter [1]. The unloading rates were high enough to avoid the time dependent effects in hardness measurements by instrumented indentation due to viscoelastic properties of the polymer. Viscoelastic properties were investigated by applying loads in 5 s and holding for 400 s with and spherical indenter with radius equal to 150 mm. The derivative of displacement at constant load was used to determine the apparent viscosity of polymers under this test condition.

The Table 1 summarizes the results for hardness for gamma irradiation doses of 25 kGy and 100 kGy. The viscoelastic properties are also modified by the gamma irradiation. The apparent viscosity of the four polymers is influenced in a similar way by gamma irradiation [3].

Table 1 – Hardness of four polymers submitted to gamma irradiation at doses of 25 kGy and 100 kGy

Material	Not irradiated (GPa)	Irradiated Gamma 25 kGy (GPa)	Irradiated Gamma 100 kGy (GPa)
UHDPE	0.28	0.27	0.13
LDPE	0.019	0.018	0.016
PC	0.19	0.16	0.12
PU	0.10	0.10	0.11

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