STRAIN RATE EFFECT ON SEMI-CRYSTALLINE PLLA MECHANICAL PROPERTIES MEASURED BY INSTRUMENTED INDENTATION TESTS

S. C. Cifuentes[a,b], E. Frutos[c,a], R. Benavente [b], J. L. González-Carrasco[a,e], V.Lorenzo[d *]

[a]*Centro Nacional de Investigaciones Metalúrgicas, CENIM-CSIC, Avda. Gregorio del Amo 8,28040 Madrid, Spain*
[b] *Instituto de Ciencia y Tecnología de Polímeros, ICTP-CSIC, Calle Juan de la Cierva 3, 28006 Madrid, Spain.*
[c] *Department of Control Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague, Technická 2, Prague 6, Czech republic*
[d] *Escuela Superior de Ingenieros Industriales, Universidad Politécnica de Madrid, Spain*
[e] *Centro de Investigación Biomédica en Red de Bioingeniería, Biomateriales y Nanomedicina CIBER-BBN, Spain.*

Introduction

Poly(L-lactide) is a widely studied biomaterial, currently approved for use in a range of medical devices. Its mechanical properties can be tailored giving the material different crystallinity degrees. PLLA presents a complex non-linear behaviour that depends not only on structural parameters such as crystallinity degree but also on external parameters such as strain rate and temperature. Failure of polymeric implants is attributed to their intrinsic time-dependent performance under static loading conditions.

This work explores the potential of instrumented indentation tests as a suitable technique to measure the complex non-linear time-dependent mechanical properties of PLLA. The applicability of the Oliver-Pharr[1,2] method, typically used in ceramic and metals materials, will be discussed through the sensitivity of elastic modulus, hardness and material creep response to different strain rates. Likewise, the strain rate influence depending on the crystallinity degree will be considered. The results of this study provide important information about PLLA viscoelastic behaviour.

Materials and methods

Poly(L-lactic)acid pellets were moulded by compression. To obtain different crystallinity degrees, three different cooling routes were used: quenching from the melt at 50 °C/min, hereafter named P-Q discs; cooling from the melt with a slow rate of 2 °C/min, hereafter P-T1 discs; cooling to 140 °C at 10 °C/min, maintaining isothermal crystallization at that temperature during three hours, then cooling to ambient temperature at a rate of 2 °C /min, hereafter P-T2 discs.

The characterization of the material was performed by DSC and X-ray scattering. The influence of the strain rate in the hardness and modulus values of the PLLA samples with different crystallinity degrees, have been determined by micro-indentation measurements, with a Berkovich (three-sided pyramidal) diamond indenter on the surface, using a load of 2000 mN for three different unloading- loading rates (25, 50 and 200 mN/s) which lead to the following strain rates 6.25×10^{-3} s-1, 12.5×10^{-3} s-1 and 50×10^{-3} s^{-1} respectively. A maximum hold time of 15 s is applied. In order to obtain measurements with a higher strain rate, indentations at high speed were performed using a load of 20 mN and a loading-unloading rate 13.32 mN/s, which leads to a strain rate of 335×10^{-3} s^{-1}. A maximum hold time of 5 s is applied. In all cases, at least 10 indentations have been performed on different regions of the polymer surface.

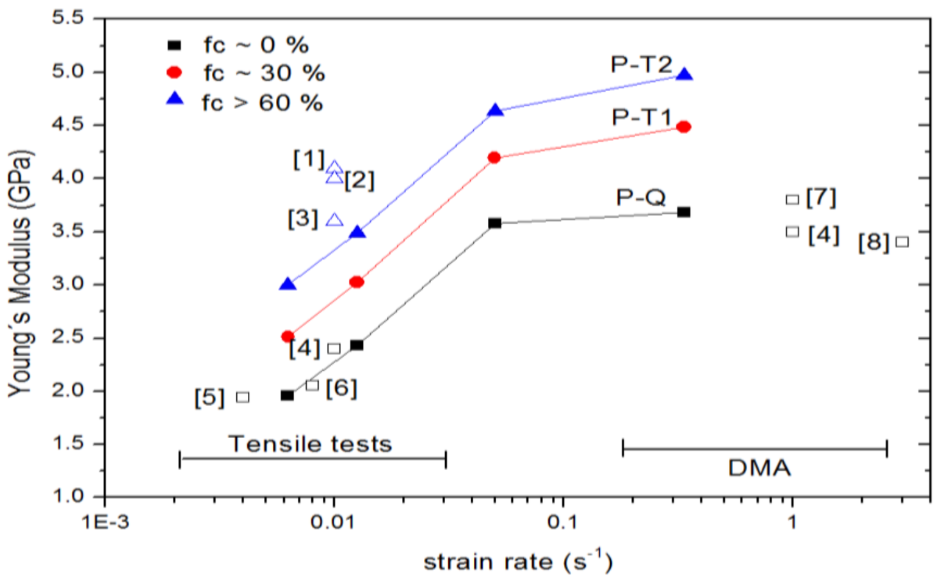

Figure 1. Young’s modulus dependences to the different strain rates and crystallinity degrees.

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