Analysis of the process variables in Laser Spinning controlling the geometry of nanofibers

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The great interest that quasi-1D structures involve in nanotechnology applications have triggered many researches about methods to produce nanofibers[1]. Special importance has the control of composition, structure and geometry to obtain useful nanofibers[2].

Laser spinning is a new technique enabling the production of large quantity of ultra-long amorphous ceramic nanofibers, showing extremely high length to diameter ratio and with tailored composition. This technique has been demonstrated successfully with several compositions, probing its capability to produce fibers of inorganic oxides that can not be fiberized by any other technique[3]. The process involves a high power laser focused over the surface of the precursor plate, so a very small volume of material is melted, at the same time as a high speed gas jet stretches the molten material to produce a viscous filament. A relative movement between the plate of precursor material and the laser keeps the process ongoing to sustain a uniform mass flow of the liquid volume[4] In order to make possible the rapid cooling and elongation of the viscous filament by the high speed gas jet before it breaks, the process must be carefully controlled[5]. In this way large quantity of intertwined micro- and nanofibers can be obtained in a very short time (figure 1 shows typical appearance of the fibers). The ceramic nanofibers obtained by this technique are always amorphous due to the rapid cooling of the molten material. Furthermore, the composition of the fibers can also be easily controlled just by adjusting precursor composition are obtained from a small melted volume and cooled at ultra-short time.

In the present work we study how working conditions influence on nanofibers geometry and the quantity of nanofibers produced. We carried out several series of experiments varying different working conditions to study their influence on the process and on the fibers produced. The area irradiated by the laser beam on the surface of the precursor material is expected to have an important influence as it changes the energy density supplied to the molten volume and affects to its temperature. In fact, the area of the surface of precursor material irradiated by the laser changes the quantity of fibers obtained: there is an optimum distance which maximizes the quantity of fibers produced. The speed of the cut is likely to have an influence since it may change the shape of the melting front and, again, its temperature. Figures 2.a and 2.b illustrate some of the results we observed depending on this parameter. Cutting speed is the most relevant variable to control geometry of the fibers as expected from the outcomes of the previous theoretical work[5]. Thus, an interesting conclusion from this result is that the distribution of diameters can be controlled by simply changing the speed of the process. Gas pressure was found to be not an influential variable, as it does not produces any change on geometry or quantity of fibers, provided that supersonic regime is reached in the gas jet. Three types of assist gas were used: argon, dry air and wet air. Switching assist gas between argon and dry air do not produce changes on the fibers. However, using wet air enlarges the diameters, which means that thicker fibers are obtained by using wet air as drag gas. This result may be explained by the fact that heat losses are greater on wet air than on dry air due to the change in convective factor. Therefore cooling of the fibers is faster and, consequently, elongation process finishes sooner.

Acknowledgments

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Figures

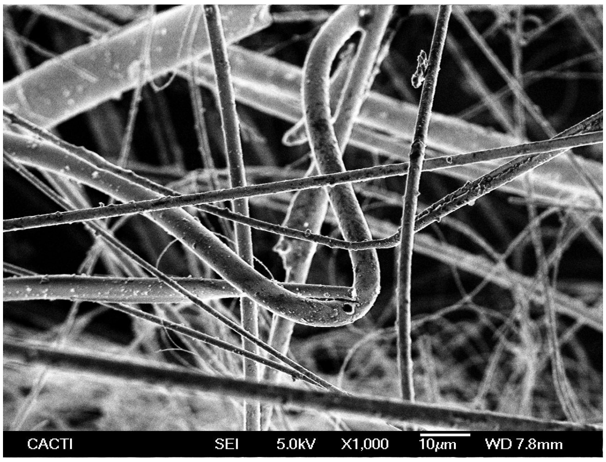
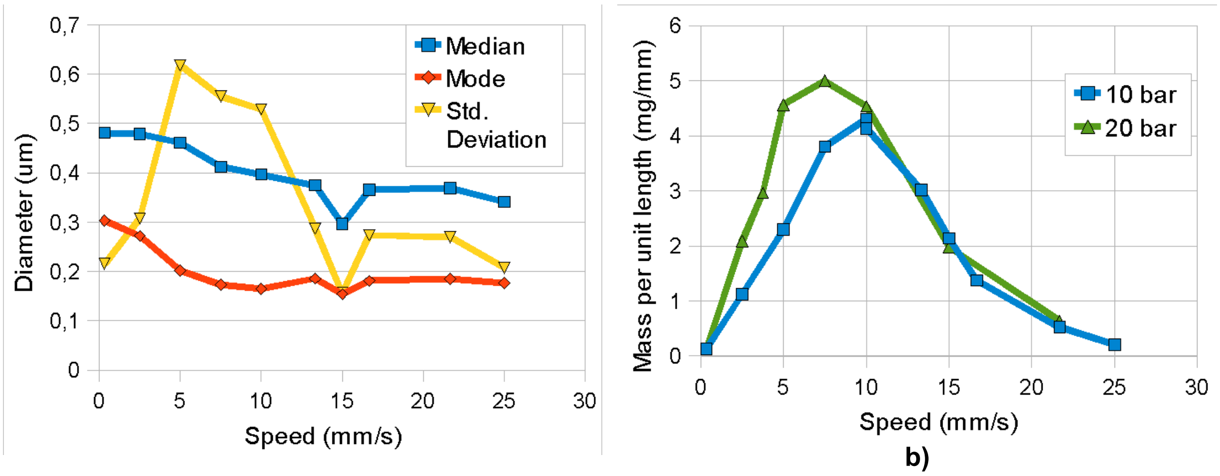


Figure 1. SEM micrograph showing the typical appearance of the micro- and nanofibers produced by Laser Spinning.



b)

a)

Figure 2. a) Diameters Distribution of the fibers produced as a function of the speed of the cut. b) Mass of the fibers obtained per unit length of precursor material processed as a function of speed of cut.