Optimization of glass nanofibers productivity in Laser Spinning process

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Abstract

Nanometric structures have attained an enormous importance over the last two decades because of its singular and interesting properties. The quasi-one dimensional structures such as nanofibers or nanowires are one of the most prominent among nanomaterials.

Laser Spinning has demonstrated the capability to obtain very long amorphous ceramic nanofibers. It mainly consists in melting a small volume of material (precursor drop) by a laser beam while stretching it by means of an assist gas applied at high speeds (supersonics). Then, this assist gas rapidly chills the melted material so it solidifies in a vitreous fiber. The production of nanofibers from different materials was previously reported [1-4]. There are several factors affecting this process, but viscosity is a key factor in the process determining whether the formation of a nanofiber succeeds or not. The viscosity of the molten volume must remain in a certain range in order to allow the elongation and keep stability; therefore its temperature must be restrained to produce fibers. More specifically, the surface tension to viscosity ratio of the melted material determines whether the precursor drop just breaks up to form small droplets or it is effectively stretched to form a fiber. Therefore, the evolution of the process involves a proper balance between a low viscosity to allow the stretching of the fluid filament and high viscosity to surface tension ratio to avoid break up by capillary forces. So far, these two factors were studied as totally dependent on each other. However, Parikh [5] reports the chance of changing the surface tension of glasses regardless of viscosity by controlling the relative humidity of the atmosphere. Accordingly, in the present work, we outline an extensive experimental research on the productivity of Laser Spinning and, in particular, on the influence of the relative humidity value of the assist gas on the produced fibers.

An extensive study on the working conditions of the process by varying the laser power and the advance precursor material was performed. The study was divided in two steps, both carried out with dry air: in the first one we have gotten the mass of obtained fibers per unit length of precursor material with the aim of optimize the efficiency of the process (figure 1). Then, we fixed the laser power in the optimal and varied the advance speed to obtain the distribution of final diameters of fibers produced as a function of this speed. These diameters were measured by using a Scanning Electron Microscope (SEM) (figure 2). We have carefully analyzed the resulting data trying to optimize the entire process. It led to an improvement in the efficiency and a better control in the final diameter of the fibers by just setting the suitable working conditions.

Then, we carried out an analysis on the influence of the surface tension of the melted volume by varying the relative humidity of the assist gas. The optimal values of laser power and sample speed were used now to perform it. We varied the relative humidity between 20 and 110 % (supersaturated) and measure the mass of obtained fibers per unit length of precursor material. As the main outcome, we have successfully increased this mass up to a 300 % by controlling the humidity of the assist air jet.

In summary, we optimized the working conditions of the process to maximize its productivity and to achieve a better control of the final diameter of the fibers. Moreover, we have demonstrated the relative humidity as an important parameter to optimize the process.

Acknowledgements

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Figures

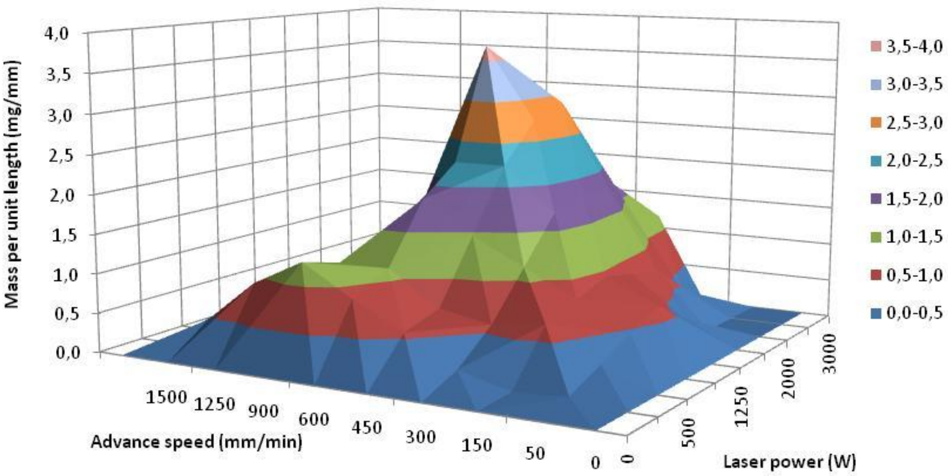

Figure 1. Graph showing the productivity of the Laser Spinning process. The mass per unit length as a function of the laser power and the sample speed is plotted.

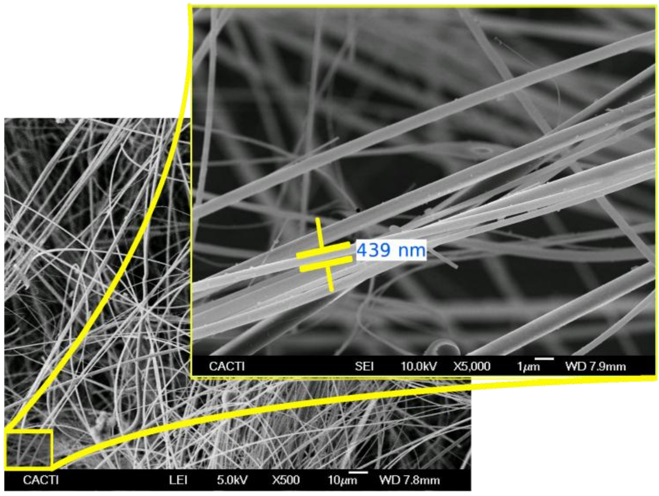

Figure 2. SEM images showing the way to measure the diameters of the fibers. They were obtained with a laser power of 2 kW and a sample speed of 600 mm/s with dry air.