Production of glass nanofibres by a novel technique: Laser Spinning

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New applications of one dimensional nanostructured materials are quickly evolving [1]. We have developed a new method, Laser Spinning, for the production of ultralong amorphous ceramic nanofibers with lengths up to several centimetres. This technique allows large quantities of nanofibres to be made with specific, controllable chemical compositions. Furthermore, the production of amorphous nanofibres of non-ready glass former materials was demonstrated. This will potentially open up a whole new range of applications for the fibres.

The fundamentals of the technique will be outlined. It employs a laser to melt a small volume of a solid precursor material while a high pressure gas jet drags it. Thus, the molten material forms glass fibres as a result of its viscous elongation by the drag force and rapid cooling by the convective heat transfer promoted by the gas jet. Figure 1.a exhibits a SEM micrograph showing the typical morphology of the fibres. They form a disordered mesh of intertwined fibres with different diameters, typically in the range from tens of nanometres up to several microns. Each fibre has a uniform well-defined cylindrical morphology of near constant diameter with smooth surface, as can be observed in the TEM picture presented in Fig. 1.b. Because of the speed of the cooling the final structure is amorphous as the diffraction pattern in the inset of TEM micrograph demonstrates.

In this presentation experimental evidence on the mechanism of formation of the nanofibers will be shown using a high speed camera to record the formation of microfibers in some milliseconds by elongation of the viscous molten material during Laser Spinning. This process of fibre formation is mathematically modelled by applying the basic theories of elongational flows to the specific case of uniaxial stretching during melt blowing. The fundamentals of the model and the key parameters controlling the process will be outlined. The mathematical model allows to extrapolate the experimental evidences obtained for the production of microfibres to explain the formation of the nanofibres in a matter of microseconds. The dimensions and temperature of the molten volume together with its viscosity to surface tension ratio are revealed to be the controlling factors in determining the formation of the nanofibres [2, 3].

A crucial point question with regard to the composition of the fibres is to verify if they keep exactly the same chemical composition than the precursor material. The most likely alteration on the composition might be a depletion in the most volatile species due to the high temperatures of the melt and variations of composition among the fibres. For this reason we performed several experiments and analyses of the resulting fibres. In order to compare the composition of the precursor material with that of the fibres, a series of homogeneous glass plates were prepared and processed to obtain the nanofibres. Then, both series of samples were analyzed by X-Ray Fluorescence (XRF) and compared with corresponding pairs, demonstrating a good correlation of the chemical composition. Furthermore, a study of the compositional homogeneity of the fibres was performed analyzing the composition mapping of a set of fibres by Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS). These analyses proved that Laser Spinning can be used to produce nanofibres with homogeneous and controlled chemical composition [4].

Finally, some of the promising applications of the glass nanofibers will be outlined, ranging from the production of Bioglass® nanofibres for tissue engineering [5], to the design of nanofibres with new compositions for special functional textiles or carbon capture.

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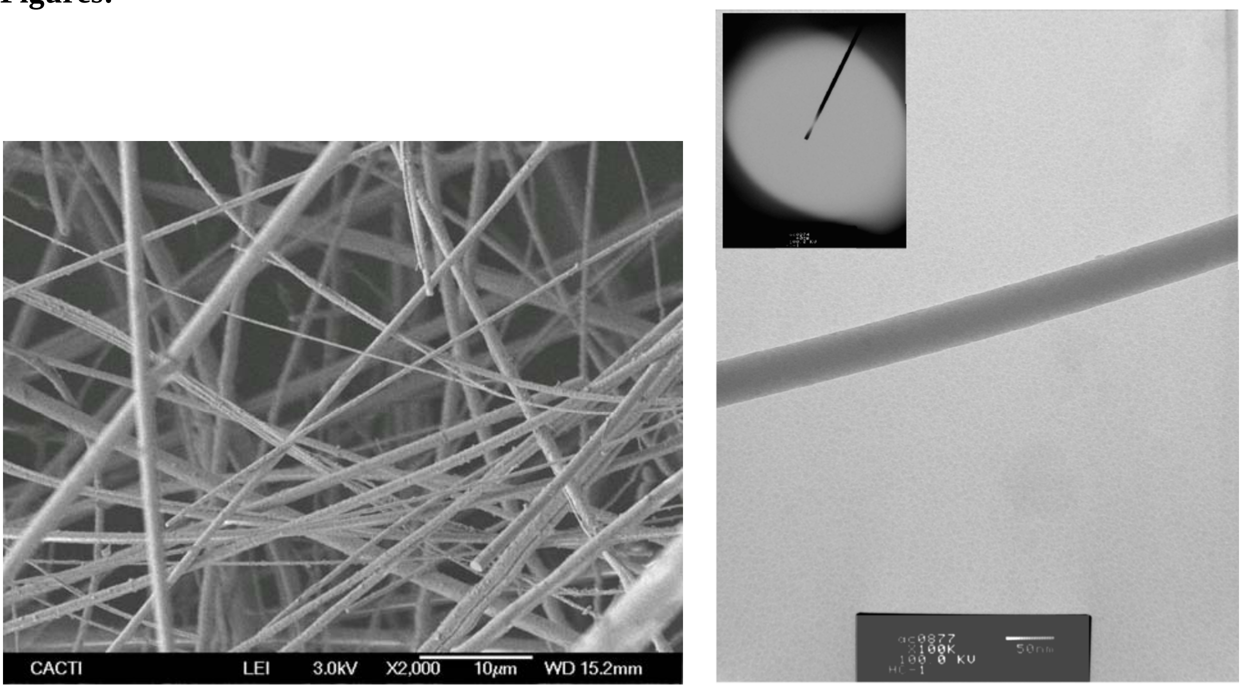
Figures:



a) **b)**

Figure 1. a) The SEM micrograph presents the typical appearance of the micro- and nanofibres produced by means of the Laser Spinning technique. b) The TEM micrograph shows a detail of a nanofibre with a diameter of 35 nm and the inset shows its amorphous structure.