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Growth Of Monocrystalline Strontium Titanate Fibers By Laser Melting

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Strontium titanate is an incipient ferroelectric material of the perovskite structure and high melting point (2080 ° C). It is a material which has a remarkable chemical and thermal stability, and has an interesting potential for the development of applications, particularly in manufacturing laser diodes, sensors, oxygen at elevated temperatures, UV sensors, and optical sensors, among other possibilities of development new optical devices. We present growth results $SrTiO_3$ crystal fiber by the technique "Laser Heated Pedestal Growth".

Keywords: Crystal Growth, Fibers, LHPG, Strontium Titanate

Introduction

Strontium titanate is considered foundational material of complex oxides electronics. Depending on conditions, this may have ionic conduction or electronic type (p) or (n) [1]. Persistent photoconductivity was observed in strontium titanate single crystals [2]. This new property of the strontium titanate will enable new application fields, being of particular interest the development of active optical memories. In this way, the "Laser-Heated Pedestal Growth (LHPG)" method allow growth to single-crystalline fibers of millimeter and sub-millimeter dimensions. LHPG technique compared with the conventional crystal growth methods has significant advantages, such as high pull rate (mm/min), not used crucible, allow crystals growth with high melting point (≥1500°C) and melting zone is of reduced size ($<1mm^3$) [3,4].

In this work, we present result of the single-crystal strontium titanate pure fiber growth. The fibers are obtained from pedestals constructed by the technique of solid state and cold extrusion. The results presented are the preliminary study to search for persistent photoconductivity in single-crystalline strontium titanate fibers for optical applications.

Experimental part

Figure 1(a) shows a schematic of the LHPG system used. The growth system consists of an optical arrangement whose radiation source is a CO_2 laser (Synrad model: Evolution 125). The laser is focused on top of the pedestal to create the molten zone. To start the pulling of the single-crystal fiber, the seed is inserted into the melted zone and removed in a way controlled to the surface of the liquid phase. This permits the crystallization of the compound in the contact between the solid/liquid interfaces.

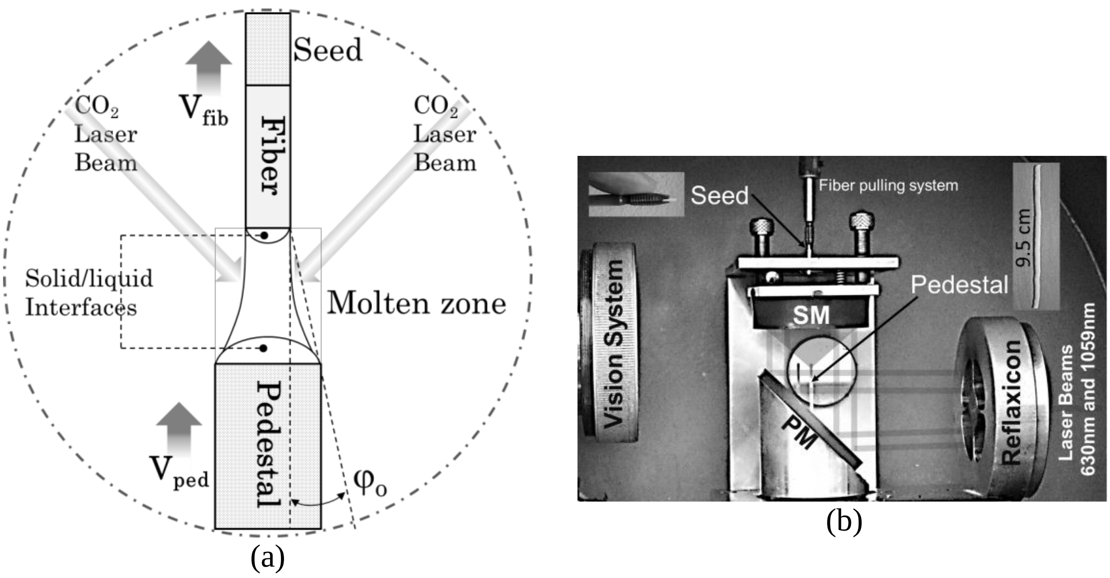

Fig. 1 –*(a) Schematic drawing of the Laser Heated Pedestal Growth system. (b) Photography inside the growth chamber LHPG used in this work. SM: spherical mirror; PM: plane mirror.*

The growth process is guided by a computer, which controls the growth rate (V_{fib}), and CO_2 laser power, and the feed rate (V_{ped}) is manually controlled (in general, it is fixed). In this way, the diameter of de fiber is controlled. The growth process is summarized in the Figure 2. Sintering, synthesis and pulling fiber occur during this growth process.

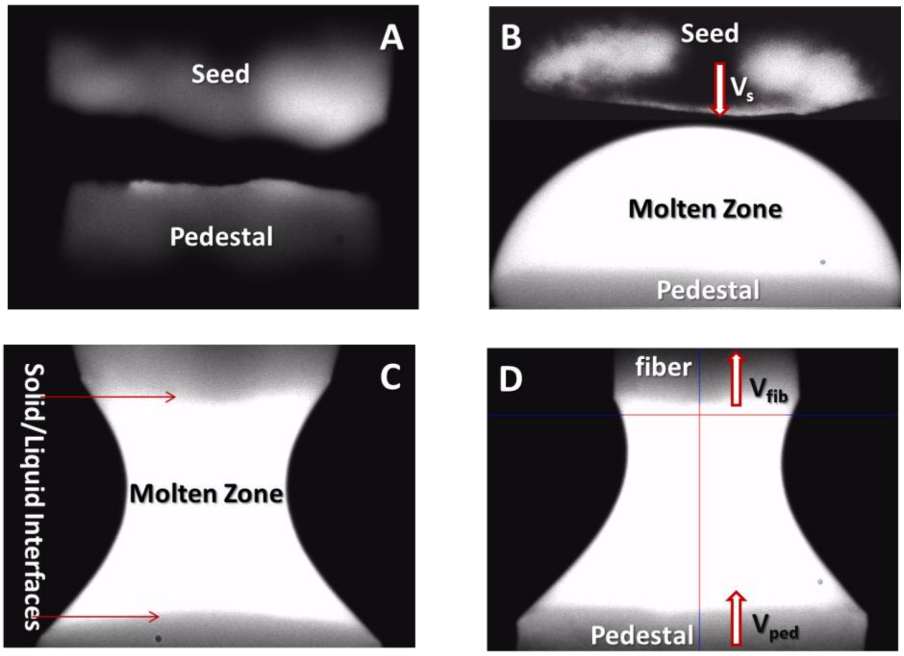

Fig. 2 – *Images of growing single-crystal fiber by LHPG system (Fig.1). A, B, C and D are the steps of the fiber growth process. Step A: mechanical alignment of the pedestal and seed. Step B: creation of a small molten zone on the top of the pedestal. Step C: Contact of the seed with the melted region pedestal. Step D: fiber growth.*

The melted zone form is a very important growth parameter. The variation of the contact angle (φ_o) is responsible by the fiber diameter fluctuation [3]. Minimum variations of this parameter commit the growth stability. Ideally, when the contact angle reaches this equilibrium value, the growth process is stable and should not have fluctuations. However, the real conditions of the growth system produce fluctuations in the form of the floating zone, thus modifying the contact angle. The LHPG system operates through four basic steps: (1) Mechanical alignment of the seed and the pedestal (Fig.2A), both aligned on the optical axis of the laser beam; (2) Creation a molten zone small on the pedestal top. (Fig.2B), slowly increasing the laser power; (3) The seed is then introduced in the liquid phase and there is creation a molten zone (Fig.2C); (4) The motors are started and the pulling-fiber process begins, with controlling manually or automatically the fiber diameter. (Fig.2D).

The pedestals were prepared by solid state technique and cold extrusion. $SrCO_3$ + TiO_2 stoichiometric mixture, under both precursor powder of high purity (99.8% purity -Vetec-) was prepared. The pedestals have a circular cross section form (Approximate diameter: 1.65mm). This format is suitable for LHPG technique. In the growth process of the fiber the following reaction takes place:

$$\mathrm{SrCO_3} + \mathrm{TiO_2} + \Delta \mathrm{T} \uparrow \rightarrow \mathrm{Sr}\mathit{Ti}\mathrm{O_3} + \frac{1}{2}\mathrm{O_2} + \mathrm{CO}$$

Results and discussion

The image in the Figure 3 shows some results obtained by using different feeding speeds and growth. Figure 4 is the result of the phase obtained by X-ray diffraction, using the powder method. On the same Figure 4 are shown: the XRD patterns of the pedestal and fiber, and the XRD pattern reference (Ref [5]). In the fiber XRD pattern only is observed the presence of the strontium titanate crystalline phase.

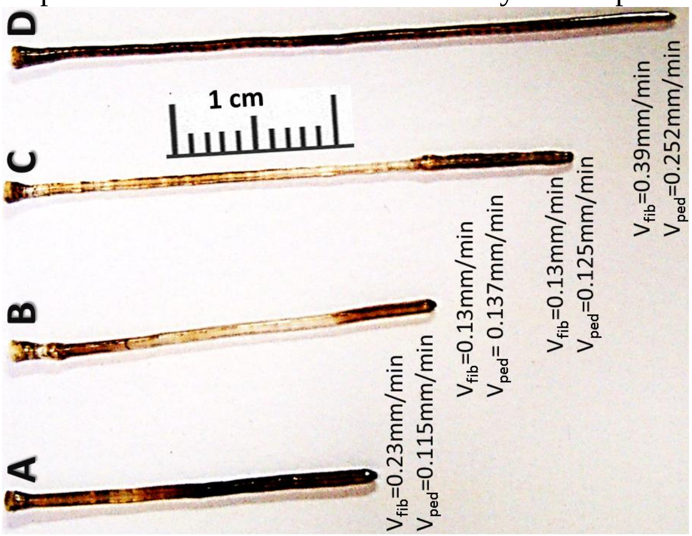

Fig. 3 – *Images of the fibers strontium titanate, these were obtained with different rates of growth and feeding. The A, B and C fibers were grown without automatic diameter control (V_{ped} are average values), and V_{fib} = constant. D Fiber was grown with automatic control, where V_{fib} is the average value and V_{ped} = constant.*

All XRD pattern peaks of the fiber coincide with the XRD reference (crystal lattice of pure strontium titanate)[5]. We use the six peaks of the fiber XRD pattern to calculate the value of the lattice parameter (ā=3.9098Å). The growth of the A, B and C fibers (Fig.3) was not automatically controlled. In this case, adjust manually V_{fib} = constant and V_{ped} was varied. In the growth of the D fiber (Fig.3) was used automatic control system of V_{fib}, and where we adjust V_{ped}=constant. All growth was done in an air atmosphere. The colors on the fibers are due to oxygen vacancies caused during the growth process. Thus particularly, the A, B and C fibers, all they present one distribution non-homogeneous of oxygen vacancies. We attribute this performance to variations in both growth rate and the melt temperature.

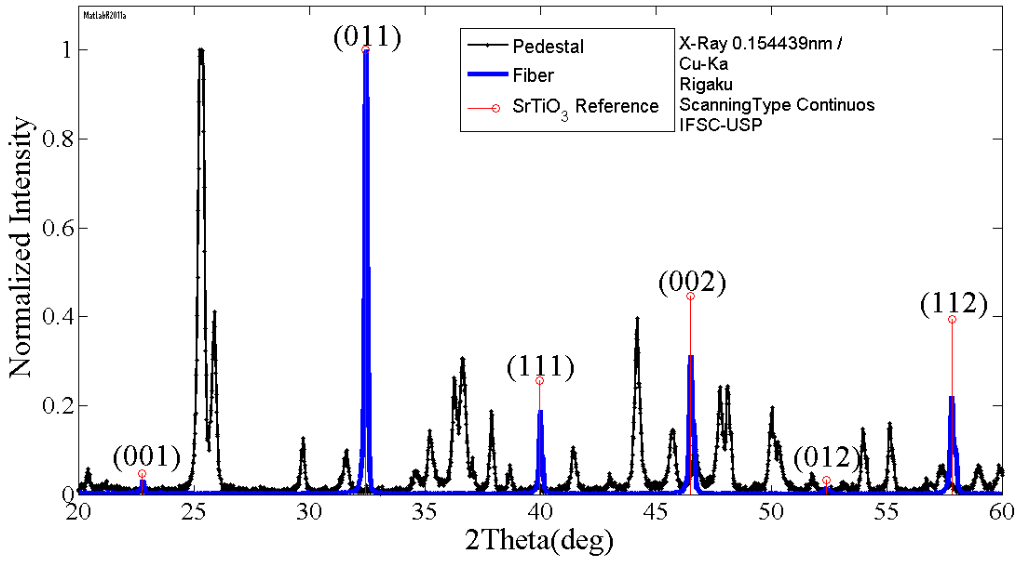

Fig. 4 – *X-ray diffraction pattern obtained by the technique of polycrystal. XRD pattern of: fiber, ($SrCO_3$ + TiO_2) pedestals, and reference pattern. Space-Group Pm-3m (221)-Cubic; $\bar{a}$=3.9098 Å average value determined from the XRD pattern of the fiber, and a=3.901Å value reported in Ref [5].*

The results presented in this work are preliminary tests the final objective. The idea is obtain fibers with persistent photoconductivity for optical applications. The research should lead us to determine the growth rates, necessary to obtain single-crystal fibers, high quality optical, and with persistent photoconductivity in the electromagnetic spectrum optical region.

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