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Modifying the growth morphology of aluminum crystals by magnetic mirror in a thermal plasma reactor

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Abstract. Effect of magnetic fields on growth morphology of aluminum crystals was studied in a fluidized bed thermal plasma reactor assisted by magnetic mirrors. Aluminum crystals were precipitated in the reactor using aluminum powder or aluminum-graphite mixture as precursors. The absent of magnetic field was also studied for comparison. Products were characterized by scanning electron microscopy (SEM) and X-ray Diffraction (XRD). Results indicated that, regardless the precursor used, it was observed the presence of aluminum nanowires when the external magnetic mirror was applied, suggesting that magnetic fields are able to modify growth morphology at nanoscale.

1. Introduction

Control and effects of electromagnetic fields on crystals growth morphology and crystalline structure during the synthesis of new species, have been intensely studied in the last thirty years, and the subject has emerged even more with the recent impulse of nanostructured materials.

In 2002, Khomutov *et al.* [1] studied the effect of electric and magnetic fields on the growth of colloidal amorphous particles. They found that the size and shape of synthesized nanoparticles dramatically changed when an external magnetic field was applied, due to the alignment of growth direction with field lines, resulting in needle-like particles.

Similar results were obtained by Kaneko et al. [2], which presented studies on the influence of variation of magnetic fields intensities on the formation of carbon nanotubes using a rf glow-discharge plasma. They established that nanotubes synthesized under the highest intensity magnetic field studied tended to be smaller in diameter and extended with the typical crystalline structure of carbon nanotubes.

Furthermore, Li Shuqin et al. [3] observed preferential growth of silicon nitride (Si_3N_4) under the effect of magnetic fields. Also, L. Bárdoš et al. [4] reported in 2005 the modification of growth morphology of TiN coatings by applying magnetic fields.

In 2006, Takahashi et al. [4] studied the maglev synthesis of new materials using a furnace assisted by magnetic field. They concluded that the synthesis in magnetic fields generates a magnetic orientation effect in anisotropic susceptible materials.

In addition, other studies [5, 6] suggest that magnetic field applied during synthesis of materials, not only affects size and morphology of particles, but also produces an increment on the synthesis efficiency and product quality.

Thus, the objective of this study is to determine if the presence of external magnetic fields influences the growth morphology of aluminum in a thermal plasma reactor fluidized bed.

2. Experimental procedure and results

The fluidized bed thermal plasma reactor was fabricated in the lab, and the external magnetic field was applied in order to determine its effect during precipitation of aluminum crystals. External magnetic consisted of a copper solenoid powered by an HP 13215A power supply of 52.2 Volt DC and 2.7 ampere. The solenoid is rolled on a refrigerated steel reel with 30 mm of internal diameter. The reel generates such magnetization that magnetic flux is more intense at the ends. This configuration is known as a magnetic mirror. In the lower base of the solenoid, it was adapted the thermal plasma torch Plazjet^{TM} 105/15. The solenoid tightly goes into the cylindrical reactor, within which there is an expansion chamber of 200 mm of diameter, where it is expected that liquids and/or vapor condense rapidly and the synthesis of new materials takes place.

The torch was refrigerated by the heat exchanger HE 200 USA using ethylene-glycol at 75 psi and was powered by a power source Plazjet Whitco of 70 ampere and 200 V DC. This energy is used to make the plasma from 13.2 lpm of high purity nitrogen.

Some tests were performed using aluminum powder (Riedel-de Haën # 11010) as a precursor. However, other tests were executed with a mixture aluminum-graphite. The precursor was transported with nitrogen to 1 psi and a feeding rate of 3 g/min. Feed rate was kept constant and controlled by a Sylko Mark XII dosifier (see figure 1).

Figure 1. Experimental set.

The magnetic field was measured experimentally with a gaussmeter YOKOGAWA model 325i. A maximum intensity of 0.1 Tesla (1000 Gauss) was obtained at the ends of the solenoid. For comparison, procedure was applied with and without application of external magnetic field [7].

Products were characterized by scanning electron microscopy and X-ray diffraction using a JEOL/EO 1.0 SEM and an X-ray diffractometer Philips XpertPro, respectively.

3. Results and discussion

Figures 2 and 3 shows the SEM images of aluminum particles precipitated from a fluidized bed thermal plasma reactor using as a precursor aluminum powder (2) or a mixture of aluminum-graphite powder (3); without application of magnetic field 2 (a) and 3 (a) and assisted by magnetic mirrors 2 (b) and 3 (b). It is clear that, regardless the precursor used, there is a morphological difference of aluminum crystals obtained under the magnetic field, respect to those achieved in the absent of the field. It is evident an elongated morphology similar to nanowires with diameter of 27 nm approximately, when compare with micrometric particles obtained when magnetic field is not applied.

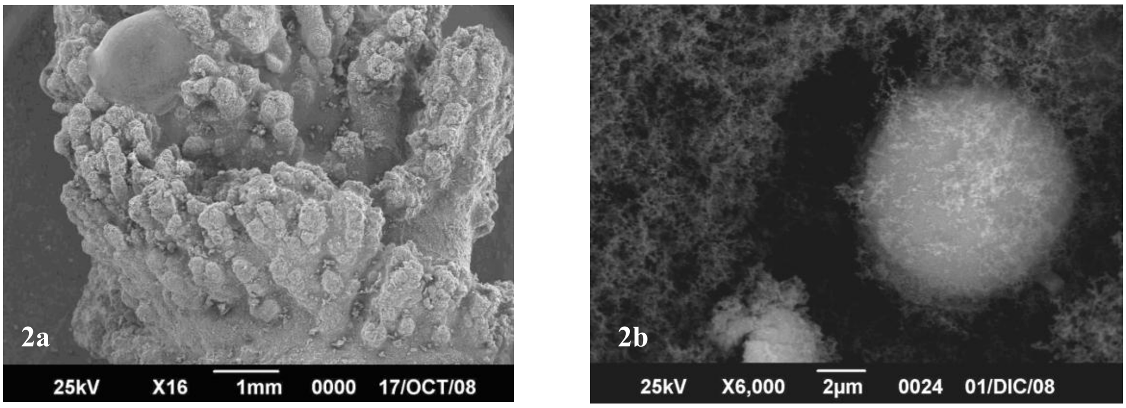

Figure 2. SEM photomicrographs of samples obtained from an assay performed in a thermal plasma reactor employing as aluminum powder precursor without application of external magnetic field 2 (a) and assisted by magnetic mirror 2 (b).

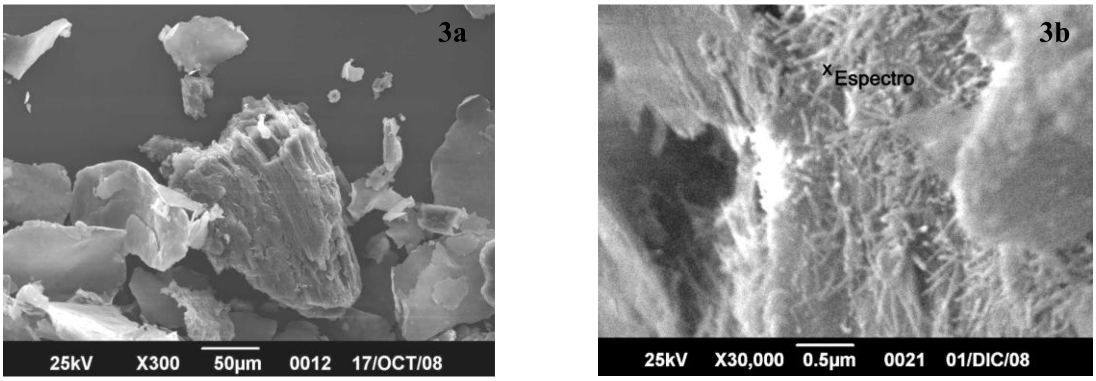

Figure 3. SEM photomicrographs of sample obtained from a test performed in a thermal plasma reactor using as precursor a mixture of aluminum powder with graphite without external magnetic field 3(a) and assisted by magnetic mirror 3 (b).

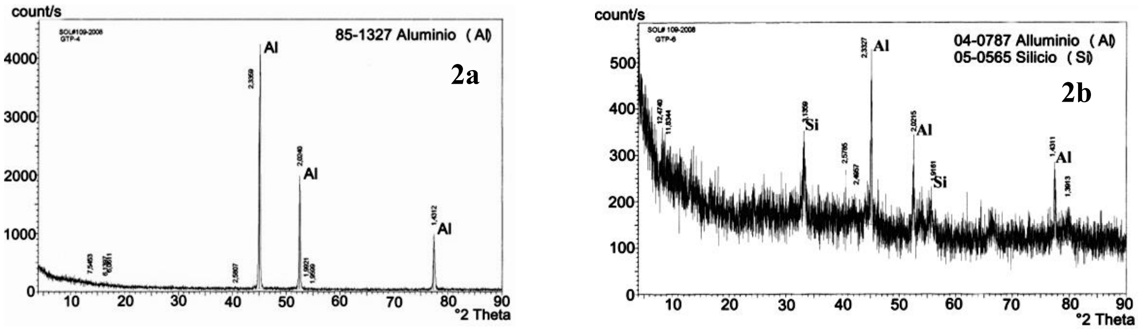

Figure 4. X-ray Diffraction of dendrite synthesized into a thermal plasma reactor and nanotubes synthesized with aluminum powder precursor without magnetic field 4 (a) and assisted magnetic mirror 4 (b).

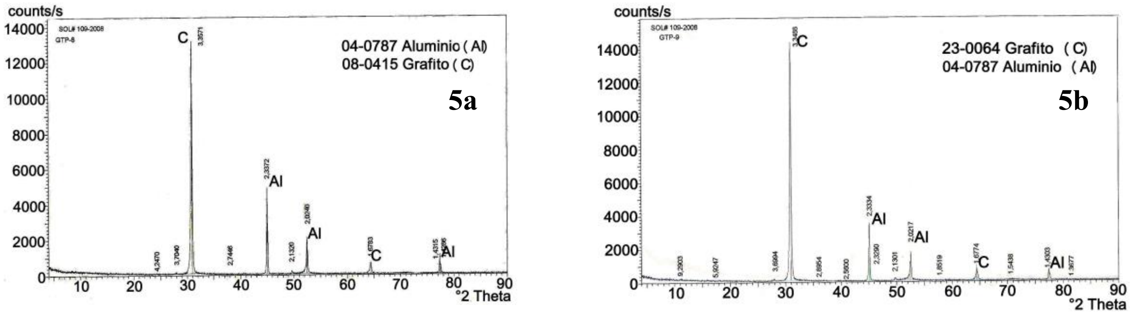

Figure 5. X-ray Diffraction synthesized from a mixture of graphite powder and aluminum precursor in a thermal plasma reactor without magnetic field 5 (a) and with assisted magnetic mirror 5 (b).

Diffractograms depicted in figure 4 and 5 support the results shown previously, due to there is a notably reduction on peak intensities of products achieved under the effect of external magnetic field, typical of nanometric particles. In addition, other diffraction peaks are presented on the spectrum suggesting that magnetic field induces the particle growth through certain preferential direction, in agreement with suggestions of several authors [7].

4. Conclusions

Applying an external magnetic field to a fluidized bed thermal plasma reactor promotes the precipitation of aluminum nanowires, this suggest that the magnetic mirror modifies the crystal growth pattern.

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