Effects of the magnetic field over the nanometric growth morphology on the material synthesis in a liquid spray thermal plasma reactor

L. Beiras, G. Torrente, J. Puerta, F. Blanco
Departamento de Física, Departamento de Mecánica, Universidad Simón Bolívar, Apdo: 8900, Caracas - Venezuela
E-mail: laurischiq@gmail.com, gtorrente@usb.ve, jpuerta@usb.ve, fblanco@usb.ve

Abstract. It is possible that the magnetic field affect the growth morphology of the materials at nanometric scale while there are synthesized. In this work is developed a thermal plasma reactor in fluidized bed assisted by magnetic mirror for material synthesis using a liquid spray. An aluminum solution is carrier in the plasma reactor with a without magnetic external magnetic field applied. We found from the characterization of material synthesized that: Aluminum nanowire and alumina nanofiber are generated when the external magnetic mirror is applied to the thermal plasma reactor.

1. Introduction
Recently the interest on the works of investigation about the synthesis under the influence of electric and magnetic fields has increased. Possibly this interest has been generated by the advances on investigations of nanostructured materials. Since 2002 in Lomonosov Moscow State University the professor Khomutov [3] studied the effect of applies electric and magnetic fields in the growths of amorphous colloidal particles. He found that the size and the forms of nanoparticles synthesized changes dramatically aligning itself when a external magnetic field parallel to the plane is applied during the synthesis. He accomplished that to control the morphology of nonstructural materials by synthesis under magnetic fields will be a promising proposal for the engineering of nanofaces and nanotech. In 2005 other authors notified the modification of morphology growths and crystalline direction by the applications of external magnetic fields, among them L. Bárdoes [1] from Uppsala University in Sweden, he informed about the modification of the morphology of growth of coating of TiN by the application of magnetic fields, and Takahashi [4] from Yamagata University in Japan reported the synthesis of carbon fibers aligned by the application of magnetic fields. Nowadays plasma spraying is a good established technology used in laboratory and in the nanofacturing. Several interesting uses are in biomedical, petrochemical, etc [2]. In our case this phenomena that can govern the formation of the plasma jet inside the thermal reactor has been simulated with and without magnetic field generated by a mirrors type machine in order to improve [5] the plasma conditions. With the magnetic field we have observed better properties in nanostructured material. Around several nanometers has been obtained for this system through the machine we use. In the reactor its routing the liquid using a peristaltic pumps and in a conventional (DC) plasma torch. This
paper show the results of this experiments using Al in solutions.

2. Experimental Model
To perform good predictable capabilities of our plasma torch experiments, 2D simulation has been carried out, but in order to make this job in a better way 3D simulations must be made in order to understand the physics here involved assuming thermodynamic equilibrium in the stationary phase. In our experiment the gas mixture is $N_2$ with a nozzle of 5mm in diameters and the liquid injection is made transversally into the plasma via a peristaltic pump. Good spray condition was obtained with the parameters given by the table.

The reactor parameters:

| $V_{EF}, I_{EF}$ | 220Volts, 54Amp |
|-----------------|------------------|
| $m_g$           | Nitrogen 13.2lpm, 40psi |
| $R_r$           | 0.7874inch |
| $m_p$           | Aluminium 22µm, 0.3g/s |

The experimental procedure was realized using an stainless steel cylindrical reactor. Inside this one was placed a magnetic coil (see fig. 1) and in backside of the reactor we find the plasma torch, " Plasjet 105/15" by Thermal Dynamics of 15Kw total power. Connected to the system we have a peristaltic pump in order to introduce the neutralized Al-solution. In fig. 2 we show a schematic of the complete experiment. The magnetic field intensity inside of the magnetic coil along the $z$ - axis, was realized with a gauss meter and shown in fig.3. The structure of the field present the minimum B field configuration. This type of field was obtained due to the positive susceptibility of the bobbin(made of steel 1050), in such a way that a counter magnetic field is achieved near of the center and quasi same sense at both sides(front and back) of the coil. We speak also, about of a mirror field configuration. In our point of view, that is a nobel experiment considering the literature in this area of plasma spray. The solution of Al was prepared using HCl and after this neutralized with NaOH in the appropriate Al concentration useful for our experiment. We analyze the products via TEM. Figure 1 - 4 shown some of the preliminary results we obtained.
Figure 2. Magnetic field measurement inside the coil using a gauss-meter model YOKOGAWA 325i

(a) Espectro 1  (b) Espectro 2

(c) Espectro 3  (d) Espectro 4

Figure 3. Espectros

3. Conclusions
In figures 3 we shown some results from our past and present preliminary experiments. The results has been very successfully.

The plasma temperature profile (Fig.4) inside the reactor assisted by a magnetic field shows that the highest temperature are near the plasma torch and decrease along the plasma, far away from the plume. The electron temperature profile inside the reactor assisted by a magnetic field shows that the highest electron temperature are near the plasma torch and better confined along the reactor in comparison with the case without magnetic field.

It is interesting to mention here, that a result of our past simulation(paper Bochum), the heating of the aluminium powder in the center is higher than near the wall of the reactor. That is due to the fact that in the center the plasma temperature of the plume is higher than near the
wall and also due to the residence time for the powder in the reactor is longer than for lighter particles. Finally it is to conclude, that the application of the magnetic mirror reduces the plasma flow velocity on radial direction, displacing it to the reactor’s walls and confining it partially. These decrease the heat losses in the gas flow and mainly on the electron flow. The diminution of the axial and radial plasma velocity by effect of the magnetic field, directly affects the collision frequency between heavy particles and electrons. Therefore the collision frequency is the main mechanism of energy transfer between these components in the plasma. These two factors shift away the plasma from thermal equilibrium increasing the temperature difference between the heavy particles and electrons, observing a slight increase of heavy particles temperature but a greater increase on electronic temperature. Figure 4 show the effect of the magnetic field in the plume via a computer simulation where we observe that the electron temperature increase along the z-axis compared with the case with no magnetic field.

4. Acknowledgments
Work supported by DID, Universidad Simón Bolívar

5. References
[1] L. Bárados, L. E. Gustavsson, and H. Barnkov. Effect of ferromagnetic substrates on the film growth in magnetized plasma systems. Surface and coatings technology, 200:1862–1866, 2005. Issues 5-6.
[2] J.R. Davis, editor. Handbook of thermal spray technology. ASN International, 2004.
[3] G. B. Khomutov, S. P. Gubin, V.V. Khanin, A. Yu. Obydenov, V. V. Shorokhov, E.S. Soldatov, and A.S. Trifonov. Formation of nanoparticles and one-dimensional nanostructures in floating and deposited langmuir monolayers under applied electric and magnetic fields. Colloids and Surface A, 198-200:593–604, 2002.
[4] Tatsuhiro Takahashi, Taichi Murayama, and Ayumu Higuchi. Aligning vapor-grown carbon fibers in polydimethylsiloxane using dc electric or magnetic field. Carbon, 44:1180–1188, 2006. Issues 7.
[5] G. Torrente, J. Puerta, and N. Labrador. Two-temperature single-flow model of a thermal plasma reactor in fluidized bed assisted by magnetic mirror. Physica Scripta, T131(014010), 2008.

Figure 4. Electron Temperature profile without and with magnetic field