

SUPER-PARAMAGNETIC NANOPARTICLES SYNTHESIS IN A THERMAL PLASMA REACTOR ASSISTED BY MAGNETIC BOTTLE

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Abstract. The present work is a study of the synthesis of super-paramagnetic particles. A preliminary study based on thermodynamic diagrams of Gibbs free energy minimization, was performed with the CSIRO Thermochemical System. In this way, the synthesis of magnetite nanoparticles from precursor powder of ore iron in a thermal reactor, was performed. Then the process was simulated mathematically using magnetohydrodynamic and kinetic equations, in order to predict the synthesis process. A cylindrical reactor assisted by magnetic mirrors was used. The peak intensity of 0,1 tesla (1000 Gauss) was measured at the end of the solenoid. A PlazjetTM 105/15 thermal plasma torch was used. The precursor powder was iron oxide and the plasma gas, nitrogen. The magnetite powder was magnetized with rare-earth super-magnets, alloy of neodymium-iron boron (NdFeB) grade N-42. The synthesized nanoparticles diameters was measured with a scanning electron microscope LECO and the permanent magnetization with a YOKOGAWA gauss meter, model 325i. Our experimental results show that it is possible the synthesis of super-paramagnetic nanoparticles in thermal plasma reactors.

1. Introduction

The study of plasma has given mankind a great amount of knowledge, and it has been very important in the development of different fields of science, technology and industry with great impact. In this way the plasma has moved to be a scientific curiosity to a fundamental tool for the development of mankind. Plasmas has become now very important in illumination, metal mechanic industry, semiconductors productions, welding, product recycle, medicine and nuclear industry. The plasma technology development has guaranteed great variety of plasma torch configurations and these can be classified as, of transferred and not transferred arch. Considering the last kind of other classification of electrodes and direct current, radiofrequency, hybrids and microwaves. The development of the torches has produced a large impact in the industry on the second period of the XX century, when revolutionized the ship construction. Now the plasma torches have become very important in industrial high technology, mainly in the production of semiconductors, nanorecovery and nanomaterials. The plasma is an state of the matter, characterized to be composed by an ionized gas with several special properties, as to interact with electric and magnetic fields. In this way, the plasma is generated by a DC plasma torch of no transferred arc. The plasma is used to produce nanoparticles and nanomaterials. The new idea is confine the plasma with a magnetic mirror system, in order to increase the



production efficiency.

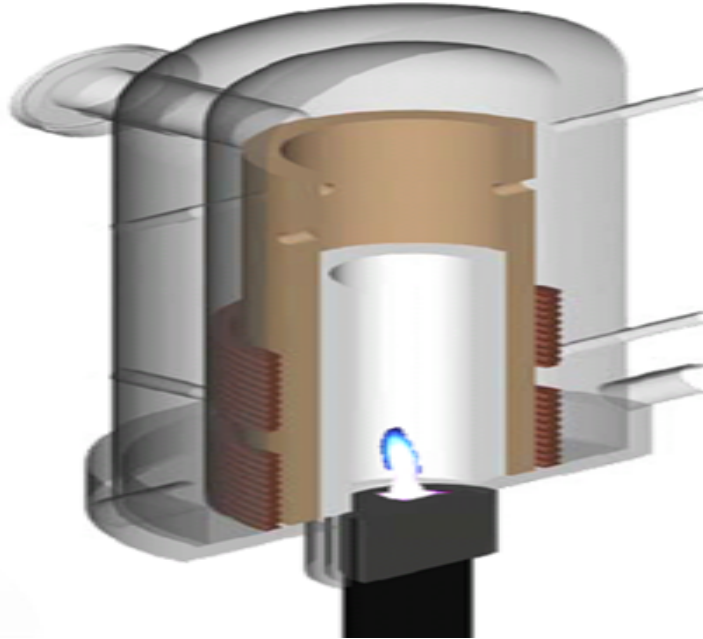


Figure 1: Artistic diagram of a thermal plasma reactor. The plasma torch (A) is shown coupled to the top part of the reactor (B). The coils (C) generating the magnetic field are coaxially inside

2. Aims

To build a thermal plasma reactor with a magnetic confinement system of magnetic mirror type. The reactor is a non transferred plasma torch to produce nanoparticles, and the process is optimized with the confinement system and the process is optimizes of nanoparticles.

3. Magnetic Confinement Fundamentals

The magnetic field application on the thermal plasma using magnetic confinement will increase the power efficiency of the DC plasma torch. The magnetic fields parallel to a wall reduce wall bombardment of ions and electrons, and therefore reduce impurity contaminations of the plasma atmosphere. The magnetic field furthermore improves uniformity of surface interactions and increases the perpendicularity of ion bombardment on the surface of deposition of nanoparticles and nano tubes.

In this work we are performed experiments with a magnetic mirror confinement configuration, which consist of an axysimmetric magnetic barrier with maximum magnetic field B_{max} in two extremes, and weaker magnetic field B_{min} between extremes in where the plasma is confined.

The fraction F_T of an initially isotropic distribution of particles changes in the uniform field region on the center which remains confined is a function of maximus magnetic field B_{max} and minimum magnetic field B_{min} .

$$F_T = (1 - \frac{B_{min}}{B_{max}})^{1/2} \quad (1)$$

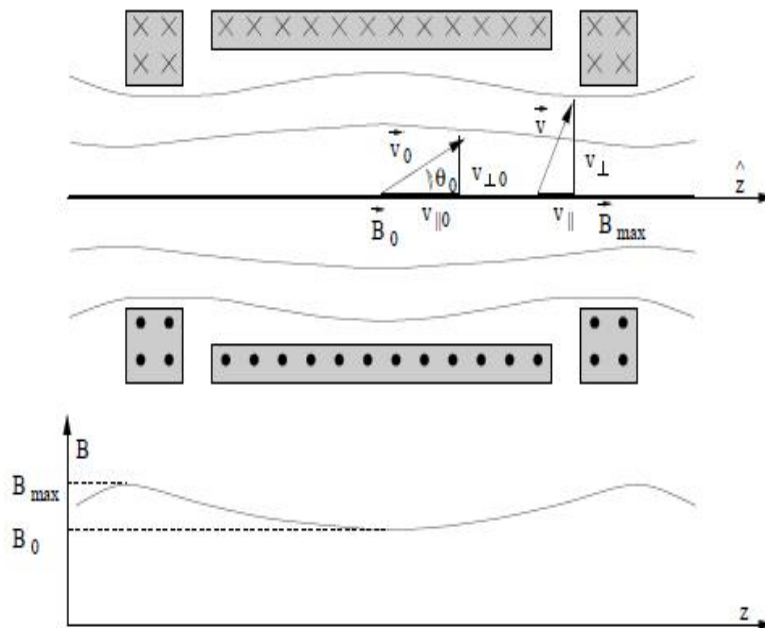


Figure 2: Diagram showing the intensity of the magnetic fields B , as a function of axial distance according to the confinement configuration by magnetic mirror, and its effect on the velocities of the plasma particles

4. Methodology

A confinement system with magnetic mirrors was built which was coupled to the plasma torch in such a way to allow the change of field intensity B inside the production chamber. To do this a plasma torch was built with autonomous power supply and refrigeration system, as well as a nanoparticles production chamber a confinement system by magnetic mirrors with variable field intensity B and materials for the nanoparticles production. Once these are produced the nano materials are characterized according to size and other characteristics. First a computational prototype was designed and simulated in agreement with the operational parameters. Once this was obtained an evaluation of the materials to be used was performed, according to those produced by the local industry taking account of cost and availability. Several simulations were performed in order to get the required parameters. Later, we entrusted to national companies the construction of different parts and equipment. Finally the experimental assembly was performed including instrumental and control equipment, measured instruments and refrigeration system. We are now in the process of building the parts of the equipment in order to proceed later to the assembly process and to evaluate the operativity of the experimental ensemble. Later we will proceed to couple the thermal plasma reactors and to evaluate the interoperability of the different parts of the systems. Finally, carrying out all the security procedures, we will perform the first experiment with the aim of studying the different conditions. After the experiments the study of the results will be performed.

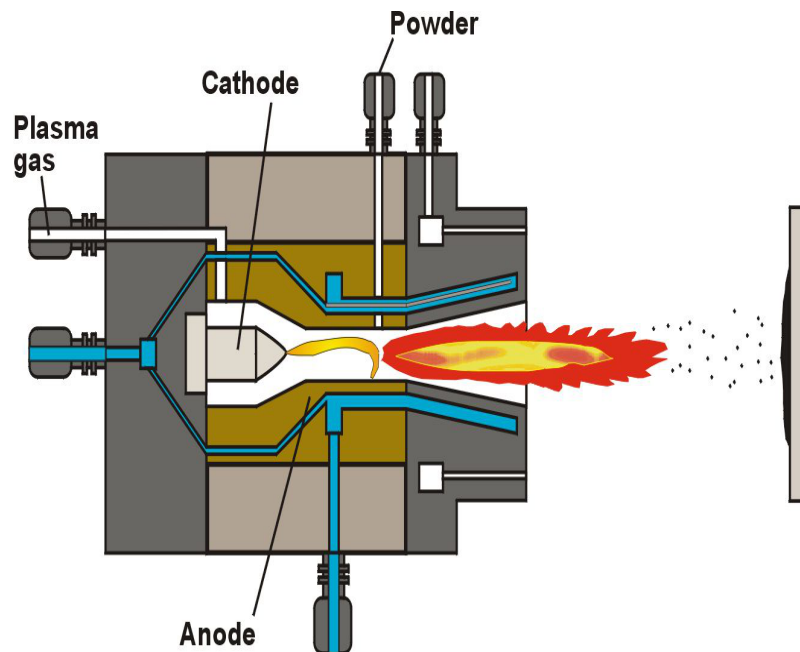


Figure 3: It is shown, schematic representation of DC electrodes torch mouthpiece of the non transferred arch type (A), the refrigeration system (C), the powder injection system (D), the surface for nano particles and nano materials deposition (E), the cathode (F) and the anode (G).

5. Results

The computational model already developed is based for numerical calculations in the finite element method. In this way the temperature profile, velocity density, electric potential and density of the are were obtained for all parameters of the current established. The results obtained in the simulation have been consistent with the theoretical estimations. The experimental phase have not been begin, therefore we do not known if then is agreement between there In the experimental phase we hope to produce nanoparticles, nano and nano recovery with electrodes no-transferred electrodes plasma torch in combination with a confinement system, magnetic mirror type. Our idea is to find the best experimental parameters to increase the efficiency in the production of nanoparticles, nano tubes an nano recoveries. To obtain the best parameters for the introductions of the materials to be processed in liquid state through the use of peristaltic pumps. Referring to the magnetic confinement system, there are two main parameters to be determine during the experimental peocess: average intensity of the magnetic field B , and ratio between the maximum magnetic field B_{max} an minimum one, B_{max}/B_{min} . In reference to the catalyst, there are several options to be consider (Fe), nickel (Ni) and cadmium (Cd).

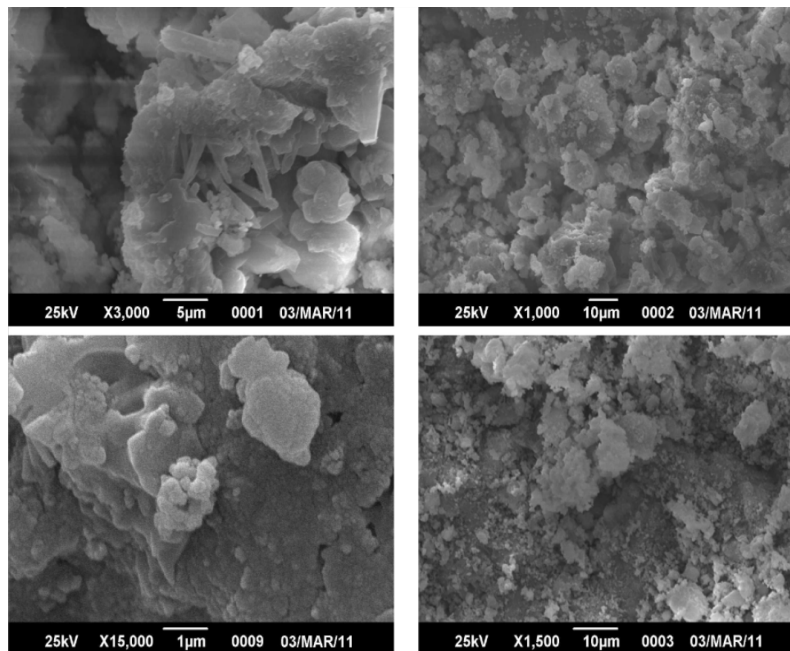


Figure 4a: It is shown, the results obtained in a previous work realized by the Plasma Physics Group of the University Simon Bolivar in studies on effects of magnetic fields, in this image is shown the results of the nanoparticles formation without the effects of magnetic fields.

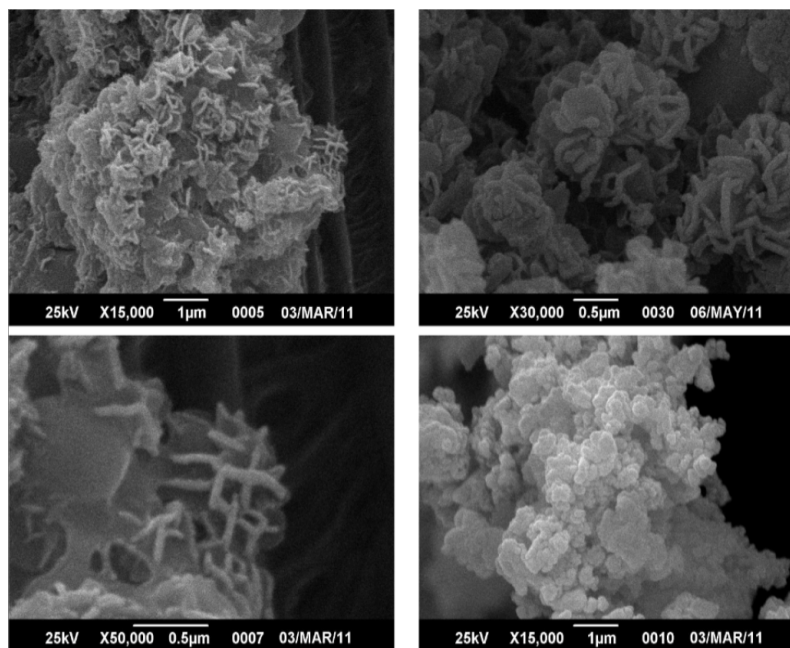


Figure 4b: Can be seen how the efficiency of nanoparticles productions increases with the magnetic field application.

6. Acknowledgments

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7. References

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