



STUDY OF THE EFFECTS OF MAGNETIC FIELD ON THE PROPERTIES OF COMBUSTION SYNTHESIZED IRON OXIDE NANOPARTICLES

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ABSTRACT

The objective of this study is to study the effects of magnetic field on the synthesis of iron oxide nanoparticles in terms of morphology and magnetic properties. These particles are produced in an iron pentacarbonyl-carbon monoxide ($\text{Fe}(\text{CO})_5 - \text{CO}$) air diffusion flame system with and without the application of magnetic field. An Electro-Magnet was designed for the application of magnetic field on the system. Inhomogeneous magnetic fields have been found to promote combustion reactions in diffusion flames. Transmission Electron Microscopy (TEM) images and visual observations have shown the influence of magnetic field on morphological parameters i.e., the diameter of the primary particles formed and their aspect ratios. Studies have revealed that the chain like nano – aggregates consist mainly of Fe_2O_3 , a material which plays a vital role in magnetic storage devices. Nevertheless, the control of the degree of uniformity of aggregate particle morphology has been shown in [1] to be difficult under flame conditions. Thus, there exists a critical need for the application of external magnetic field for effective control of particle aggregate morphology under reaction conditions.

INTRODUCTION

Magnetic fields are known to affect flame behavior as a result of the paramagnetic and diamagnetic behavior of the constituent gases. Paramagnetic behavior is observed in materials with atoms that possess a permanent dipole moment. In the presence of a non-uniform magnetic field, these dipole moments align with the field and thus paramagnetic materials are drawn toward the direction of increasing magnetic field strength. In diamagnetic materials there are no permanent atomic dipole moments. When a non-uniform magnetic field is applied, the atoms then develop a net dipole moment and oppose the applied field resulting in a weak repulsion to applied magnetic field [2]. The oxygen of room air which used as oxidizer in this study is paramagnetic and thus shows an effect when an external magnetic field is applied. Fig.1 (a) and Fig. 1(b) show the behavior of carbon monoxide-air diffusion flame with and

without magnetic field. The selection of this particular flame system and fuel/oxidizer combination is justified since the primary particles formed in this type of flame have a natural tendency to form linear strings of aggregates [3].

EXPERIMENTAL SET UP

A diffusion flame system was designed in the combustion and laser diagnostics laboratory [4]. The particle-laden flame is formed by directing a controlled flow of iron pentacarbonyl [$\text{Fe}(\text{CO})_5$]-seeded with CO through a ¼ inch tube of a diffusion type burner. At a certain temperature, $\text{Fe}(\text{CO})_5$ decomposes and oxidizes in the presence of oxygen to form polyhedral primary particles of Fe_2O_3 [4,5] that tend to agglomerate into chain – like structures. The CO stream is seeded with $\text{Fe}(\text{CO})_5$ by bubbling a portion of the CO through a temperature-regulated bath of liquid $\text{Fe}(\text{CO})_5$ using a customized evaporator system. The mass flow rate of $\text{Fe}(\text{CO})_5$ has a linear relationship with the flow rate of carrier gas (CO). Thus, the amount of $\text{Fe}(\text{CO})_5$ seeded in the flame can be controlled by the amount of by-passed fuel. The postevaporator fuel tube is electrically heated to a mean temperature of 102°C to reduce the condensation of the $\text{Fe}(\text{CO})_5$ on the tubing walls. The choice of the $\text{Fe}(\text{CO})_5$ along with CO to generate iron oxide aggregates is based on the realization from previous works [1,4] that in this system chain like aggregates are formed.

A thermophoretic sampling system was designed to collect iron oxide nanoparticles on 200 mesh carbon coated copper grids. This technique is well suited for collection of particles for morphology studies. A probe in this system provides an instant cold surface in the hot flame to establish a temperature gradient which drives the flame-born particles to deposit on the surface. The cold surface also quenches the reaction of particles that are already captured. The thermophoretic sampling system, consisting of pneumatic cylinder, solenoid valve and control box can accurately control the position and movement of the thermophoretic

probe. Thermocouples were used to monitor the temperatures along the tube lines.

RESULTS

The effect of magnetic field on CO diffusion flame is clearly shown in Fig.1. When the flow rate of CO was 3.9cm/sec without any field, the upper part looked orange colored. In the presence of field, the flame height was reduced and became more intense which indicates that magnetic field also promotes combustion.

The TEM micrographs shown in Fig.2(a),(b) show the iron oxide chain aggregates which are formed at a flow rate of 450cc/min of CO and 25cc/min of Fe(CO)₅ at 35°C temperature of the evaporator cylinder. The diffraction patterns shown in the figure correspond to that of hexagonal or polyhedral and this indicates that the particles formed are iron oxide particles.

FIGURES

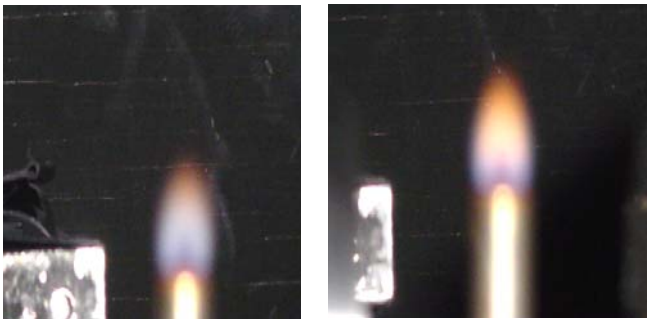


Fig.1 (a)

Fig.1 (b)

Fig. 1(a): CO Diffusion flame without any magnetic

Fig. 1(b). CO diffusion flame with magnetic field

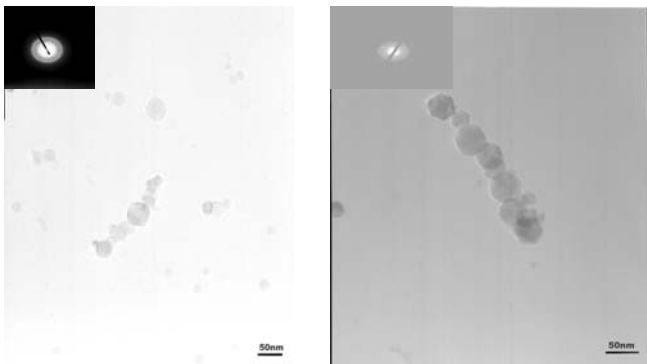


Fig. 2 (a)

Fig.2 (b)

Fig.2 (a): TEM micrographs of Iron oxide nanoparticles without magnetic field

Fig 2(b): TEM micrographs of Iron oxide nanoparticles with Magnetic field of 0.5 Tesla

WORK IN PROGRESS

Analysis of the particles formed at different flow rates of CO and Fe(CO)₅ is in progress after which the magnetic properties will be studied using a SQUID magnetometer.

FUTURE WORK

1. Validation of all the results using FLUENT software.
2. Temperature measurements at various locations in the flame to confirm the increase in the flame intensity.
3. Study of Magnetic Properties of the nanoparticles using SQUID magnetometer.
4. XRD and XPS Analysis for knowing the exact composition of the particles formed.

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