RESEARCH PAPER

Sono-Chemical Synthesis of Magnetic, Photocatalyst and Antibacterial $CoFe_2O_4$-Au Nanocomposites for Photo-Degradation of Methyl Orange and Acid Black

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ABSTRACT

The aim of this work is to prepare magnetic, photocatalyst and antibacterial $CoFe_2O_4$-Au nanocomposites. Aromatic dyes such as methyl orange and acid black were selected as control dyes and the results showed that were destroyed by ultraviolet light and in the presence of nanocomposites. Also, to control the non-growth and penetration of bacteria, the disk diffusion test was used against coliform, staphylococcus aureus and pseudomonas bacteria (which can be very dangerous). Related to biological risks for organisms, magnetic nanostructures are less dangerous due to their controllability. Therefore, the possible risks of entering the cell membrane and being uncontrollable are ruled out. In the first step, the magnetic core of cobalt ferrite with magnetization of 44 emu/g and magnetic coercivity of 20 Orsted was prepared. In the next step, gold nanoparticles were coated on the magnetic cores using the sono-chemical method. Scanning electron microscope, along with other common spectroscopic methods, examines the dimensions of nanocomposites.

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INTRODUCTION

Since last years, scientists have realized the importance of magnetic force in various applications. From electricity generation to the simplest household applications, magnetic field is an integral part of industry and life. One of the most important features of this amazing force is its safety for humans. On the other hand, the price of preparing and manufacturing most magnetic materials it is not very high. For example, there are mines of magnetic materials with suitable purity in different countries, including Iran, where magnetic materials can be used at low costs. In some mines that require the purification of magnetic materials, pure compounds can be prepared with relatively simpler processing methods. As we know, the most important feature of these materials is their controllability by a simple external field, which is very important in purification and performance. As we know, by changing the magnetic field, an electric field is produced and vice versa, and today mankind is looking for low-cost ways with the least pollution to produce electricity. Unfortunately, electricity is still produced by

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burning heavy petroleum compounds such as diesel fuel, and magnetic power, as one of the safest sources, should be given more attention. In terms of magnetic property, materials are either attracted or repelled by the field, the materials that are attracted are called paramagnetic and the materials that are repelled are called diamagnetic. If in the composition all the electrons are paired and even, it has diamagnetic properties and if it has only one single electron, it has paramagnetic properties. Magnetic materials that are attracted to the magnetic field are divided into two main categories: hard magnets and soft magnets. Hard magnets have permanent magnetic fields that show good magnetic properties even without the presence of an external field. But soft magnetic materials do not show a magnetic field without the presence of an external field, and in the presence of an external field, they align their spins and become magnetized [1-7].

Nanotechnology has attracted attention for two main reasons, one is that by reducing the size of the material, the amount of material consumption is significantly reduced, and the other important feature is that by reducing the size below the critical size, new properties and quantum limits for materials are created. which changes the properties. Therefore, nanotechnology is defined as the ability to manipulate atoms to reach the desired goal, which is the desired properties. In this research, both properties of nanotechnology have been used, on the one hand, cobalt ferrite magnetic cores are used by reducing the size (reducing the amount of consumption). On the other hand, gold nanoparticles are used as a coating on magnetic cores, when the dimensions of gold nanoparticles are smaller than the critical dimensions, a very suitable photocatalytic property is created due to surface plasmon resonance, this phenomenon means that the conductivity of gold changes semi-conductive, which is very useful in destroying bacteria and pollutants. Cobalt ferrite is a common magnet from the inverse spinel family, which has received a lot of attention due to its cheap price. This ferrite is used as photocatalyst magnetic cores due to its very good magnetic properties, because by applying a magnetic field (strong magnet)) At the end of the water purification pond, the nano-photocatalysts are easily collected and there is no longer any danger to the health of water and the environment, and these catalysts can be reused in the new cycle of purification, which greatly lowers the costs of the purification operation. .

Since ancient times, gold has been considered as a metal that has attractive properties. In the industrial age, the four main metals of gold, platinum, palladium and gold are known as royal metals due to their extraordinary catalytic properties and low reactivity. Due to the high price of gold, this metal has been used in certain

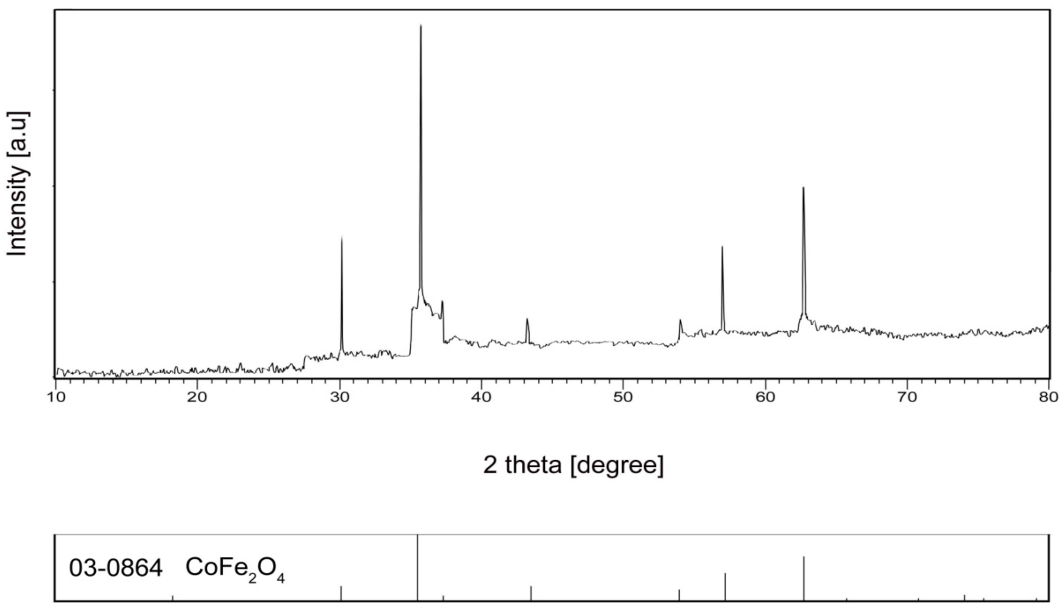

Fig. 1. XRD pattern of cobalt ferrite nanoparticles

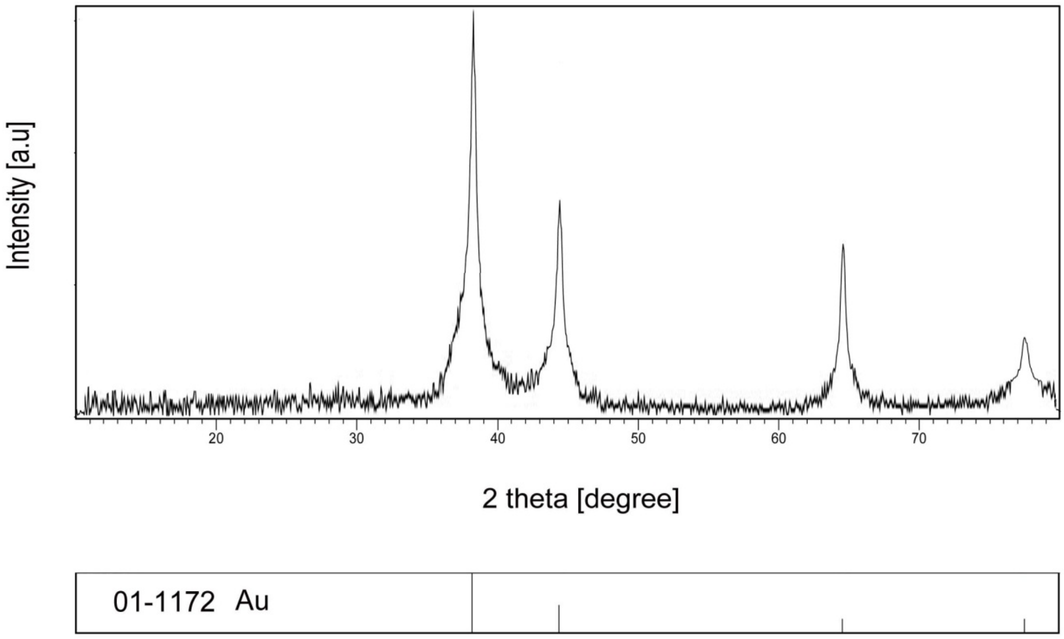

Fig. 2. XRD pattern of gold nanoparticles

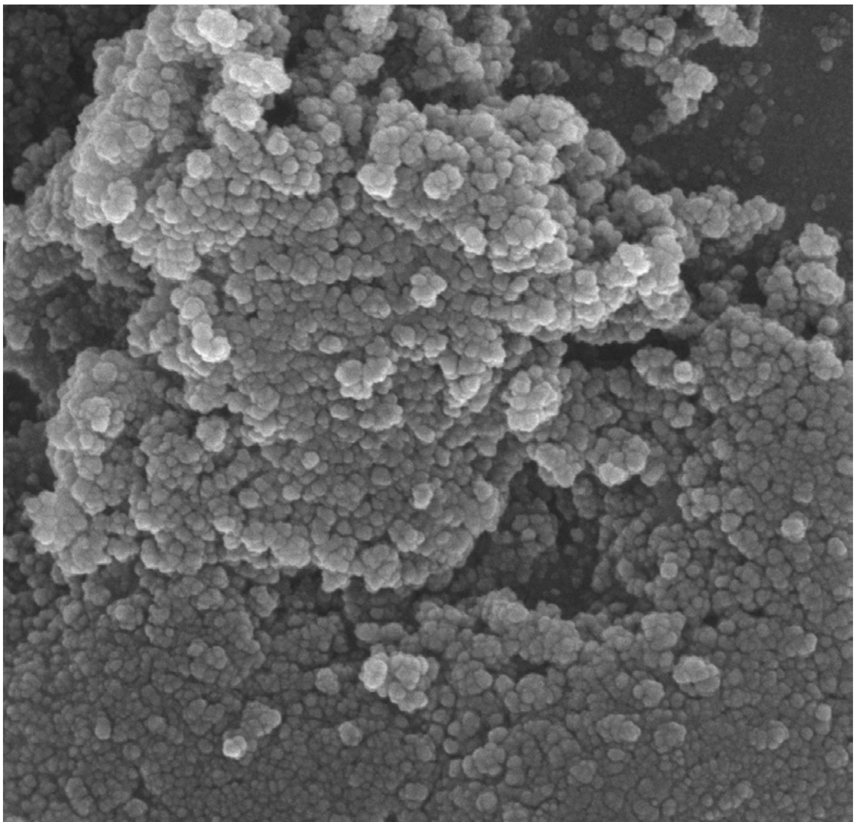

Fig. 3. SEM image of cobalt ferrite nanoparticles

situations, but nanotechnology has solved this problem by significantly reducing raw materials to a large extent [8-15].

In this work, cobalt-gold ferrite nanocomposite with magnetic and photocatalytic properties was synthesized and identified using ultrasonic method. In this project, an attempt has been made to use sunlight that contains small amounts of ultraviolet radiation (low risk and no cost) instead of using ultraviolet radiation, which is expensive and risky.

MATERIALS AND METHODS

Synthesis of cobalt ferrite-gold nanocomposite

First, 0.001 mole of cobalt nitrate (hexahydrate) and 0.002 mole of iron nitrate (hexahydrate) are dissolved in 200 ml of deionized water and placed under ultrasonic waves (400 watts) for

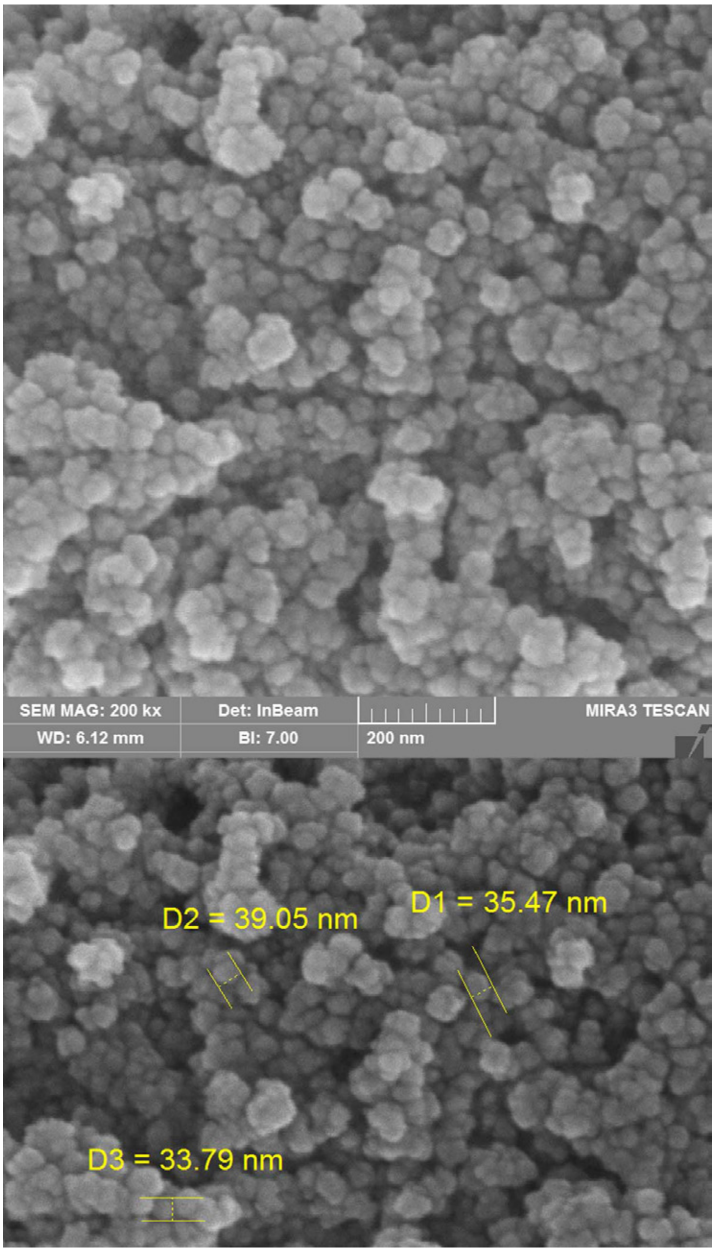

Fig. 4. SEM image of gold nanoparticles

60 minutes. At the same time, we use sodium hydroxide (one molar) as a sediment receiver. To adjust the temperature, we use a heater and heat the solution at 80 degree of Celsius for one hour. At the end of the reaction, the magnetic nanoparticles will be separated by centrifugation and washed with deionized water and acetone.

To synthesize the gold photocatalyst layer on cobalt ferrite, first, the synthesized and dried magnetic nanoparticles are weighed in the amount of one gram and dispersed in the deionized water solvent under nitrogen atmosphere by the super bath, then the gold chloride salt is dissolved in the solution. And we let them mix for two hours, so that the gold ions are properly absorbed on the surface of the cobalt ferrite. Then sodium citrate is first used as a capping agent and then sodium borohydride is used as a reducing agent. The resulting nanocomposite sediment is centrifuged and dried in that vacuum.

RESULTS AND DISCUSSION

Fig. 1 is related to the X-ray diffraction pattern, the pattern shows the presence of cobalt ferrite structure. Strong spades are a good match for Miller index with card number 03-0864. In X-ray scattering, a copper source is used as a cathode and X-ray supplier. The wavelength of the X-ray corresponds to the first fall of the first layer of copper, theta is equal to the Bragg angle and beta, the width at half the maximum peak. Also, the crystal size of cobalt ferrite was calculated to be 16nm. The type of crystalline phase, plate structure and purity of gold nanoparticles are also determined by XRD pattern in Fig. 2. Cubic structure (inverted spinel) Space group: Fd-3m is indicated by JCPDS code 01-1172.

Fig. 3 shows the scanning electron microscopy image of cobalt ferrite nanoparticles with a magnification of 100 thousand times at high voltage (10 kV), which confirms the formation of magnetic nanoparticles with an average particle size smaller than 70 nm. The manufactured magnetic nanoparticles have high saturation magnetization so the nanoparticles tend to attract each other and become lumpy. Transmission electron microscopy along with sample preparation will determine the exact size. Fig. 4 shows the scanning electron microscope images of gold nanoparticles with a particle diameter less than 40 nm.

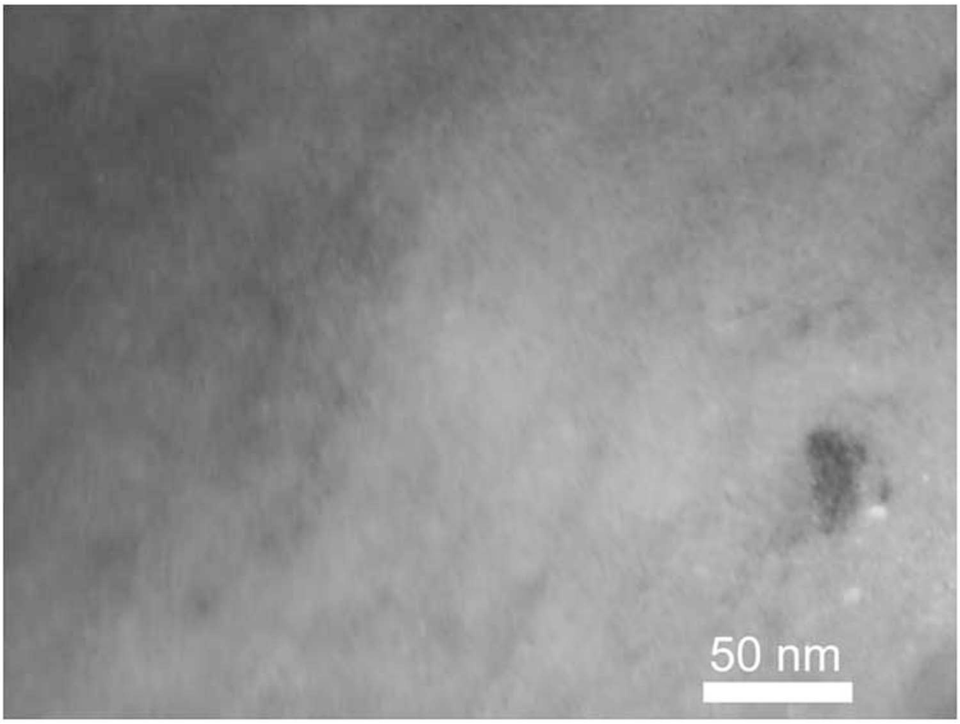

Fig. 5. TEM image of cobalt ferrite-gold nanocomposites

Synthesized gold nanoparticles do not need a conductive coating due to their high purity and proper conductivity, which indicates the controlled method of chemical synthesis, because in most cases, during the production of metal nanoparticles, due to the high surface to volume ratio and the reactivity of the metal. Transmission electron microscopy image (Fig. 5) confirm the synthesized cobalt-gold ferrite nanocomposite with a size of 80 nm.

Fig. 6 shows the UV-Vis absorption spectrum of cobalt-gold ferrite nanocomposite. It shows an absorption peak around 250 nm, which is attributed to the transitions of gold nanoparticles. According to the articles, the peak in the area of 350 is related to cobalt ferrite

The photocatalytic property of cobalt ferrite-gold nanocomposite was investigated by monitoring the degradation of aqueous solution of methyl orange and acid black 24 under ultraviolet irradiation (8 watt lamps). Azo dyes are very stable due to the resonance of aromatic rings with each other and nitrogen-nitrogen bonds, and they are not easily destroyed by sunlight, After one hours, less than 90% of the colors were destroyed under UV light and the use of cobalt-gold ferrite nanocomposite. Photo-degradation at 30 and 60 minutes are shown that confirm toxic

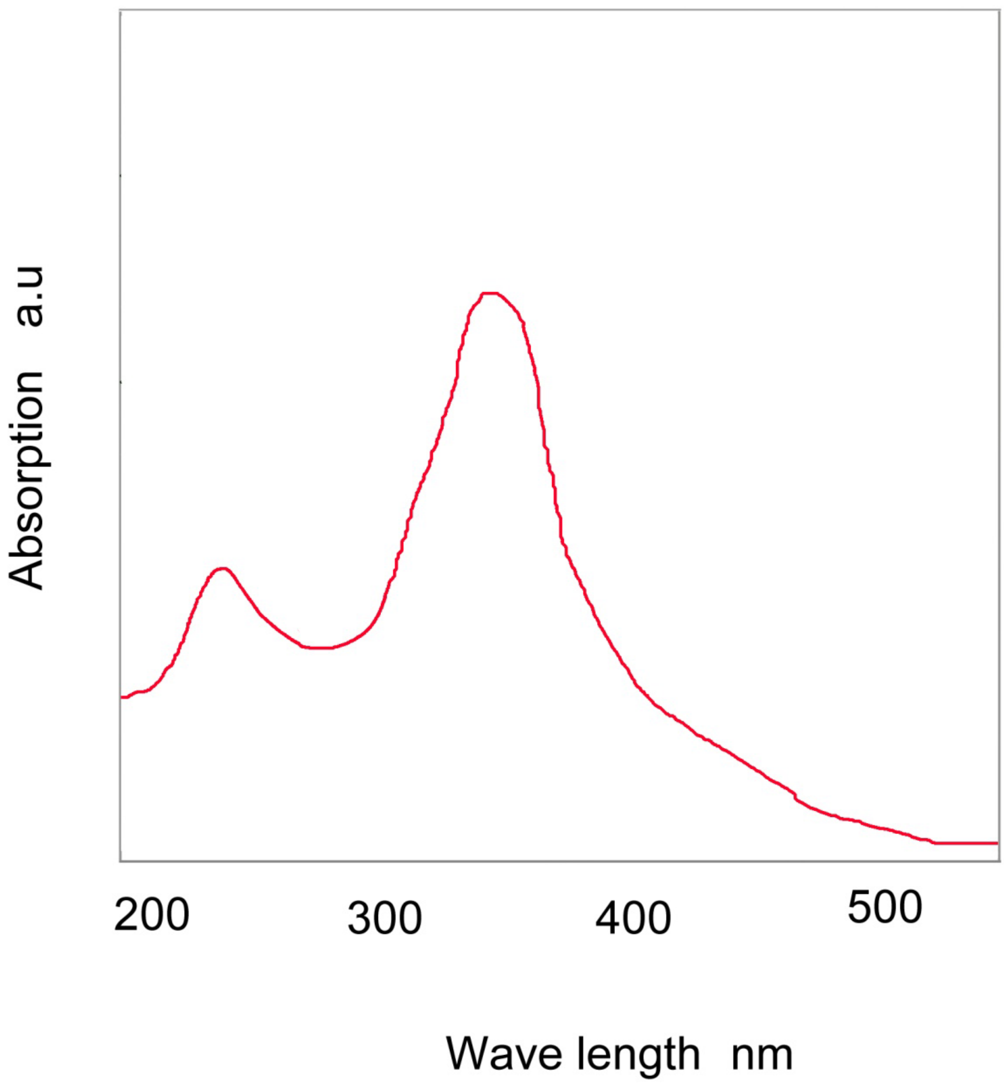

Fig. 6. UV-vis absorption of cobalt ferrite-gold nanocomposites

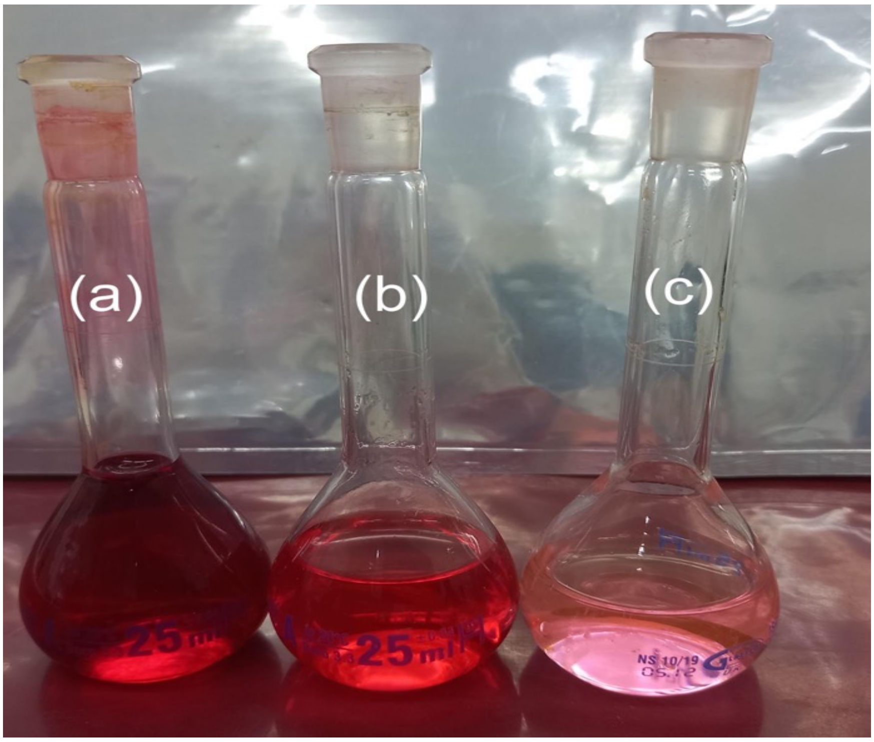

Fig. 7. Photo degradation of methyl orange under UV irradiation (a) 0 min (b) 30 min (c) 60 min

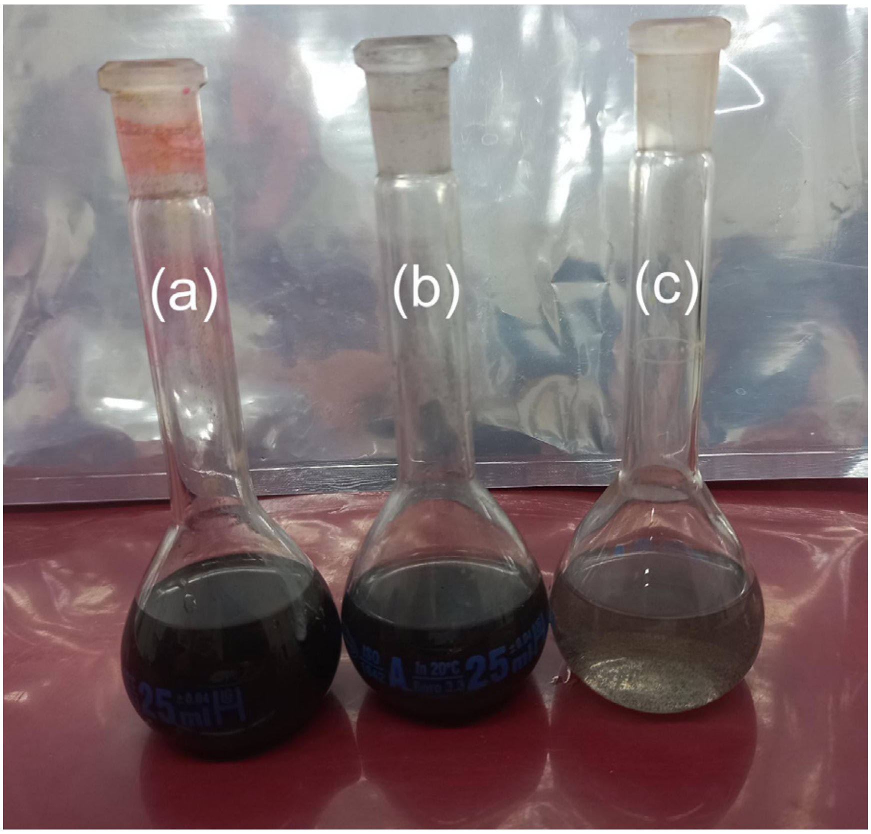

Fig. 8. Photo degradation of acid black under UV irradiation (a) 0 min (b) 30 min (c) 60 min

dyes (aromatics) are decomposed into harmless components of carbon dioxide and water (Figs. 7 and 8)

The magnetic properties were investigated using the vibrating sample magnetometer technique. The hysteresis loops of cobalt ferrite and its nanocomposite with gold are shown in Figs. 9 and 10, respectively. Magnetic cores have good magnetization, which makes them suitable for recyclable photocatalyst core. Ferrite

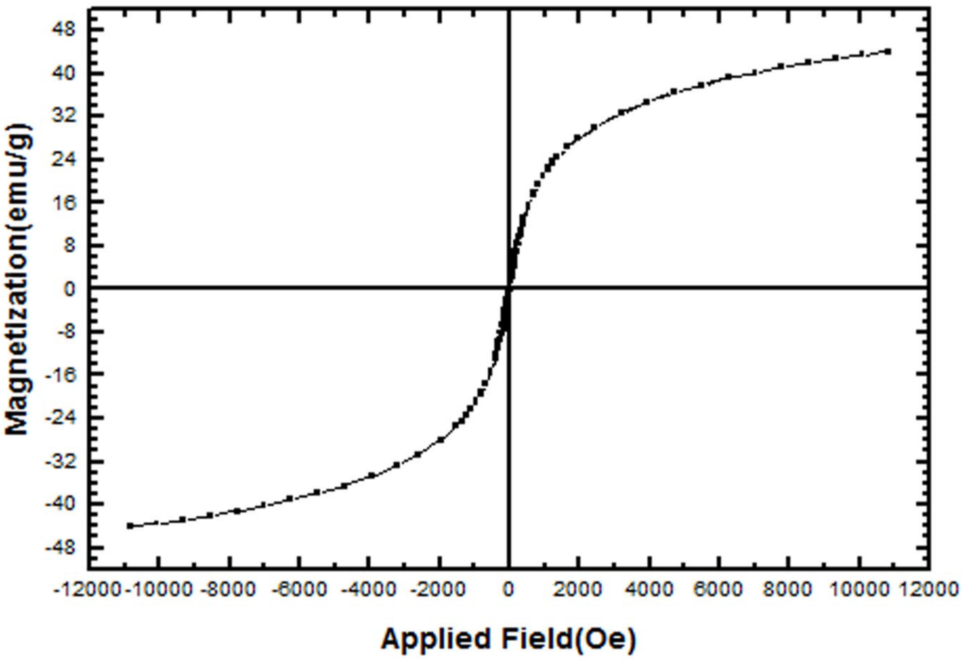

Fig. 9. VSM graph of cobalt ferrite nanoparticles

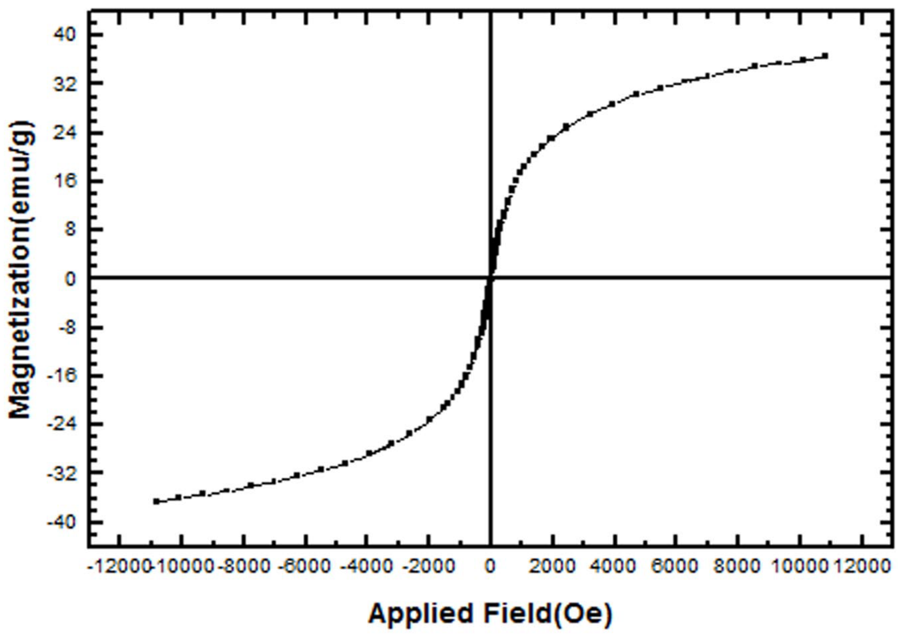

Fig. 10. VSM graph of cobalt ferrite-gold nanocomposite

nanoparticles show saturation magnetization of 44 emu/g and a coercivity of about 30 Orsted. The nanocomposite magnetic ring has a saturation magnetization of about 37 emu/g and a coercivity of about 50 Orsted. Magnetization is a quantitative quantity in nanocomposite, there is a non-magnetic gold coating, so the magnetization of nanocomposite is reduced compared to pure

Fig. 11. Disk diffusion test of cobal ferrite against staphylococcus aureus bacteria

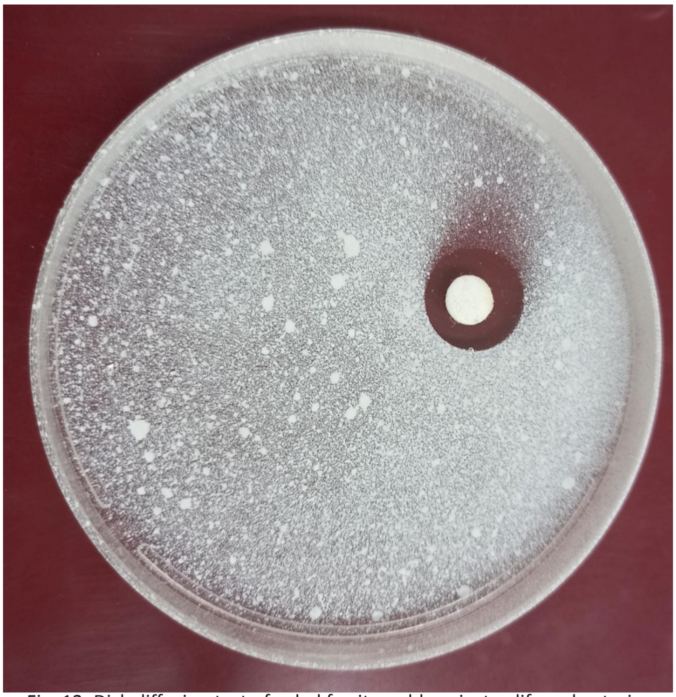

Fig. 12. Disk diffusion test of cobal ferrite-gold against coliform bacteria

cobalt ferrite. Also, the interaction between nanoparticles surrounded by gold was studied, this interaction leads to a increasing (from Oe 30 to Oe 50) of nanocomposite coercivity compared to pure ferrite nanoparticles.

The antibacterial test was performed by

Fig. 13. Disk diffusion test of cobal ferrite-gold against pseudomonas bacteria

Fig. 14. Disk diffusion test of cobal ferrite-gold against staphylococcus aureus bacteria

measuring the halo of non-growth in the disk penetration test. The test is done in such a way that three-mm discs are placed in nanoparticle fluids and then placed in medium. Then, pathogenic bacteria will be smeared on the agar and placed in an incubator for 24 to 48 hours to grow. After 48 hours, it can be seen that all the plates contain bacterial growth. At the same time, if the nanoparticles have antibacterial properties, around the disk we will see a halo of non-growth of bacteria (space empty of bacteria). Without applying gold no effective antibacterial were detected (Fig. 11). This test has been done for coliform, staphylococcus aureus and pseudomonas bacteria for synthetic materials and the results showed that nanocomposites will have good antibacterial properties for environmental effluents (Figs. 12-14).

CONCLUSION

In the first step, the magnetic core of cobalt ferrite with magnetization of 44 emu/g and magnetic coercivity of 30 Orsted was prepared. In the next step, gold nanoparticles are coated on the magnetic cores using the sono-chemical method. Then, photoactive, magnetic and antibacterial catalytic nanocomposites of cobalt-gold ferrite were successfully synthesized. Toxic and aromatic are destroyed in the presence of nanocomposites made of these dyes. Also, to control the non-growth and penetration of bacteria, the disk diffusion test was used against coliform, staphylococcus aureus and pseudomonas bacteria. Magnetic nanostructures are less dangerous due to their controllability. Therefore, the possible risks of entering the cell membrane and being uncontrollable are ruled out.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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