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Micro-emulsion synthesis of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ nanoparticles: effect of Cr doping on ferroelectric, dielectric and photocatalytic properties

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Abstract: In the present study, $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$) was synthesized by micro-emulsion route and characterized by X-ray Diffraction (XRD), Fourier Transform Infrared (FTIR), Scanning electron microscope (SEM), Energy-dispersive X-ray (EDX) techniques. The dielectric, ferroelectric and photocatalytic properties were investigated and compared with un-doped material. The XRD analysis revealed orthorhombic geometry of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$), Cr was doped successfully into the lattice structure of LaFeO_3 and particles were spherical and in agglomerated form. The grain sizes were recorded to be 15, 16.9, 17.1, 17.65 and 18.3 (nm) for $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$), respectively. EDX analysis confirmed the purity of LaCrFeO_3 samples. The lattice parameters, bulk density, X-ray density, crystalline size and porosity were determined were also determined of all the $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ samples. The dielectric constant and dielectric loss values decreased at higher frequency and Cr concentration affected the dielectric properties. The photocatalytic activity (PCA) was evaluated by degrading Congo Red (CR) dye under solar light irradiation and up to 85.43% dye degradation was achieved within 45 min of

irradiation. Phyto-toxicity analysis before and after dye degradation was performed, which revealed the toxicity reduction in response of dye degradation. Results revealed that lanthanum ferrite (perovskite) doping with Cr could possibly be employed to enhance the ferroelectric, dielectric and photocatalytic properties.

Keywords: dielectric properties; doping; lanthanum ferrite; micro-emulsion route; perovskite; photocatalytic activity.

1 Introduction

The perovskite materials have proven to be very effective energy materials for numerous electronic applications and nanotechnology offer various advantages to enhance the properties of the materials (Khomane and Kulkarni 2008; Sun and Kaliaguine 2016; Toledo et al. 2018). The distinctive properties of perovskites include long-range ambipolar charge transport, high-absorption coefficient, high dielectric constant, low exciton binding energy and ferroelectric properties, which have been used in optoelectronic and photovoltaic devices (Varma 2018). The perovskite oxides having composition of ABO_3 (A is the rare earth metal cation and B is the transition metal cation) form an important class of practical materials (Parrino et al. 2016). The perovskites oxides have wide advanced applications, i.e., in fuel cells, magnetic devices, photocatalysis and sensors (Ajmal et al. 2019; Bibi et al. 2019; Wang et al. 2006).

The LaFeO_3 perovskite with La as rare earth metal and Fe as transition metal is an important material due to their excellent physico-chemical properties (Peng et al. 2016). For instance, it is employed in solid oxide fuel cells as a catalyst and also in various devices owing to its high piezoelectricity and promising dielectric properties (Ismael and Wark 2019). Doped LaFeO_3 perovskites have gained much attention due to enhanced properties and doping of LaFeO_3 have been reported by many researchers and there is lack of studies reporting chromium as dopant in order to enhance the physico-chemical characteristics of LaFeO_3 perovskites using different techniques, i.e., hydrothermal,

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microwave combustion, sol-gel, thermal combustion, coprecipitation and electrospinning (Cheng et al. 2020; Choudhary, Uphade, and Pataskar 1999; Dhiman and Singhal 2019; Hu et al. 2019; Huang et al. 2020; Li et al. 2018; Lin et al. 2018; Lin et al. 2019; Omari, Omari, and Barkat 2018; Rezanezhad et al. 2020; Sukumar et al. 2019). A dopant is an impurity component which is inserted in the lattice to modify the properties of the materials. After doping, iron and chromium occupy the B-site of ABO_3 structure randomly (Pecchi et al. 2011). Report revealed that the micro-emulsion is not adopted for the synthesis of Cr doped LaFeO_3 (Table 1). The pollution and contamination due to the textile industry is alarming, which is increasing day by day. Textile industries generate huge volume of wastewater that contains dyes and other chemical auxiliaries, which are disposed into water bodies without treatment. It is necessary to deal the water pollution issue by treating the wastewater before discharging in to the water sheds (Iqbal et al. 2019). Different biological, chemical and physical techniques are in practice to treat the wastewater for the elimination of dyes and other contaminants (Alaqarbeh, Shammout, and Awwad 2020; Alasadi,

Khaili, and Awwad 2019; Albadarin et al. 2017; Alkheraz, Ali, and Elsherif 2020; Alqadami et al. 2016; Awwad, Amer, and Al-Aqarbeh 2020; Benabdallah et al. 2017; Daij, Bellebia, and Bengharez 2017; Djehaf et al. 2017; Minas, Chandravanshi, and Leta 2017; Naushad et al. 2019). Among these techniques, the photocatalytic treatment is efficient since it degrade the pollutant to harmless end product and there is no secondary pollution issue and the nanotechnology has emerged as a state-of-the-art for the fabrication of NPs, which have been utilized for the degradation of toxic pollutant in wastewater (Maruthamani et al. 2017; Naushad, Sharma, and Allothman 2019; Tatarchuk et al. 2019).

Keeping in view the above mentioned facts, $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$) perovskites were synthesized by micro-emulsion route. As-synthesized particles were characterized by X-ray Diffraction (XRD), Fourier Transform Infrared (FTIR), Scanning electron microscope (SEM), Energy-dispersive X-ray (EDX) techniques. The dielectric, ferroelectric and photocatalytic properties were also investigated. The photocatalytic activity was evaluated by degrading CR dye (Figure 1) under visible light irradiation.

Table 1: Reports on the doping of LaFeO_3 using different dopants via different synthesis routes and applications.

S. No	Perovskites	Route	Application	Reference
1	Nd–Mn doped LaFeO_3 @nitrogen-doped graphene oxide	Hydrothermal	Outstanding super-capacitor performance	(Rezanezhad et al. 2020)
2	Fe^{3+} doped $\text{La}_2\text{CuO}_4/\text{LaFeO}_3$	Microwave combustion	Excellent catalytic performance	(Sukumar et al. 2019)
3	Mg^{2+} and Ba^{2+} doped LaFeO_3	Sol-gel	Excellent catalytic performance with enhanced magnetic properties	(Lin et al. 2019)
4	Sr doped LaFeO_3	Sol-gel	Enhanced catalytic performance	(Cheng et al. 2020)
5	Phosphorus-doped $\text{LaFeO}_3 - \delta$	Thermal combustion	Remarkable electrocatalytic performance	(Li et al. 2018)
6	Co and Zn doped LaFeO_3	Sol-gel	Excellent electro-catalytic properties	(Omari, Omari, and Barkat 2018)
7	Europium, gadolinium, dysprosium and neodymium doped LaFeO_3	Sol-gel	Excellent photocatalytic activity	(Dhiman and Singhal 2019)
8	Mg doped LaFeO_3	Sol-gel	Enhanced magnetic properties	(Lin et al. 2018)
9	Sr doped LaFeO_3	Sol-gel	Enhanced magnetic and microwave absorption properties	(Huang et al. 2020)
10	Ca, Sr and Ba doped $\text{LaFeO}_3 - \delta$	Solution route	Remarkable electrocatalytic performance	(Hu et al. 2019)
11	Ag and Co doped LaFeO_3	Co-precipitation	Excellent photocatalytic activity	(Choudhary, Uphade, and Pataskar 1999)
12	Ca doped LaFeO_3	Amorphous citrate method	Excellent photocatalytic activity	(Pecchi et al. 2011)
13	In doped LaFeO_3	Electrospinning	Excellent sensing performances	(Zhang et al. 2019)
14	Cr doped LaFeO_3	Micro-emulsion route	Enhanced dielectric, ferroelectric and photocatalytic properties	Present study

Figure 1: Structure of congo red dye.

2 Material and methods

2.1 Synthesis procedure

The LaCrFeO_3 were prepared via micro-emulsion route. Solutions of respective metal salts were prepared by mixing stoichiometric amounts in de-ionized water. The prepared solutions were mixed and stirred along with heating. CTAB was used as surfactant and pH of the solutions was adjusted at 11–12 using ammonia solution. After adjusting pH, the solution was stirred for 6 h. The resulted precipitates were washed thoroughly several times using de-ionized water to neutral pH and then dried in oven at 80 °C and annealed at 950 °C for 7 h in the muffle furnace. The resulting product was characterized by X-ray Diffraction (XRD, Bruker D8 Advanced X-rays diffractometer Germany), Fourier Transform Infrared (FTIR, Nexus 470), Scanning electron microscope (SEM, JSM-6490 JEOL) and Energy-dispersive X-ray (EDX) techniques.

2.2 Photocatalytic activity (PCA) procedure

The PCA was evaluated by degrading CR dye under visible light. The dye solution 100 mL (5 mg/L) was mixed with catalyst (5 mg) and kept in dark for 15 min and eliminated to solar light (150 W Xe lamp). After stipulated time periods, sample (2 mL) was withdrawn and absorbance was measured at 497 nm and dye degradation was estimated using relation shown in Eq. (1). Where, A^0 and A are the absorbance before and after treatment, respectively

$$\text{Degradation (\%)} = \frac{A^0 - A}{A^0} \times 100 \quad (1)$$

2.3 Phyto-toxicity procedure

The phytotoxicity of treated and un-treated dye solution was evaluated by germinating seeds of *Triticum aestivum*. In order to evaluate the percentage germination, 12 healthy seeds were selected and grown in 5 mg/L dye solution in petri plates before and after treatment in triplicate. Four seeds were grown in each petri plates and kept at room temperature. The seed germination percentage was noted for both treatments.

3 Results and discussion

3.1 Characterization

XRD patterns of all the samples of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$) are shown in Figure 2. The diffraction

peaks match with standard pattern (JCPDS card 01-074-2203), which implies pbmn space group and 62 space group number and orthorhombic geometry of fabricated $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ samples (Jamil et al. 2016). The 2θ values were observed at 220, 250, 32.10, 34.10, 35.70, 390, 410, 460 were of (002), (111), (112), (021), (120), (022), (113), (004) crystal planes, respectively. The intensity of peaks was higher as the concentration of dopant was increased. The crystalline size of the particles was determined through Scherer's formula as shown in Eq. (2) (Aziz et al. 2016). The cell parameters (bulk-density, lattice constants, volume of cell, X-ray density, and crystalline size) were measured from XRD data.

$$D = K\lambda/\beta\cos\theta \quad (2)$$

where “ D ” is the crystalline size, “ K ” is the constant and its value is 0.94, “ λ ” is the wavelength ($\text{CuK}\alpha$), “ β ” is the full width at half maximum, “ θ ” is Bragg's angle of diffraction. The crystalline sizes for all samples were in the range of 15–18.1 nm. The lattice constants a , b , c were also estimated. The cell volume was calculated using relation shown in Eq. (3). The value of volume increases by increasing the concentration of Cr ions (Table 2).

$$V = a \times b \times c \quad (3)$$

Bulk density of prepared sample was determined as shown in Eq. (4). Where “ m ” is mass of the pellet, “ r ” is radius of the pellet, “ h ” is thickness of the pellet. The X-ray density was calculated using relation shown in Eq. (5), Where “ Z ” equals four for orthorhombic geometry (Aziz et al. 2016). The porosity was determined as shown in Eq. (6).

Figure 2: XRD pattern of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$).

Table 2: Cell parameters, volume, density and crystallite size of LaCrFeO_3 samples for different concentrations of Cr ions.

Parameters	$x = 0$	$x = 0.3$	$x = 0.6$	$x = 0.9$	$x = 1.0$
a ($\text{\AA}$)	5.55	5.68	5.58	5.63	5.61
b ($\text{\AA}$)	5.56	5.56	5.57	5.54	5.58
c ($\text{\AA}$)	7.86	7.89	7.86	7.85	7.85
Volume ($\text{\AA}^3$)	243.03	243.9	244.62	244.8	245.7
Bulk density (g cm^{-3})	4.93	4.44	4.37	4.36	3.73
X-ray density (g cm^{-3})	8.05	8.00	7.99	7.97	7.95
Porosity %	25	40	45	45.3	50
Crystalline size (nm)	15	16.9	17.1	17.65	18.3

$$\rho_m = m / \pi r^2 h \quad (4)$$

$$\rho_{\text{X-ray}} = ZM / N_A V_{\text{cell}} \quad (5)$$

$$P = 1 - \rho_m / \rho_{\text{X-ray}} \quad (6)$$

The bulk density of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$) decreased as the concentration of dopant (Cr ions) increased, which may be due to the porosity in the material (Chaudhari et al. 2013). X-ray density decreased and volume increased as the dopant amount was increased. The X-ray densities for all samples were higher versus bulk counterpart density, which revealed the existence of well-defined pores in the LaFeO_3 crystallites. Similar results were shown by $\text{Gd}_{1-x}\text{M}_x\text{CrO}_3$ NPs where $M = \text{La, Co, Bi}$ (Bibi et al. 2019). The range of porosity values are 25–50% (Table 2). The crystalline size is increased as the Cr concentration increased. It can be due to large grain growth of Cr doped LaFeO_3 particles (Mote, Dargad, and Dole 2013).

Figure 3 shows SEM images of LaFeCrO_3 . The particles were in agglomerated form with no sharp boundaries. There is imperfect alignment of grains, which is the specific feature of poly-crystalline material. The shape of individual particle was round with average size of 50 nm. EDX revealed that the composition of LaCrFeO_3 samples. Spectra show clear peaks of lanthanum, iron, chromium and oxygen. Cr, O, Fe and La weight percentages were recorded to be 4.95, 25.48, 28.65 and 40.92, respectively, which revealed that the LaCrFeO_3 was in pure form. Figure 4 shows the FTIR spectrum for the prepared LaCrFeO_3 samples. The FTIR spectrum exhibits well defined peaks for LaCrFeO_3 . The peaks in the range of 540–600 cm^{-1} are due to (Cr–O) (Durrani et al. 2012). The peak at 650 cm^{-1} was the characteristic peak of La_2O_3 (Vasudevan, Jothinathan, and Sozhan 2013). A weak signal near 930 cm^{-1} is indicating stretching vibrations of Fe–OH (Gil Posada and Hall

2016). The peak at 1505 cm^{-1} corresponds to vibrations of lanthanum carbonate (Idrees et al. 2015) and peak at 1598 cm^{-1} is due to stretching vibration of C–O bonds (Thuy and Minh 2012). The signal at 2313 cm^{-1} corresponds to the OH bending and stretching vibration of H_2O molecule. The peaks at 3609 cm^{-1} corresponds to the stretching and bending vibrations of La–OH bonds (Mishra and Prasad 2017).

3.2 Dielectric properties

The dielectric constant (ϵ_r) was determined using relation shown in Eq. (7).

$$\epsilon_r = C \times t / \epsilon_0 \times A. \quad (7)$$

Figure 3: SEM analysis of LaFeCrO_3 ($x = 1.0$). **Figure 4:** FTIR spectra of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3$).

where “ ϵ_r ” is the dielectric constant, “ C ” is capacitance, “ t ” is thickness of pellet, “ ϵ_o ” is free space permittivity, and “ A ” is the cross sectional area of pellet. The dielectric properties are depicted in Figures 5–8. The dielectric constant values were higher at lower frequencies and these values decreased as the frequency was increased (Figure 5). Figure 6 shows the variation in tangent loss versus frequency. The tangent loss values were low at lower frequency, which were increased with frequency and vice versa. This behavior of tangent loss (tany) can be attributed to the presence of conduction mechanism and polarization explained in the cases of dielectric constant and dielectric loss (Ajmal et al. 2019). The values of dielectric constant decreased sharply in the lower frequency region and decreased linearly in the higher frequency region. Same trend was observed for the dielectric loss (Figure 7) that was due to the exchange of electrons between the ions which is responsible for the electronic displacement that causes polarization (Bibi et al. 2019). It can be seen that the values of both dielectric loss and dielectric constant are higher when the dopant concentration was = 1.0. It is normal that the values of dielectric constant (ϵ_r) and dielectric loss decreased by increasing the frequency. The higher values of dielectric constant (ϵ_r) in low frequency region are due to polarizations (space charge, orientational, electronic and ionic polarization). The dielectric constant lower values in the high frequency region are probably due to the loss of any of these polarization (Bibi et al. 2019). The contribution of space charge polarization relies on the purity of the sample. The space charge polarization has great impact at the lower frequencies. Since the dielectric constant has higher values at low frequencies, it may be due to the defects in crystal lattice and space charge polarization (Majid et al. 2019). When the frequencies was increased, at certain limit the space charge polarization did not carry on and act in accordance with the externally applied field. At this point, space charge polarization decreased as frequency was increased and the values of dielectric loss and dielectric constant are diminished (Arputha Latha et al. 2017). Maxwell Wagner model and Koop’s theory explains the causes of dielectric loss and dielectric constant. The decline in the dielectric constant is also due to the externally applied field when electric moment is induced in the dielectric material. When high frequency region is reached, induced electric moment and exchange of electrons between Fe^{+2} and Fe^{+3} ions cannot harmonize with the applied field and charge carriers did not synchronize with external field and values of dielectric constant are decreased (Ajmal et al. 2019; Bibi et al. 2019). The high values of dielectric loss in the low frequency region are also

attributed to the grain boundaries. This can also be due to the fact that high energy is required for the exchange of electrons in Fe^{+2} and Fe^{+3} ions. At higher frequency, the exchange of electrons between ions is easy, that is why, small amount of energy is enough for electronic exchange and dielectric loss values are low in the higher frequency region. Table 3 shows the values of dielectric constant, dielectric loss and tangent loss at frequency 1.3 Hz. Figure 8 shows the value of dielectric constant as a function of Cr concentration, which an increment in the resistivity of LaCrFeO_3 . The decrease in dielectric constant and increase in resistivity revealed that the LaCrFeO_3 samples are useful in fabricating microwave devices (Aziz et al. 2016).

3.3 Ferroelectric properties

The polarization electric hysteresis loops were investigated for the doped and un-doped samples. The polarization saturation was high of the sample where doping of Cr ($x = 1.0$) was higher (Figure 9). Results revealed that the prepared samples were ferroelectric in nature and the values of polarization saturation were variable among samples, which indicates that Cr doping affected the ferroelectric property of LaCrFeO_3 . The hysteresis loops shows that, as the concentration of Cr increased, the polarization saturation value was also increased. This enhancement in the polarization is useful for energy storage materials (Rahman, Hossain, and Radford 2017). There is also a variation in the area of the hysteresis loops. As the concentration of Cr was increased, the loops became wider indicating that they retain a greater fraction of saturation field when the applied field drops

Figure 5: Graph between $\log f$ and dielectric constant of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$).

Figure 6: Graph between $\log f$ and tangent loss of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$).

Figure 7: Graph between $\log f$ and dielectric loss of $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 0.0, 0.3, 0.6, 0.9, 1.0$).

to zero. The ferro-electric property makes the fabricated NPs useful in making multi-layered capacitors, liquid crystal displays and information storage devices. In liquid crystal displays, ferro-electric material can transform the fundamental properties of liquid crystal materials devoid of costly production. Ferro-electric materials have potential to modify the properties of liquid crystals on the improvement of electro-optical, optical and non-linear optical responses of such materials. These reformed materials are very remarkable and appropriate to use in switchable lenses, displays and tunable filters (Garbovskiy, Zribi, and Glushchenko 2012).

Figure 8: Graph between Cr concentration and dielectric constant.

Table 3: Dielectric constant, dielectric loss and tangent loss of LaCrFeO_3 .

Parameters	$x = 0$	$x = 0.3$	$x = 0.6$	$x = 0.9$	$x = 1.0$
Dielectric constant	75	152.8	696.4	46253.9	130095.8
Dielectric loss	137	256.7	497.3	27,970	78672.2
Tangent loss	0.60	0.604	0.7	1.67	1.81

3.4 Photocatalytic activity

To check the PCA of LaCrFeO_3 , CR dye was degraded under visible light irradiation. The effluents from textile industry are discharged in to rivers, which contains dyes i.e., paper, leather, chemical fiber, food, drugs, and cosmetics industries, which induced toxic effect to the living organisms (Djehaf et al. 2017; Igbanoi, Ihunda, and Iwuoha 2019; Iqbal et al. 2019; Iwuoha and Akinseye 2019) and LaCrFeO_3 was used for the degradation of CR textile dye under visible light irradiation and response is shown in Figure 10. The percentage dye degradation was 85.43% within 45 min of irradiation. The CR dye degradation mechanism is shown in Figure 11. Catalytic sites are activated at the surface of catalyst by exposing it to light. The electrons are transferred from VB to CB and a hole is generated that converts water molecule in to hydroxyl radical (OH). The hydroxyl radical is a strong oxidizing agent which oxidizes dye molecule low molecular weight by-products. Conversely, the oxygen (O_2) scavenges the electron and

Figure 9: (A) Polarization electric loop for sample 1 ($x = 0$), (B) polarization electric loop for sample 2 ($x = 0.3$), (C) polarization electric loop for sample 3 ($x = 0.6$), (D) polarization electric loop for sample 4 ($x = 0.9$) and (E) polarization electric loop for sample 5 ($x = 1.0$).

transformed to a superoxide anionic radical (O_2^-) which is protonated generating HO_2 radical and finally, H_2O_2 . The H_2O_2 is also dissociated into OH radicals, which are highly reactive and cause degradation of dye molecules (Manikandan et al. 2014; Manikandan, Durka, and Antony 2015; Maruthamani et al. 2017; Naushad, Sharma, and Alothman 2019). The recycling, reusability and stability LaCrFeO_3 was investigated up to five repeated cycles. For this, one batch was run and catalysts was separated by filtration and dried at 60°C for 3 h the dried catalyst again mixed with dye solution and second cycle was run, which was repeated up to five cycles and results are depicted in Figure 12. The catalytic activity of LaCrFeO_3 reduced slightly for first three cycles and it was decreased to 73.25% after five cycles,

which indicate the stable nature of LaCrFeO_3 . The bio-efficiency of PCA was evaluated by germinating *T. aestivum* seeds in treated and un-treated dye solution. The germination percentage increased significantly when seeds were grown in treated dye solution (Figure 13). The treated solution of dye showed 98% seed germination with only 2% germination inhibition. These findings revealed that the LaCrFeO_3 is highly active catalyst and could possibly be used for treatment of textile wastewater contains dyes.

4 Conclusions

$\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ was successfully prepared by micro-emulsion route, which were confirmed by advanced characterization techniques. The $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ revealed the orthorhombic geometry and successful doping of Cr metal into the structure of LaCrFeO_3 was observed, which were

Figure 12: Reusability and recycling study of LaCrFeO_3 for the degradation of CR dye.

Figure 10: UV-VIS spectrum for the degradation of CR dye using $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 1.0$).

Figure 11: Photo-degradation mechanism of congo-red dye using $\text{La}_{1-x}\text{Cr}_x\text{FeO}_3$ ($x = 1.0$).

Figure 13: Wheat seeds germination in treated (B) and un-treated CR dye solutions (A).

round in shape and in aggregates form. The Cr concentration significantly affected the magnetic properties (dielectric constant, dielectric loss and tangent loss) as well as ferroelectric property of LaCrFeO_3 . The PCA of LaCrFeO_3 was also promising for the degradation of CR dye and up to 85.43% degradation was achieved within 45 min irradiation. The phytotoxicity analysis confirmed the promising bio-efficiency of LaCrFeO_3 as a photocatalyst since phytotoxicity was reduced after treatment. The Cr doping significantly affected the magnetic, ferroelectric and catalytic properties of LaFeO_3 , which could be useful for the preparation of LaCrFeO_3 for practical applications.

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