

## One-pot synthesis of 1,2,4,5-tetrasubstituted Imidazoles using BiFeO<sub>3</sub> perovskite-type oxide

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### ABSTRACT

The BiFeO<sub>3</sub> perovskite-type oxide was synthesized using the citrate gel method and the catalytic activity of the BiFeO<sub>3</sub> was assessed in a multicomponent reaction of benzil, an aromatic aldehyde, and an amine in the presence of ammonium acetate under solvent-free conditions. The physical and chemical properties of the catalyst were determined using X-ray diffraction, Fourier transform infrared spectroscopy, scanning electron microscopy, and Energy dispersive X-ray spectroscopy and Imidazole products were identified by comparing their melting points with already reported papers. SEM illustrated a smooth surface with a uniform morphology for the catalyst. Meanwhile, XRD indicates two phases of BiFeO<sub>3</sub> and Bi<sub>2</sub>Fe<sub>4</sub>O<sub>9</sub> at the same time. Moreover, IR and EDS both showed the absence of any impurities in the mentioned catalyst. The experimental data revealed excellent catalytic performance for BiFeO<sub>3</sub> in absence of any solvents. Therefore, BiFeO<sub>3</sub> can be used as an efficient and green catalyst for the synthesis of 1,2,4,5-tetrasubstituted Imidazoles.

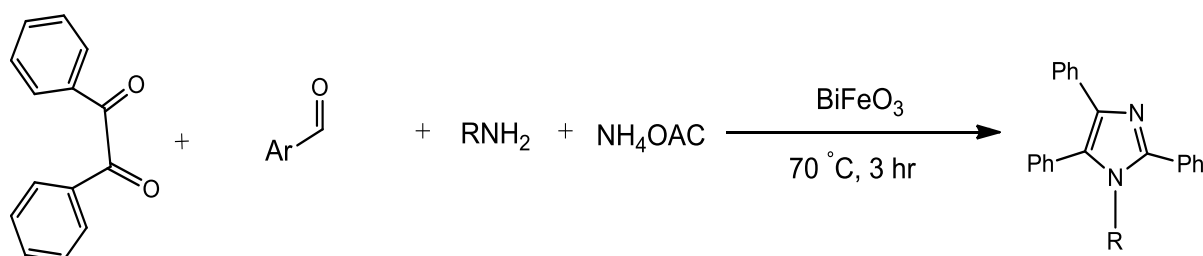
**Keywords:** BiFeO<sub>3</sub>; Multicomponent reactions; Perovskites.

## 1. Introduction

Imidazole family are among well-known classes of heterocyclic compounds with immense potential in the field of chemistry, biology and medicine [1-5]. These scaffolds are existed in the biological systems such as Losartan and Olmesartan. These attributes makes them more attractive for the scientific studies. However in the field of organic chemistry, thus far, only few routes are available to synthesize them. Hence, more attention was paid to enhancing the existing methods using different catalytic systems rather than coming up with new synthesis methods.

The perovskite-type oxide materials (POMs) with the general formula of  $ABO_3$  are one of the most studied metal oxide families due to their diverse applications [6-9]. Over the years POMs were applied in rather some unique fields; from waste water treatment applications to catalysis, gas separation, solar cells, and sensors. POMs have also illustrated high catalytic activities in the several organic reactions, such as oxidation, reduction, and cross coupling reactions.

It would seem that combination of POMs and MCR could kindle sparks of new scientific ideas. Therefore, in this work synthesis and catalytic activity of  $BiFeO_3$  for the reaction of benzil, an aromatic aldehyde and an amine in the presence of ammonium acetate was reported (Scheme 1).



**Scheme 1.** Synthesis of 1,2,4,5-tetrasubstituted Imidazoles.

## 2. Experimental

### 2.1. Chemicals and Characterization

All chemical were obtained from Aldrich or Merck and were used without further purifications unless otherwise stated. The FT-IR spectra were recorded on a Perkin-Elmer BX-II IR spectrometer. The crystalline structures were analyzed by X-ray diffraction (XRD, X'Pert Pro MPD, PANalytical) using Cu K $\alpha$  radiation (40 kV and 40 mA). Scanning electron microscope (SEM) model VEGA\\TESCAN-XMU instrument and operated at 20 kV. The melting points of products were determined with an Electrothermal 9200 melting point apparatus.

### 2.2. General procedure for synthesis of BiFeO<sub>3</sub>

BiFeO<sub>3</sub> (BFO) was prepared using the citrate-gel method. Citric acid was added to an aqueous solution of Bi(NO<sub>3</sub>)<sub>3</sub>.5H<sub>2</sub>O and Fe(NO<sub>3</sub>)<sub>3</sub>.9H<sub>2</sub>O, with molar ratio of (Bi:Fe:Acid, 1:1:10). The mixture was continuously stirred for 2 h under reflux condition. After completion of the reaction, the solvent was evaporated to produce a gel. A dry gel was obtained by placing the sol in an oven at 383 K for 8 h. The gel was ground in an agate mortar to give a powder. Finally, the powder was calcined in air at 923 K for 8 h with a heating rate of 1 K min<sup>-1</sup> to obtain brown powder.

### 2.3. General procedure for the synthesis of 1,2,4,5-tetrasubstituted imidazoles:

Benzil (1 mmol), amine (1 mmol), aldehyde (1 mmol), ammonium acetate (1 mmol) and catalyst (5% w/w) were mixed together. The reactants were heated at 70 °C for 3 h (Table 2). The progress of the reaction was followed by TLC. After completion of the reaction, the mixture was cooled to room temperature. Chloroform was added to the mixture which was filtered to remove the catalyst. After evaporation of the solvent, an oily residue or an impure solid was obtained. By adding ethanol and water to the residue, a milky to yellow solid was

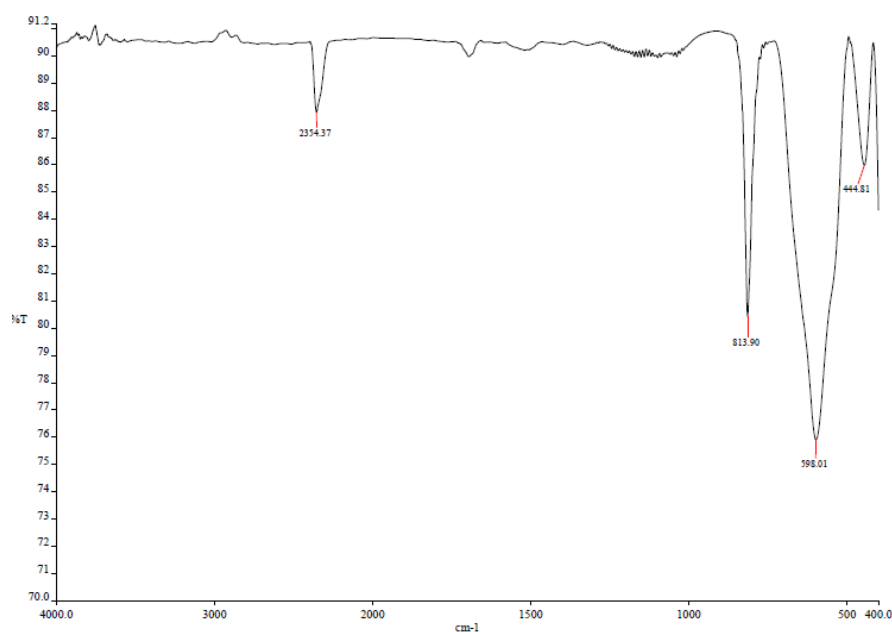
obtained. The solid was then crystallized from ethanol. All the products are known and were identified by comparison of their physical and spectral data with those of authentic samples.

### 3. Results and discussion

#### 3.1. Catalyst characterization

##### 3.1.1. FTIR studies

Fig. 1 shows FTIR spectra for the catalyst. The catalyst sample shows signals at 446, 560 and 814  $\text{cm}^{-1}$ . The signals at 446 and 814  $\text{cm}^{-1}$  are attributed to the Fe-O stretching vibration, and the signal at 560  $\text{cm}^{-1}$  is attributed to the Fe-O-Fe bending vibration.



**Fig. 1.** FTIR of BiFeO<sub>3</sub>

##### 3.1.2. XRD studies

The quality and structural ordering of synthesized materials were identified by powder X-ray diffraction. Fig. 2 shows wide-angle XRD patterns of catalyst. XRD analysis of catalyst shows BiFeO<sub>3</sub> and Bi<sub>2</sub>Fe<sub>4</sub>O<sub>9</sub> phases are co-existent at the same time without any impurities. All the signals were identified and assigned based on their correspondent standard JCPDS cards.

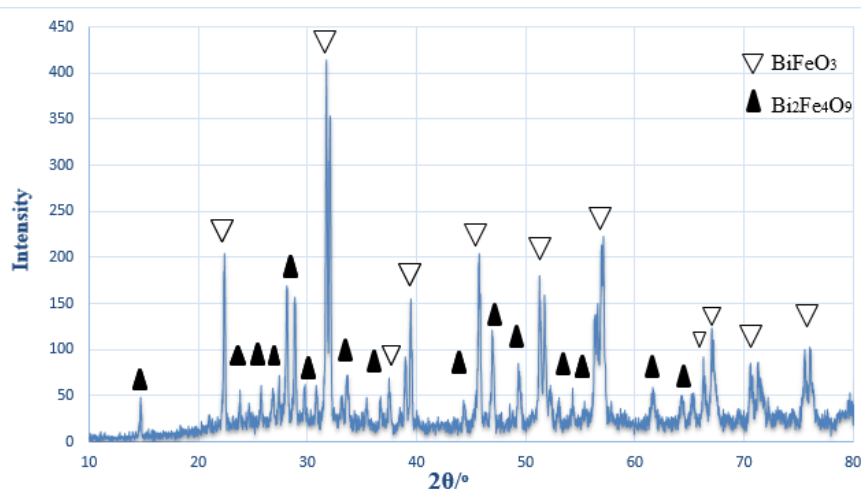


Fig. 2. Wide-angle XRD patterns of  $\text{BiFeO}_3$ .

### 3.1.3. Morphology analysis of catalyst

SEM has been applied to explore the surface morphology of the catalyst (Fig. 3). SEM images of catalyst show that the structures are somewhat of uniform rock-shaped with narrow diameter distribution. The EDX analysis (is not shown here) was performed alongside SEM which showed the presence of Bi, Fe, O. Both EDX analysis and FTIR spectra confirmed the absence of any impurities in the catalyst.

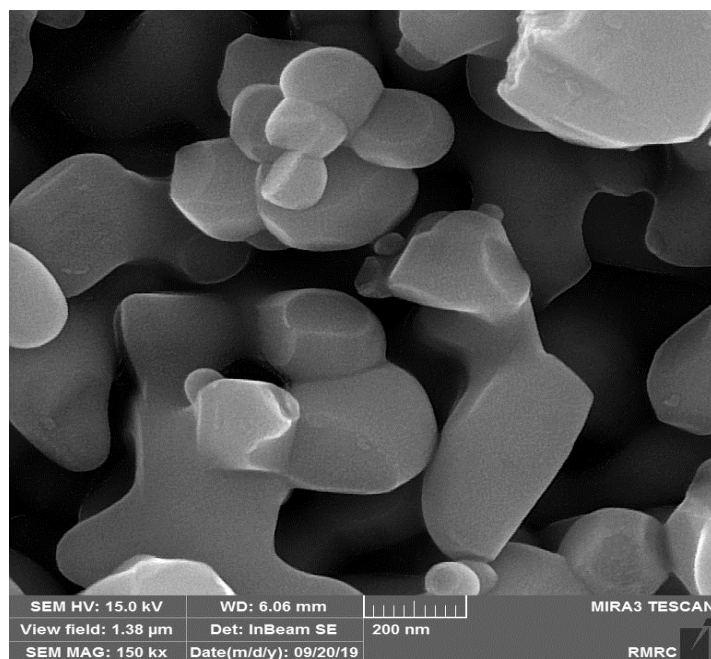


Fig. 3. SEM image of  $\text{BiFeO}_3$ .

### 3.2. Catalytic assessment

To evaluate the catalytic performance of  $\text{BiFeO}_3$  as a Lewis acid, the reaction of benzil, an aromatic aldehyde and an amine in the presence of ammonium acetate was carried out under solvent-free conditions (Scheme 1). Initially, to show the effectiveness of the catalyst, the model reaction was studied once without the use of any catalyst, and afterward with introduction of the catalyst into the reaction. In the absence of catalyst formation of final product was not observed (Table 1, entry 1). On the contrary, with addition of catalyst to the reaction system the product was obtained. To investigate the role of solvent on the catalytic activity of the  $\text{BiFeO}_3$ , the model reaction was carried out in the presence of  $\text{H}_2\text{O}$  and  $\text{EtOH}$ . The results show that the use of solvent did not improve the product yield nor the reaction time. Next, the model reaction was carried out in the various temperatures, as can be seen from Table 1 the yield increases by increasing the temperature from r.t, however rising the temperature above the  $70^\circ\text{C}$  did not improve the reaction time to a greater extent. In order to achieve desirable catalyst loading, different amounts of  $\text{BiFeO}_3$  loading was studied (1, 2, 5 and 10% w/w). The best result was obtained by using 5 % w/w of  $\text{BiFeO}_3$ . The scope and limitations of this reaction was studied by performing the reactions of various derivatives, the results are summarized in the Table 2.

**Table 1.** Optimization of the reaction condition for the synthesis of 1,2,4,5-tetrasubstituted Imidazoles.

Entry	Catalyst	Solvent	Catalyst loading (% w/w)	Temperature (°C)	Time (hr)	Yieldb (%)
1	-	-	-	50	5	Trace
2	BiFeO3	-	5	r.t	5	50
3	BiFeO3	-	5	50	5	42
4	BiFeO3	-	5	70	3	90
5	BiFeO3	-	5	90	3	79
7	BiFeO3	EtOH	5	Reflux	24	73
8	BiFeO3	H2O	5	Reflux	24	Trace
9	BiFeO3	-	1	70	3	51
10	BiFeO3	-	2	70	3	82
12	BiFeO3	-	10	70	3	90

**Table 2.** Synthesis of 1,2,4,5-tetrasubstituted Imidazoles in the presence of a catalytic amounts of BiFeO<sub>3</sub>.

Entry	Ar	R	Yield* (%)	mp (°C)	Ref.
1	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>	90	217	10
2	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	93	164	10
3	C <sub>6</sub> H <sub>5</sub>	Cyclohexyl	80	169	10
4	C <sub>6</sub> H <sub>5</sub>	CH <sub>3</sub> CH <sub>2</sub>	91	116	10
5	4-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>	92	149	10
6	4-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	95	163	10
7	2-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	89	140	10
8	4-HOC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>	90	282	10
9	4-HOC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	86	133	10
10	4-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>	96	187	10

As an eco-friendly methodology, the reusability of the catalyst was investigated by consecutively recovering and then reusing it up to five times. After completion of the reaction

the catalyst was separated by filtration and was washed with  $\text{CH}_2\text{Cl}_2$  ( $3 \times 5$  mL) and subsequently dried at  $50^\circ\text{C}$  to be reused (Table 3).

**Table 3.** Reusability of catalyst.

No. of runs	Yield (%)
1	90
2	88
3	83
4	80
5	78

#### 4. Conclusions

In the present study  $\text{BiFeO}_3$  was synthesized and was characterized by FT-IR, XRD, EDS, and SEM. Furthermore catalytic activity of the catalyst was successfully evaluated in the preparation of 1,2,4,5-tetrasubstituted Imidazole derivatives. Green chemistry, high yield and reusability of the catalyst are some of features of this method.

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