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RESEARCH ARTICLE

The use of unmanned aerial vehicles in the detection of forest fires with a gas detection technique

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HIGHLIGHTS

> It is aimed at bringing a new and more precise perspective based on visuals to forest fire early detection systems.
> The ability to detect CO and CO_2 gas, which is the earliest sign of fire diagnosis, has been added to the unmanned aerial vehicle.
> Metal oxide CO_2 detector was produced by screen printing technique in order to detect the CO_2 gas.

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ABSTRACT

Unmanned Aerial Vehicles (UAV) are used in many applications such as forest fire, atmosphere research, ocean observations, geological surveys, weather forecasting, and especially in military applications. While designing Unmanned Aerial Vehicles, which are generally used for reconnaissance, surveillance and operational purposes, in addition to performance and efficiency increasing studies, today researches are also conducted on which type of aircraft is most suitable for what type of mission.

In this study, it is aimed at bringing a new and more precise perspective based on visuals to forest fire early detection systems. In this period, since the number of systems used for utilizing unmanned aerial vehicles technology is increasing day by day, it would be appropriate to use unmanned aerial vehicles with perception capability to minimize the destruction of forests, which are the lungs of the world, except for the natural flow, and to manage the workforce and time resources in the best way.

In this study, metal oxide CO_2 detector was produced by screen printing technique to detect the CO_2 gas from the sensors to observe and made the necessary controls in case of a fire in the areas that can be reached or not reached by the UAV.

1. Introduction

UAV is a kind of aircraft with no pilot and no passengers, carrying only the equipment suitable for the purpose (video camera, camera, global navigation satellite system, laser scanning device, etc.) to perform its task remotely and/or automatically [1].

Unmanned aerial vehicles are increasing in importance and are mentioned in more areas. The success of the tasks they are assigned and expected to perform depends on their best performance. In this context, the place of unmanned aerial vehicles in aircraft design is increasing [2].

UAV is used in many applications such as forest fire, atmosphere research, ocean observations, geological surveys, weather forecasting, especially in military applications [3].

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Today, while designing the UAV, which is generally used for reconnaissance, surveillance and operational purposes, studies are carried out to increase the performance and efficiency. Also, some researches which type of aircraft is most suitable for what kind of mission [4].

The history of UAV started with the construction of air balloons and their use for various purposes, and with the developments in aircraft technology in the following years, it took the form of unmanned aircraft and today's modern unmanned aerial aircraft were produced. Initially, its use for military purposes came to the fore, then it is used for various purposes in meteorological studies and now in many civilian areas including agriculture. UAVs are classified according to altitude and flight range or according to their wing structures and are used in a wide variety of fields, both military and civilian [5].

While forests are of vital importance for the protection of soil and water and for the survival of all living things, forest fires are seen as the biggest threat to these resources. Air temperature, relative humidity, precipitation, wind direction and speed, etc., are effective in the formation of forest fires. Since it is important, risky areas can be determined by following these data [6].

In this study, it is aimed to monitor the fires from the air with UAV and to detect and extinguish fires at an early stage. The ability to detect carbon monoxide (CO) and carbon dioxide (CO_2) gas, which is the earliest sign of fire diagnosis, has been added to unmanned aerial vehicle. The most basic problem in common algorithms used in fire detection is the high rate of false notification and oversight. Confirming the result extracted from the image taken and defining an extra verification step will increase the reliability of the system and guarantee the accuracy of the result. Thanks to the mobile vision of the unmanned aerial vehicle, the viewpoint will be controlled by the control point, where the data can be taken from the place, clearly and continuously.

Metal oxide CO_2 detector was produced by screen printing technique in order to detect the CO_2 gas from the sensors required in order to observe and make the necessary controls in case of a fire in the areas that can be reached or not reached by the UAV used in this study.

The necessity of choosing economical and effective production methods was taken into consideration as the purpose of choosing the screen-printing technique as the sensor construction technique. Screen printing technique allows synthesizing and converting the smallest possible size films into gas detectors for gas detector applications. In addition to being one of the most economical methods for the production of gas sensor components, the screen-printing technique has several advantages such as the production of semiconductor oxide structures with excellent homogeneity and the addition of high purity additives.

2. Materials and Methods

2.1. Screen-Printing Technique

A thick film gas detector consists of three main components. These are the heater, the electrode and the sensitive layer.

While applying this technique, at each stage (heater, electrode and sensitive layer construction), the selected material is screen-printed on the substrate and the heat treatment of the created structure is performed.

In the fabrication of the CO_2 thick film gas detector made within the scope of this study, the screen-printing method was used and the planar structure of the thick film to be produced is given in Figure 1.

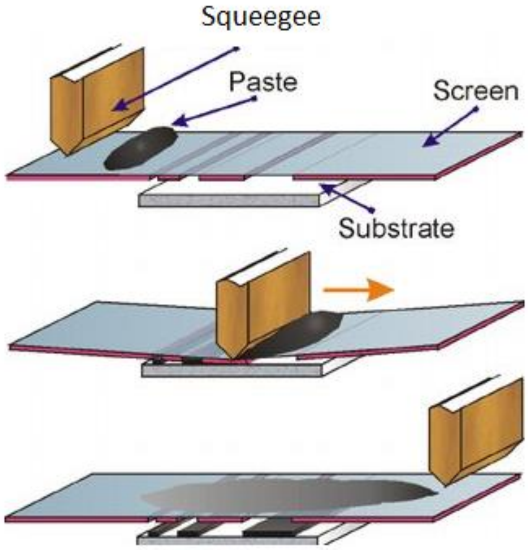

Figure 1. The basic screen-printing process

The order of application in the screen-printing process is as follows [7];

• Screen printing of the heater on the substrate and heat treatment of this layer

• Screen printing of the insulation layer and heat treatment of this layer

• Screen printing of electrodes on the substrate and heat treatment of this layer

• Screen printing of the active layer on the substrate and heat treatment of this layer

2.2. Mask

A crucial part of screen-printing equipment, the mask identifies the pattern of the printed film and also measures the amount of paste that is planned to be passed on to the underside.

The selection of a suitable mesh number for a mask is a very important criterion. The mesh itself is usually based on a flat mesh pattern as shown in Figure 2 [7].

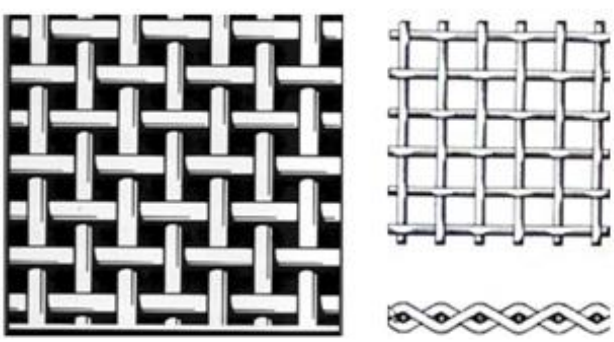

Figure 2. Flat pattern mesh for a typical thick film screen.

The selection of a suitable mesh number for a mask is a very important criterion. The type of paste used and the model to be applied are factors that may affect this choice. A typical mesh number for general purpose work is around 200 threads per inch.

It is possible to obtain the screen mesh aligned in several orientations, the most common three mesh angles are 22.5°, 45°, and 90°.

Many screen manufacturers apply the emulsion by hand coating, a skilled process which can accurately produce a standard range of thicknesses (typically between 5 to 25 μm). The specifications of screens such as mesh count, mesh angle, tension, emulsion thickness, and size of frame normally comes with a label attached to the rear of the screen.

Figure 3 shows the mask used in the preparation of the active layer in this study.

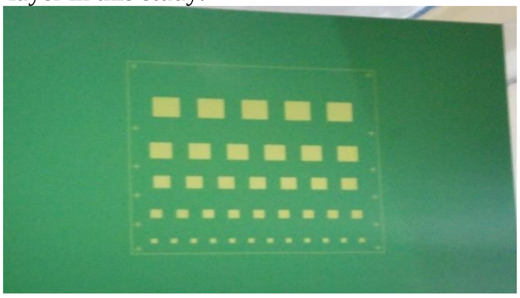

Figure 3. The mask used in the active layer

2.3. Screen Printing Process

The screen-printing process, which gave its name to the method in this technique, consists of masks designed according to the type of gas to be detected and metal oxide to be used. A small amount of organic compounds called paste is placed on the mask and pulled with the help of a rubber arm.

As can be seen in Figure 4. The prepared paste is applied to the upper part of the pattern to be used on the mask placed in the screen-printing machine, and the shape of the pattern is drawn on the substrate by applying the drawing process.

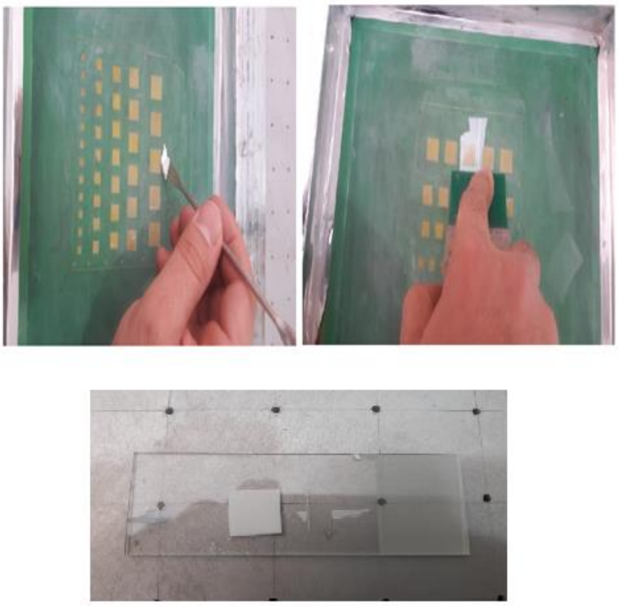

Figure 4. Pulling process by adding paste on the mask

2.4. Heat Treatment

The active layer, heater or electrodes screen-printed on the substrate are subjected to heat treatment. The temperature and waiting times in the process steps to be applied in the heat treatment vary according to the characteristics of the material.

The heat treatment steps are as follows;

- Rest
- Drying
- Annealing
- Cooling

2.5. Preparation of Binder and Paste

Both of the bonding preparation techniques described in the screen-printing method were used for comparison. The rates encountered in the literature study [7–10] to determine the proportions of chemicals to be used in the compounding were tested one by one, and the rates decided to be used in this study are as given in Table 1.

Table 1. Chemicals and ratios used in binder preparation

Binder made with linseed oil		**Binder made with ethyl cellulose**	
	wt (%)		wt (%)
linseed oil	85	Ethyl cellulose	10
m–xylene	12,5	α–terpineol	90
α–terpineol	2,5		

For the preparation of the binder, first, linseed oil and m–xylene were mixed and they subjected to magnetic stirring at 40 °C on hot plate. The stirring process was continued for about 4 hours.

After that α–terpineol was added then the temperature of was decreased to 30°C. The stirring was continued for about 2 hours to obtain a sticky liquid form binder.

Thick film gas sensor pastes usually comprise a semiconducting metal oxide powder, inorganic additives and organic binders.

In this research, tin oxide (SnO_2) was used as the base sensitive metal oxide powders.

Sensitive powder (SnO_2) was mixed with 40 wt% and binder was mixed with 60 wt% and they subjected to magnetic stirring at 40 °C on hot plate for 24 hours.

2.6. Film Preparations

The screen-printing process, which has given its name to the method in this technique, consists of masks designed according to the type of gas to be detected and the metal oxide to be used.

The base to be used during the screen-printing process is placed on the screen-printing machine used in the serigraphy technique.

A number of factors need to be considered when choosing the mesh angle. 45° mesh size was selected in this study. A 45° mesh provides the maximum flexibility for the stretched fabric but many produce a serrated edge on conductor lines which are aligned in parallel or at 90° with the direction of the squeegee

The reason for using the screen-printing machine is to prevent the base from sticking to the mask while screen-printing, since it has a vacuum feature.

The SnO_2 thick films were prepared by screen print technique using Al_2O_3 substrate. Silver electrodes were printed on an Al_2O_3 substrate. After printing the electrodes, it was kept at room temperature for 10 minutes. After these electrodes were kept at 125 °C for 10 minutes for drying. Finally, electrodes were kept at 350 °C for 20 minutes for annealing.

Sensitive layer was printed with sensitive paste on electrodes. After printing the sensitive layer, films were left at room temperature for 20 min to insure the paste is leveled off and settled and then the films are subjected to a drying and annealing process.

The sensitive layer was dried in three steps: first it was subjected to 50°C for 5 minutes and then temperature was increased to 100 °C for another 5 minutes, and finally it was dried at peak temperature of 125 °C for last five minutes. Finally, film was kept at 450 °C for 30 minutes for annealing.

2.7. UAV Aerial Platform

In this study, the investigation of the effectiveness of the use of UAV in the fire detection study was carried out using a modified 4-engine helicopter model as a platform. The UAV system used in the fire detection study consists of an air platform and a ground control station.

A rotary wing 4-engine (quadrotor) mini helicopter was used as an aerial platform. The model used has a suitable place for mounting electrical - electronic (avionic) systems and camera systems such as camera, video transmitter and standard radio transmitter. Figure 5 shows the DJI Phantom 2 Vision Plus UAV used as an aerial platform.

Figure 5. DJI Phantom 2 Vision Plus

3. Results and Discussion

3.1. XRD Analysis of Samples Produced with SnO_2

The structures of the SnO_2-based samples produced by the screen-printing method were examined by the XRD technique and are shown in the figures given below, respectively. (Figure 6).

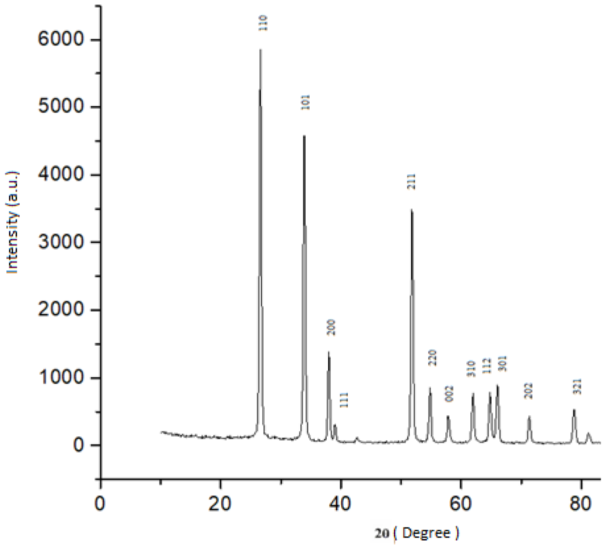

Figure 6. XRD graph of the SnO_2 sample

In the graphic shown in Figure 6. It has been observed that SnO_2 reflects in (110), (101), (211), (220), (002), (310), (112), (301), (202) and (321) planes. When these planes are compared with other studies [11–15] and with the JCPDS 71-0652 card number XRD database phases, it was observed that they are reflective peaks of pure SnO_2.

3.2. Gas Detection Measurements of SnO_2 Based Gas Sensor

The main purpose of the gas detection measurement system is to measure the change in sample resistance as a result of the interaction of the sample and the target gas.

The values used during the gas detection measurement of the SnO_2 sample measured at 300 °C temperature are given in Table 2.

Table 2. Values used during the measurement of the SnO_2 sample

Temperature	300 °C
Time to measure	400 s
External gas sweeping time	400 s
Gas measured	CO_2
External gas	Air
Period (Per Ppm)	1
PPM list	10000
Voltage source level	1 V

In order to clean the environment from various gases, nitrogen gas was sent to the environment for 40 seconds during the measurement process of the SnO_2 sample. Then, measurements were taken by giving the carbon dioxide gas to be measured together with nitrogen gas at the rate of 10000 ppm in the 40th second and shown in Figure 7.

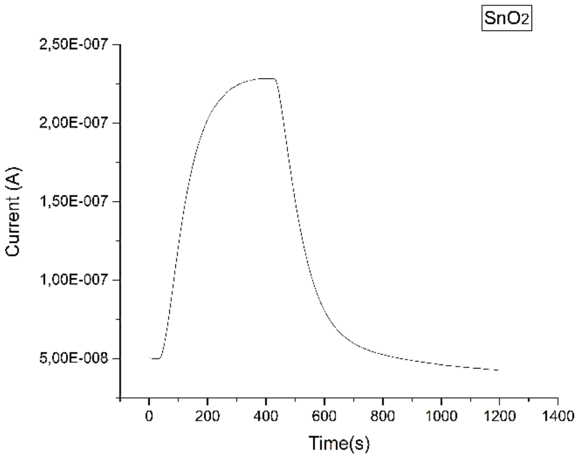

Figure 7. Gas sensor measurement chart of SnO_2 sample under 10000 ppm CO_2

The measurements of the SnO_2 sample used in this study were made at 10000 ppm CO_2 concentrations and measurement temperatures, and similar and better results were obtained with the data in this range. When the response times of the measurements were examined, it was observed that it was between 50 and 65 seconds after the fire started.

4. Conclusion

In the fabrication of the CO_2 thick film gas detector made within the scope of this study, the heater, electrode and sensitive layer, which are the three main components of a TiO_2 and SnO_2 doped thick film gas detector, were produced by using linseed oil, xylene, alpha terpineol and ethyl cellulose starting materials.

Screen printing method was used in film preparation, films were coated on glass and alumina (Al_2O_3) substrate and annealed at various temperatures. Structural analyzes were obtained by X-Ray Diffraction (XRD), the morphological properties of the films were analyzed by Scanning Electron Microscope (SEM) and their electrical properties were examined in detail.

The results obtained by interpreting the observations during the studies and the data obtained after the studies are as follows;

From the XRD results, SnO_2 phases in anatase structure were determined and it was observed that the peak intensity of these phases increased depending on the appropriate heat treatment process.

As a result of the study, low power consumption gas sensors using SnO_2 metal oxides as sensitive active materials were designed, produced and characterized. As a result of the tests, it has been shown that the developed sensors are sensitive to the materials specified in the literature. In accordance with the increase in gas concentration, an increase in sensor response was also observed.

At the end of the study, the gas detection feature of the produced SnO_2 sample was examined under the specified gases, and it was concluded that it can be used simultaneously with fire detectors to increase the detection reliability and reduce the alarm time with today's fire detectors.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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