# Ceramic Oxide Thin Film Thermocouples for Ployimide-based Flexible Substance

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***Abstract*—A ceramic oxide thin film thermocouples (TFTCs) is designed and fabricated by RF magnetron sputtering on the flexible substrate-Polyimide (PI) and its thermoelectric characteristics are investigated via analog simulation and multiple measurements. A kind of system for calibration and testing thermocouples in the low-temperature is designed. The prepared TFTCs show ideal static characteristics when the temperature changes between 10 and 200℃. The temperature resolution is less than 0.2℃ and the maximum thermoelectric output at 200℃ is 4.62mV. The maximum repeatability error, maximum temperature drift rate and average Seebeck coefficient of the flexible TFTCs can reach to 1.23%, 7.792℃/h and 23.1mV/℃.**



***Keywords—flexible, TFTCs, thermoelectric properties***


## I. INTRODUCTION

In recent years, with the continuous improvement of temperature measurement requirements, it is increasingly important to accurately measure the transient temperature of places such as aero engine combustion chambers, intelligent bionic robots and other fields[1-3].Microfabrication Process can be used to fabricate the thermocouples with small size, high sensitivity and fast response. Thin-film thermocouples fabricated by microfabrication process have typical two-dimensional characteristics and the thickness of the thermal junction is generally on the order of micron nanometers. Compared with the traditional thermocouples fabricated on the rigid substrate, the thermocouples based on a flexible substrate has incomparable advantages which can meet the application needs of real-time monitoring of surface temperature of non-planar objects, especially complicated geometry with high curvature. It has great potential in medical care, intelligent machinery, safety monitoring and other fields[4-5].

In this paper, a flexible TFTCs composed of positive film-ITO($In_2O_3$-10%$SnO_2$) and negative film-$In_2O_3$(99.9% purity) is prepared by RF magnetron sputtering technology. The structure of the sensor is shown in Fig.1. The substrate of the structure is supposed to have a mass size of 30mm×80mm×1.5μm(Width × length × height) and each film of TFTCs is about 3mm×75mm×1μm. The size of the hot end is 3mm×9mm(Width × length), the cold ends are 7mm×12mm.

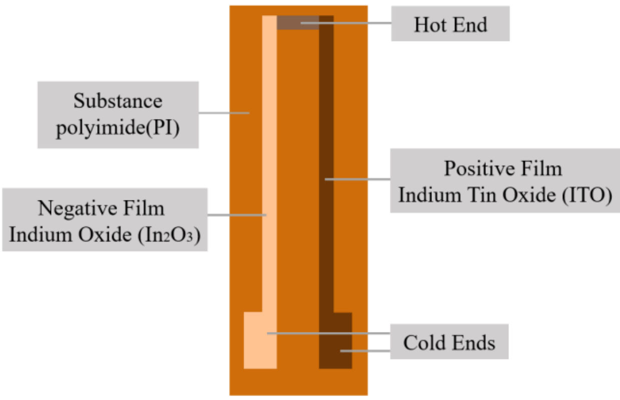


Fig. 1. The structure of ITO-$In_2O_3$ TFTCs.

## II. SIMULATION

The designed TFTCs are simulated by software-COSMOL[6]. In the simulation, the substance thickness is set as 1.75 microns, the hot end temperature is set to 200℃ and the cold end temperature is set to 0℃. The temperature distribution of TFTCs and the potential distribution are shown in Fig.2.

The simulation results show that the maximum thermoelectric voltage is generated from the two cold ends which is about 39.85mV when the temperature difference between the hot and cold ends is 200℃. Besides, it is also found through simulation that the substance is very thin, whether the heat source is located above or below the substance, the measured temperature by TFTCs are the same approximately. The curve of thermoelectric output under different temperature by simulation are also showed in Fig.3.

Equation (1) is the fitted linear by curve where T is the temperature and U is the thermoelectric output. The sensitivity is 0.1993 mV.

$$U = 0.1993T - 54.3953 \quad (1)$$

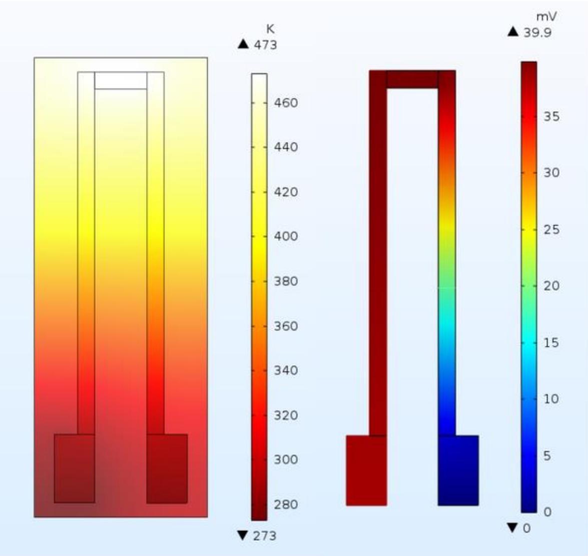


Fig. 2. The simulation of the flexible TFTCs thermoelectric output.

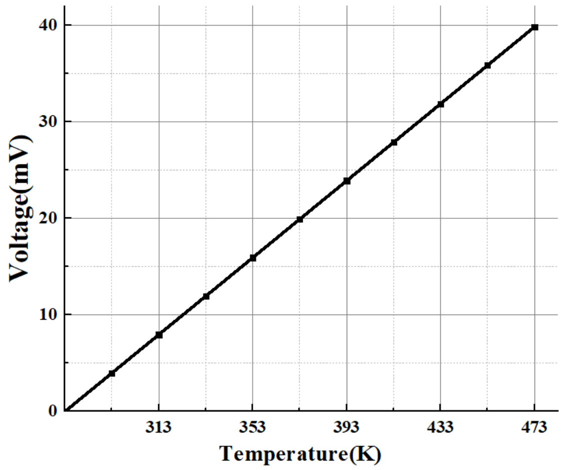


Fig. 3. The curve of thermoelectric output.

## III. Calibration and Testing System

In order to be able to calibrate and test TFTCs in a wide low temperature region, the system of Fig.3 is designed and built. At the hot end, a ceramic plate (10mm×10mm) by changing the applied current and voltage to change the temperature is used as the heat source. Besides, the software is used to set the heating and cooling process of the ceramic plate. The standard K thermocouple is used to calibrate the real-time temperature. At the cold end, a cold end compensation system is used to control the cold end of TFTCs temperature at 0°C. As for the data acquisition, the thermoelectric output of the TFTCs and the calibration temperature value are recorded by the multi-channel real-time data collector.

The experiment is carried at 10°C-200°C and the overall structure of system is shown in Fig.4.

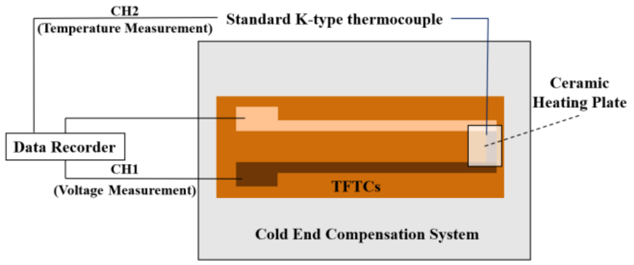


Fig. 4. The calibration system of ITO-$In_2O_3$ TFTCs.

A cycle experiment at 200°C in natural environment is done to gain the thermoelectric properties (repeatability error, temperature drift rate and Seebeck coefficient) of the flexible TFTCs. The temperature of hot junction and the thermoelectric voltage are recorded in each cycle (10 minutes for heating, 5 minutes for keeping 200°C and 10 minutes for cooling). And the experiment is repeated three times. The flexible TFTCs has not any treatment before the cycle experiment. The data measured by the data collector is shown in the Fig.5.

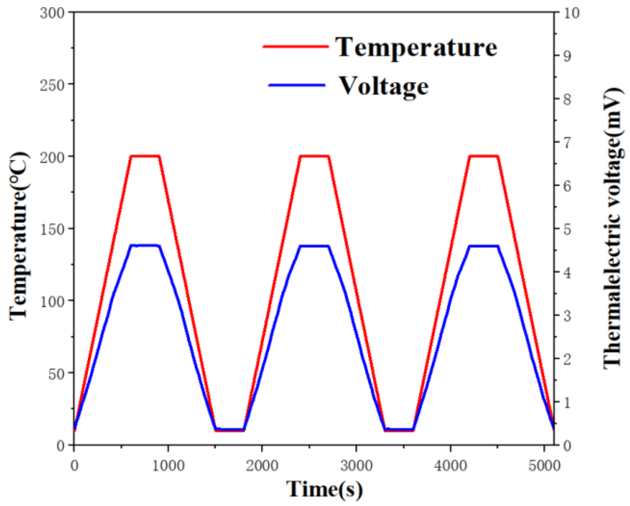


Fig. 5. The output curve of ITO-$In_2O_3$ TFTCs.

## IV. Conclusion

A novel flexible TFTCs composed of positive film-ITO and negative-$In_2O_3$ is fabricated by RF magnetron sputtering technology. The maximum repeatability error, maximum temperature drift rate and average Seebeck coefficient of the flexible TFTCs with cycle heat treatment from 10°C-200°C can reach to 1.23%, 7.792°C/h and 23.1mV/°C. The temperature resolution is less than 0.2°C and the TFTCs can measure temperature continuously for more than one and a half hours. In the field of flexible and low temperature detection, the sensor shows good application characteristics and has a good application prospect.

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