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# Organic Thin Film Transistors with Polyvinylpyrrolidone / Nickel Oxide Sol-Gel Derived Nanocomposite Insulator

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**Abstract**

Polyvinylpyrrolidone / Nickel oxide (PVP/NiO) dielectrics were fabricated with sol-gel method using 0.2 g of PVP at different working temperatures of 80, 150 and 200 ℃. Structural properties and surface morphology of the hybrid films were investigated by X-Ray diffraction (XRD) and Scanning Electron Microscope (SEM) respectively. Energy dispersive X-ray spectroscopy (EDX) was used to make a quantitative chemical analysis of an unknown material. The obtained results demonstrate the feasibility of using high dielectric constant nanocomposite PVP/NiO as gate dielectric insulator in the organic thin film transistors (OTFTs).

## 1. Introduction

There is currently interest in organic thin film transistors (OTFTs) due to their low cost and low temperature processability. Gate dielectrics have major role to the OTFTs performance. Most gate dielectrics reported thus far are based on thermally oxidation growth, chemical vapor deposition and hence are typically expensive to prepare [1-3]. Organic dielectrics have been studied as gate dielectrics including polyvinyl phenol, polyvinyl alcohol, poly methyl methacrylate and polystyrene. Organic materials can easily be formed by spin coating, dip coating, ink-jet printing and Langmuir-Blodgett techniques on large area flexible substrates at low temperatures [3-7]. In spite of the potential improvement of device operation, organic dielectrics also show the drawback of a small dielectric constant.

In order to reconcile the respective advantages of a high-K oxide for low operating voltage and polymer dielectric for a better interface with the organic semiconductor, a hybrid gate dielectric consisting of NiO / Polyvinylpyrrolidone (PVP) is reported in this study. Polyvinylpyrrolidone (or

poly-4- vinylpyrrolidone) is a unique polymer made from the monomer N-vinylpyrrolidone (Fig.1.) that provides remarkable properties such as transparency, soluble in water, physiologically compatible, non-toxic, essentially chemically inert, temperature-resistant pH-stable, non-ionic, and colorless. This remarkable combination of properties predestined its use in numerous applications in medicine pharmaceutical technology, cosmetics and in the technical industry.

In this work we focus on NiO/PVP organic-inorganic hybrid nanocomposite dielectrics. These organic – inorganic hybrid nanocomposites were synthesized by a sol – gel process, followed by heat treatment at below 200 ºC. Structural properties and surface morphology of the hybrid films were investigated by X-Ray diffraction (XRD), Scanning Electron Microscope (SEM) and Energy dispersive X-ray (EDX).
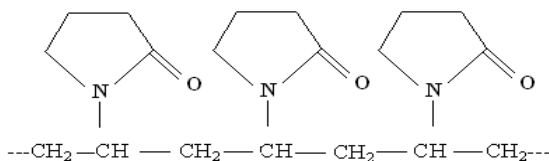


**Fig. 1.** Chemical structure of Polyvinylpyrrolidone $(C_6H_9NO)_n$

## 2. Experimental procedure

Nickel nitrate hexahydrate $[Ni(NO_3)_2].6H_2O$ was used as the inorganic precursors and polyvinylpyrrolidone $(C_6H_9NO)_n$ as organic component. Ethyl alcohol $(C_2H_6O)$ and sodium hydroxide (NaOH) were used as solvent and catalyst respectively. Nickel oxide solution was prepared from mixing of nickel nitrate hexahydrate with sodium hydroxide and deionized water. Special care is required to prepare a solution of

sodium hydroxide in water because considerable heat is liberated by the exothermic reaction. These solutions were stirred vigorously at 60 ˚C for 30 minutes.

Finally, 0.2 gr of polyvinylpyrrolidone was solved separately to the ethyl alcohol solvent. Then both above solutions were mixed and the resultant sol was continuously stirred for 24 hours and kept at room temperature until it turned into a light green sol. Viscosity and color changed as the sol turned into a stick gel. The gel was heat-treated at 80 ˚C for 48 hours and a fluffy, polymeric precursor was gained. Afterward, the gel was dried at atmospheric pressure and different calcinations temperatures for two hours. Fig. 2 shows the schematic flow chart of the NiO/PVP hybrid nanocomposites synthesized by a sol-gel process.
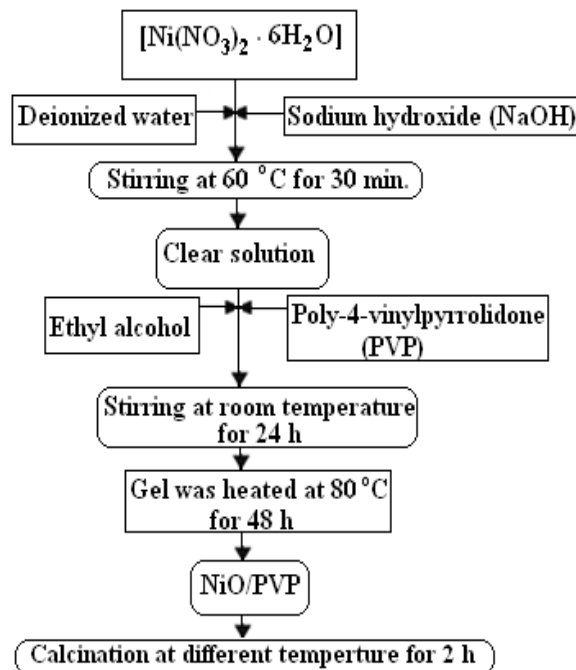


**Fig. 2.** The schematic flow chart of the NiO/PVP hybrid nanocomposite synthesized by a sol-gel process.

## 3. Results and discussion

EDX technique was used to make a quantitative chemical analysis of the prepared materials. Fig. 3 (a) and (b) give the EDX spectra for various samples. As is shown in Fig. 3(a) the pure NiO was mainly composed of Ni and O elements.
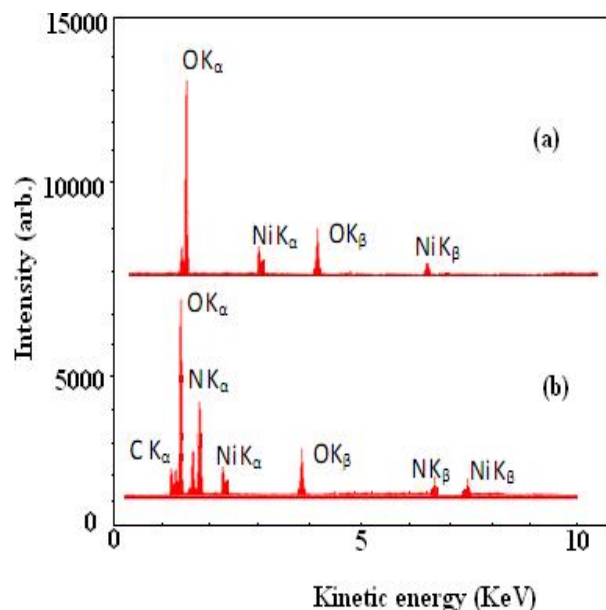


**Fig. 3.** EDX spectra of (a) pure NiO and (b) NiO/PVP synthesized by sol-gel method.

**Table 1.** The amounts of elements (C, N, O and Ni) are shown in NiO/PVP hybrid nanocomposite.

| Elt | Line | Int | K | Kr | W% | A% | ZAF | Pk/Bg |
|-----|------|-----|-----|-----|-----|-----|-----|-------|
| C | Ka | 135.3 | 0.1177 | 0.0434 | 11.46 | 12.32 | 0.3787 | 72.65 |
| N | Ka | 174.6 | 0.2051 | 0.0757 | 19.61 | 20.48 | 0.3858 | 59.31 |
| O | Ka | 1052.6 | 0.4559 | 0.1682 | 43.40 | 48.58 | 0.3149 | 656.40 |
| Ni | Ka | 93.7 | 0.1101 | 0.0406 | 25.52 | 18.62 | 0.7817 | 22.42 |
| | | | 1.0000 | 0.3690 | 100.00 | 100.00 | | |

Fig. 3(b) shows the EDX spectra for NiO/PVP nanocomposite which was mainly composed of Ni, O, C and N elements and the atomic percentage was 18.62%, 48.58%, 12.32% and 20.48% respectively (see Table 1). The H (hydrogen) element was too light to be detected in the EDX analysis. To quantify the amount of an element in a sample, signal from sample must be compared to that of a known standard. Theoretically counts from sample and counts from standard are directly related to concentration (Equation1).

$$K_{ratio} = I_{sample} / I_{std} = C_{sample} \qquad (1)$$

In equation (1), $I_{sample}$ is count from sample (or intensity), $I_{std}$ is count from standard one and $C_{sample}$ is concentration of element in a sample. In practice, $K_{ratio}$ must be corrected for sample effects (Equation 2).

$$K_{ratio} = I_{sample} / I_{std} = C_{sample} (ZAF) \qquad (2)$$

Corrections commonly are referred to as (ZAF) corrections.

ZAF means three types of corrections must be taken into account to sample data. Z is the so called atomic number correction and is made up of stopping power and backscatter terms. A is the absorption correction, because some of the X-rays produced in sample volume don't make it out of the sample. F is the fluorescence correction, corrects for X-ray induced excitation in the sample.

X-ray diffraction analysis was carried out to investigate the structural properties of PVP/ NiO nanocomposite. As shown in Fig. 4(a) pure polyvinylpyrrolidone has amorphous structure and in Fig. 4(b) major diffraction peaks of PVP/ NiO nanocomposites are observed along the (110), (111) and (200) planes.

The surface morphology of the dielectric layer was studied by the SEM technique. Fig. 5 exhibits the packing efficiency of the composite system is increased and thus is expected to enhance higher dielectric constant. The slight agglomeration of the particles especially the smaller-sized one was probably resulted from the high temperature curing process.

**(a)**



**(b)**
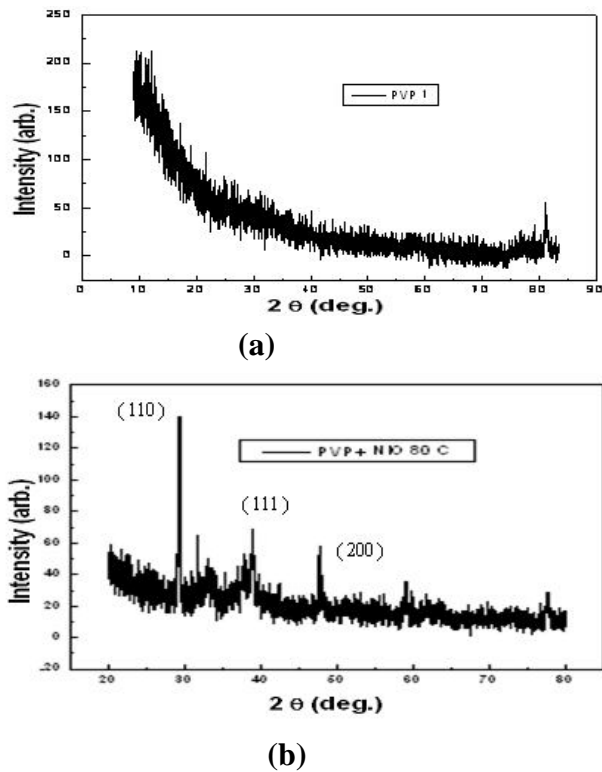
**Fig. 4.** XRD spectra of (a) pure PVP and (b) PVP/NiO hybrid nanocomposite.
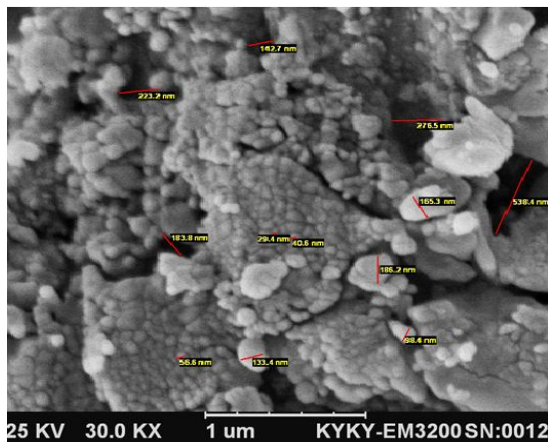


**Fig. 5.** SEM image of PVP/NiO hybrid nanocomposite.

## 4. Conclusion

A solution processible nanocomposite containing PVP and NiO nanoparticles were synthesized. The packing efficiency of the composite system is increased and thus is expected to enhance higher dielectric constant. This demonstrates the feasibility of using high k PVP/NiO nanocomposite as a gate dielectric insulator in the OTFTs. In addition, further investigation beyond that of this work is necessary.

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