Study of the effect of bending deformation on the performance of flexible polymer layered humidity sensor.

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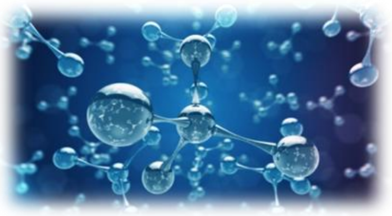


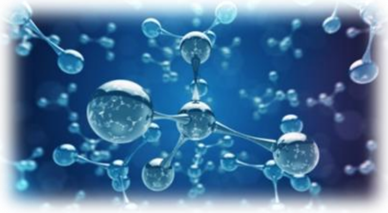
Introduction

Why Humidity?

- ✓ Relative humidity can affect the incidence of respiratory infections and allergies.
- ✓ By exposure to relative humidity between 40% and 70% the survival of airborne viruses and infectious bacteria is minimized.
- ✓ For the wound healing process to accelerate, the wound should be kept moist - the moisture of the wound is made a key parameter in the development of patches.
- ✓ Atmospheric humidity affects the sense of comfort and is also an important parameter for ensuring optimum exploitation of warehouses for food and non-food goods, building materials, museum artifacts, etc.

Why Optical Sensing?

- ✓ Traditional humidity sensors are based on the electrical measurement and suffer from high working temperature, lack of selectivity and relatively low accuracy due to the cross-temperature feature.
- ✓ Optical sensing, where detection is based on change of color of the thin film for example in response to particular analyte, offers simple and power saving method.



Introduction

Why polymers?

Great variety of materials that change their refractive index, extinction coefficient or thicknesses are implemented as sensitive media but polymers are a material that stands out.

- Easy deposition in form of thin films
- Relatively low cost
- Tailored functionality
- Fast response due to the short diffusion path length

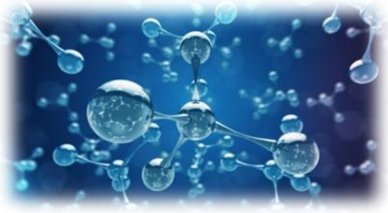
What we do?

✓ Hydrophobically modified PVA copolymer, namely poly(vinyl alcohol-*co*-vinyl acetal), is synthesized and used in a form of nanometer-sized thin films deposited on PET flexible substrate as well as borosilicate glass by spin-coating method.

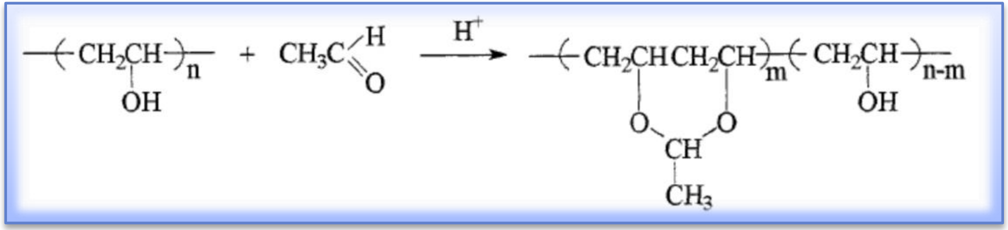
✓ PET flexible substrate and borosilicate glass were covered with Au:Pd sublayer with gold-palladium ratio of 80:20 and thickness of 30 nm before polymer deposition.

✓ Samples are thermally treated in air at 60°C after polymer film was deposited.

✓ The effect of bending deformation on the performance of flexible polymer layered humidity sensor is investigated.

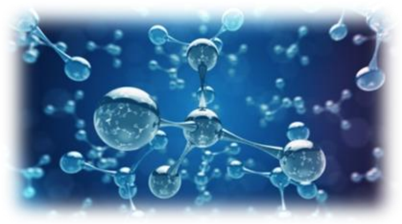


Copolymer synthesis



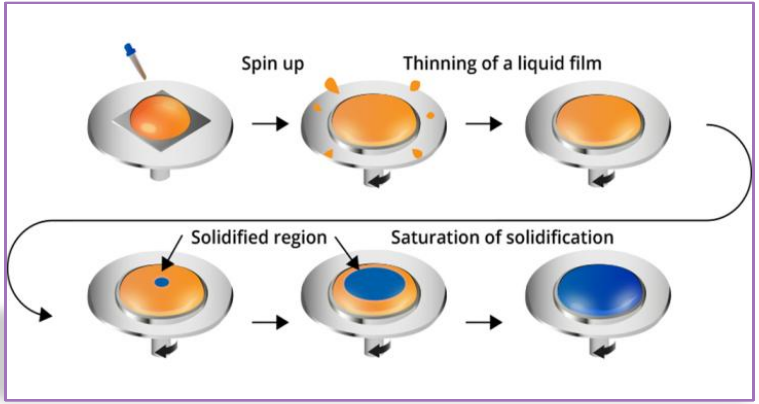
- Poly(vinylalcohol-co-vinylacetal)s of varied copolymer composition were synthesized at mild reaction conditions in aqueous media at 30°C.
- The copolymer composition was controlled by PVA-to-acetaldehyde molar ratio.

- Obtained poly(vinylalcohol-co-vinylacetal)s are smart materials exhibiting reversible phase transition in aqueous solution with increasing temperature.
- The higher the acetal content, the higher the hydrophobicity and the lower the phase transition temperature, respectively.



Thin film deposition

- Spin coating: 0.250 ml drop, speed - 4000 rpm, time - 60s
- Postdeposition annealing: 30 min in air, T = 60°C and 180°C
- Substrates: Si-wafer
- Thickness: all films have thickness around 80 nm

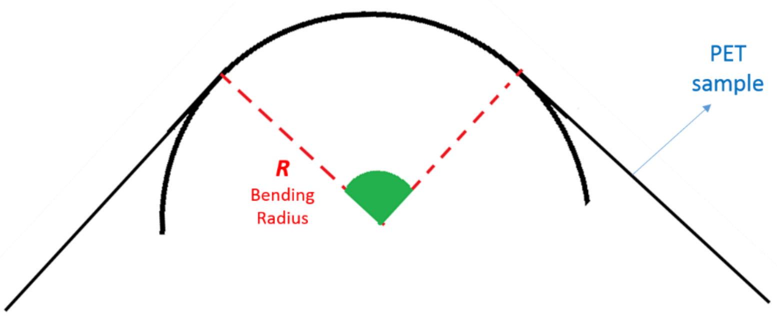


Thin films from polymer of 24% acetal content were deposited with approximate thickness of 80 nm on PET flexible substrate by the method of spin coating using 0.250 ml of 1 wt% solution of polymers in 80:20 volume ratio of methanol-to-water solvent.

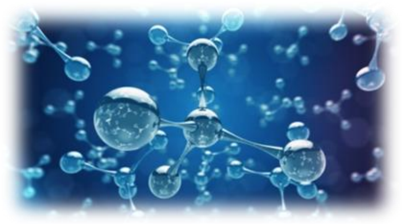
Thin film deposition

Performing bending:

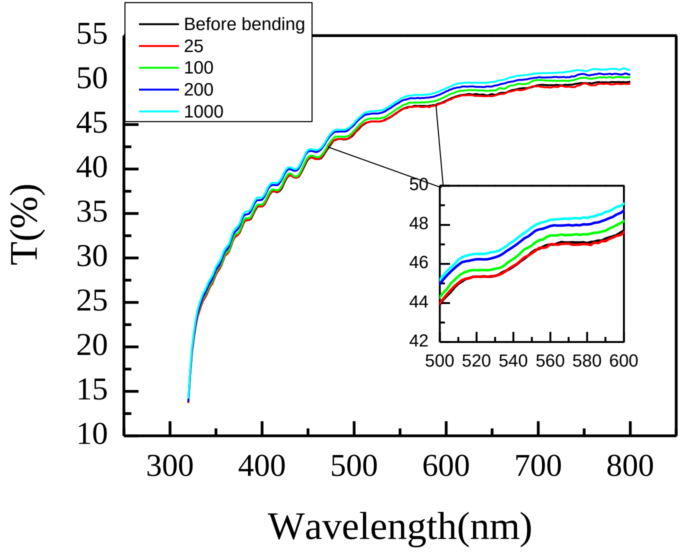
- After making all measurements of the PET substrate covered with polymer film four groups bend deformations take place.
- After each set of bends same measurements were conducted.
- Numbers of bend deformations performed: 25, 100, 200 and 1000.
- Bend radius R_b = 4.37 mm



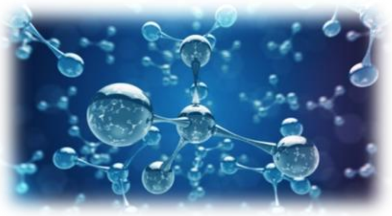
R_b = 4.37 mm



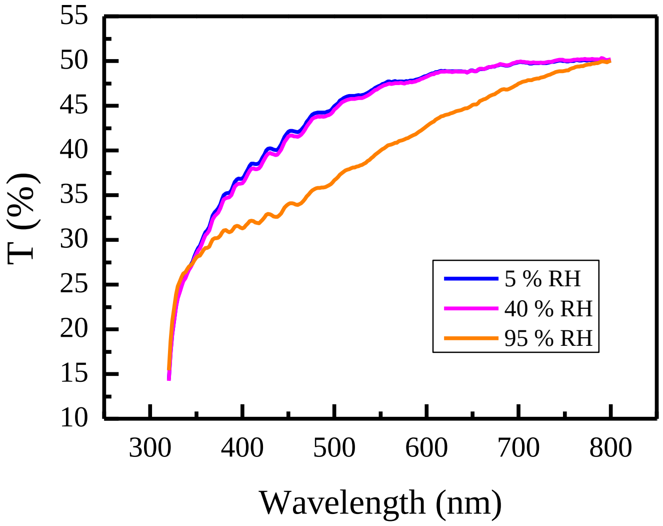
Optical characterization



- It is seen from measured transmittance spectra that the transmittance coefficient T increases with the increase of the number of bends.
- The transmission coefficient T at 600 nm wavelength after 25 bends is 47.6 % and gradually increases to 49.1 % after 1000 deformations.
- The possible reason of the observed slight increase in T is the change of transmittance of the metal overlayer due to small sub-micron cracks created as a result of bending deformations.



Humidity sensing and bending experiments

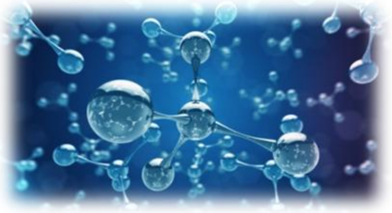


Transmittance spectra T for humidity levels of 5 %, 40 % and 95 % RH of sample after each set of bends were measured.

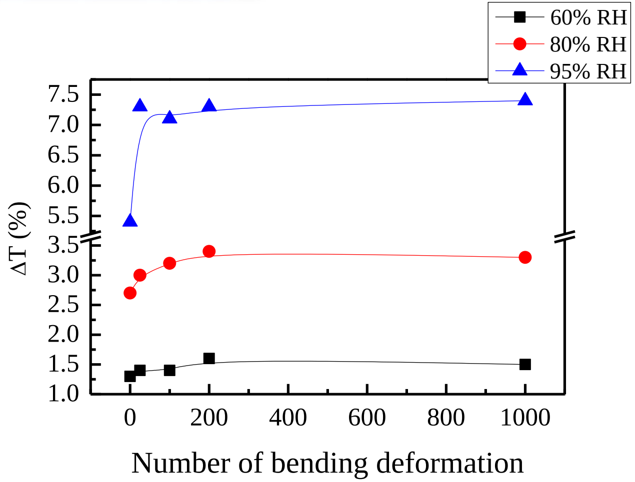
When polymer film is exposed to higher humidity it increases its thickness and decreases its refractive index. As a result a change in transmittance spectra is observed.

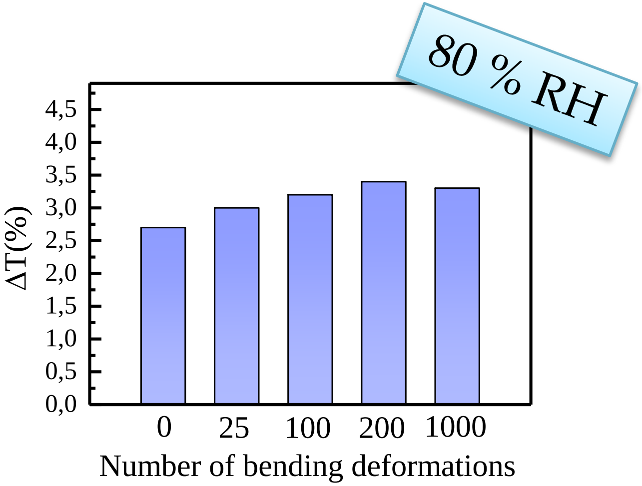
Transmittance change ΔT is calculated for each set of bends.

For the highest humidity (94 %) the spectrum shifts toward higher wavelengths and similar values of ΔT around 7 ± 1 % at 500 nm wavelength are measured after all bending deformations for the flexible PET sensor.



Humidity sensing and bending experiments

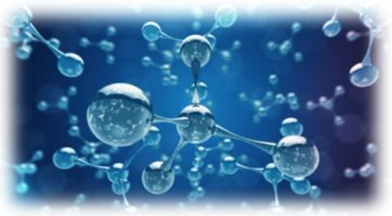




Transmittance change ΔT is calculated for each set of bends and for three different humidity levels – 60 %, 80 % and 95 % RH.

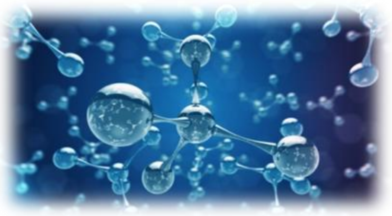
For the highest humidity (95 %) similar values of ΔT around 7 ± 1 % at 500 nm wavelength are measured after all bending deformations for the flexible PET sensor.

There is a slight increase of polymer swelling with bending deformation mostly pronounced for the highest humidity levels.



Summary

- ✓ A humidity-sensitive system of a flexible metalized PET substrate and a Poly(vinylalcohol-*co*-vinylacetal) copolymer thin film has been successfully developed.
- ✓ A change in the transmittance spectrum after exposure to different relative humidity levels in the whole range of 5-95% RH was observed.
- ✓ Series of deformation bends from 25 to 1000 led to a slight increase of transmission
- ✓ The measured change ΔT after each set of bends was about 7% and depends slightly of the number of bending deformations up to 1000. However the comparison with ΔT before bending showed an increase of polymer swelling mostly pronounced for the highest humidity levels.



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