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Analysis of Performance of Flexible Polymer Nano-Sized Layered Humidity Sensor

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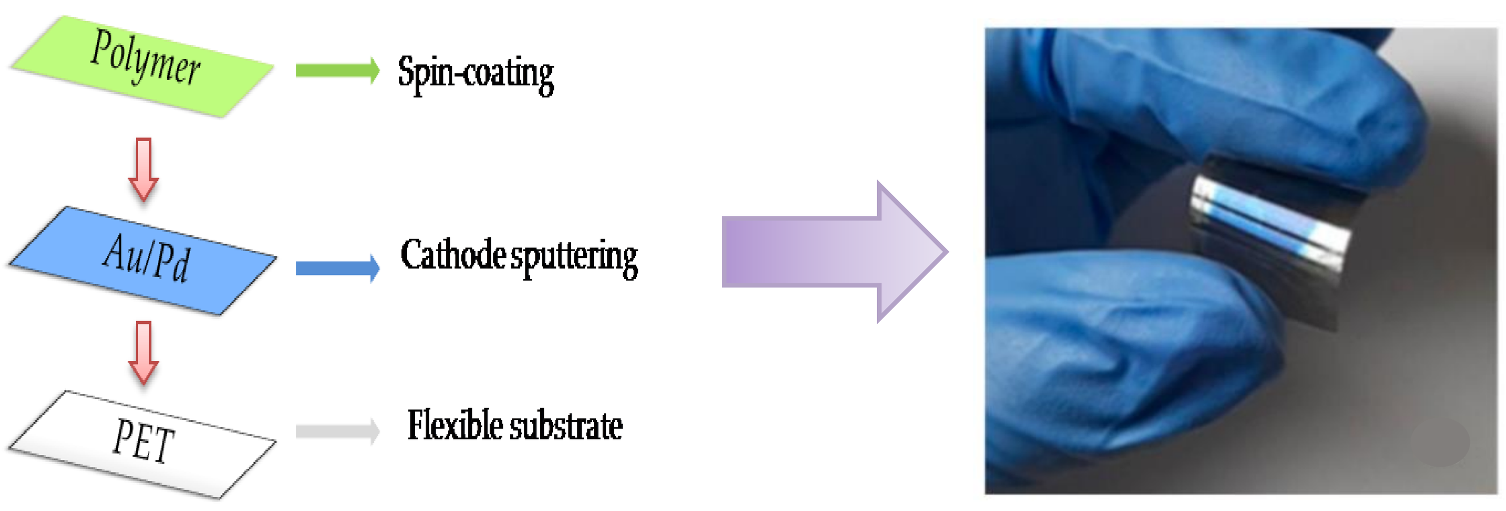
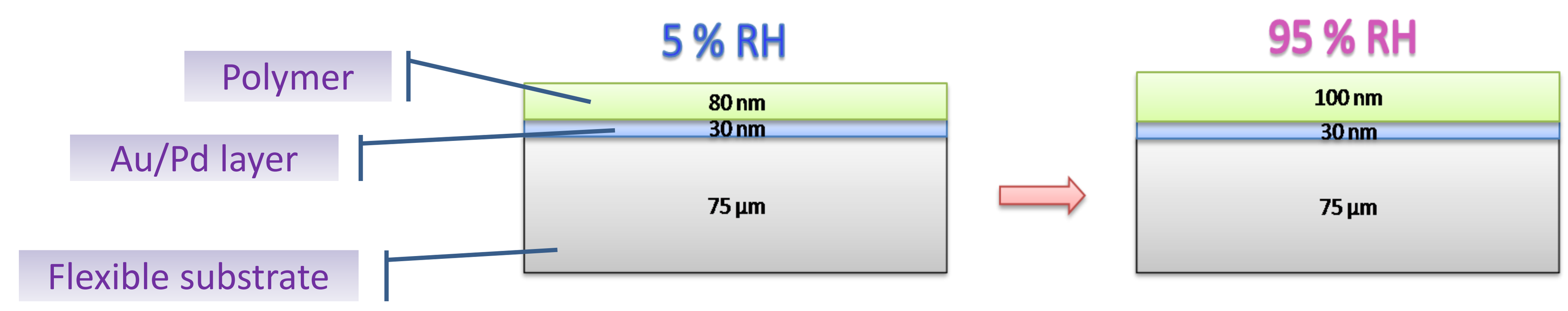
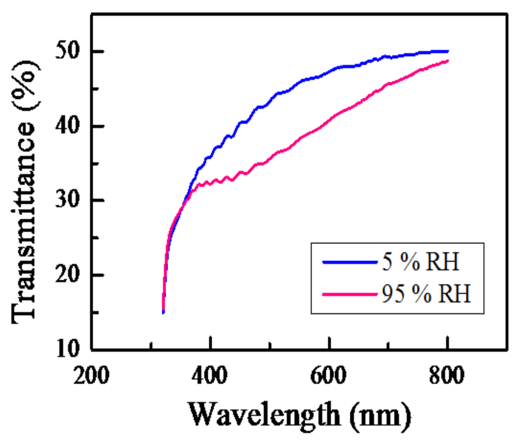
INTRODUCTION & AIM

In the present study, the influence of deformations of a flexible substrate on the active amphiphilic PVA-Ac copolymer with 24% acetal content sensing layer in a thin-film sensor is studied. To improve the optical contrast, metallization of the PET substrate is used, which also aims to increase the sensitivity. After a series of bends of up to 1000 times, certain characteristics of the sensor were studied - hysteresis, sensitivity, change in the transmission coefficient and others. The initial active layer was deposited by the spin-coating method, which is fast, easy and ensures repeatability of the result. The quality of PVA-based media with added acetal groups was monitored by 3D profilometry. It has been shown that the deformations do not adversely affect the sensor thin-film systems, and even lead to an improvement in sensitivity of over 40%. Possible reasons for this, such as a reduction in adhesion between the sensing medium and the transparent metallized substrate, are discussed.



METHOD





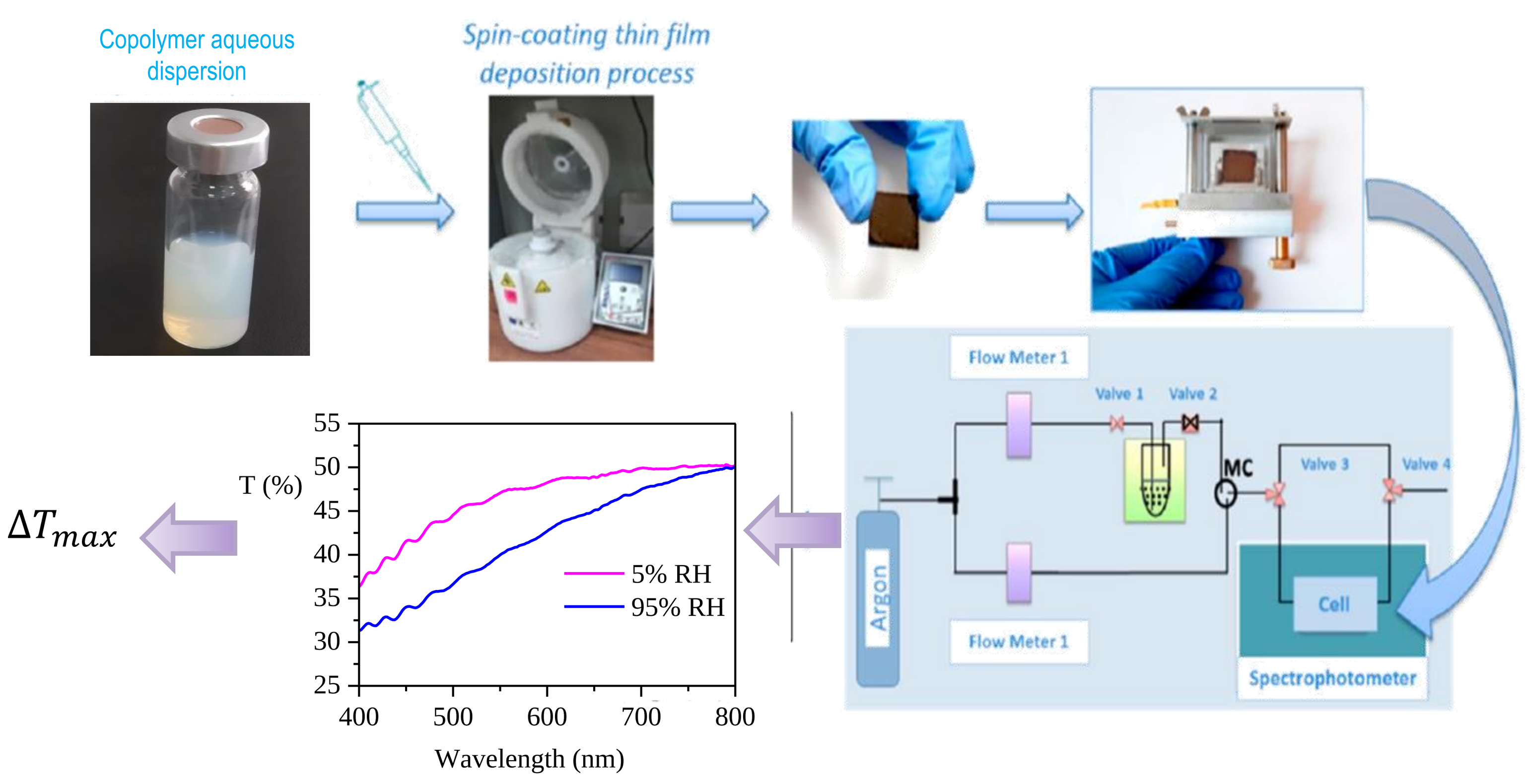
- To evaluate sensing properties of the sensor it was placed in quartz cell and the atmosphere inside is changing from air to acetone by using homemade bubbler system.
- Transmittance spectra in different humidity levels were measured
- Maximum transmittance change ΔT_{max} was calculated

The percentage of hysteresis (H) was calculated from the following equation:

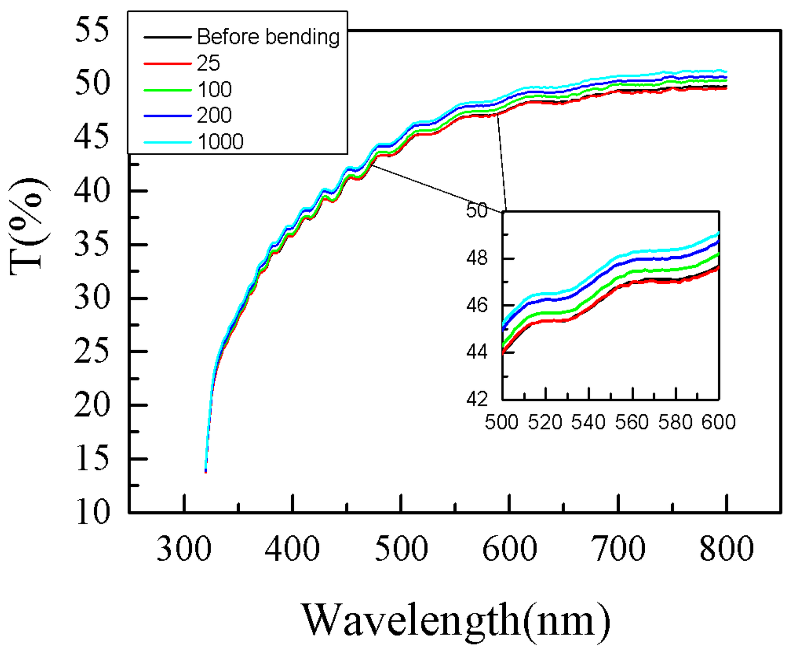
$$H(\%) = \frac{max\left|T_{up-}T_{down}\right|}{\Delta T_{max}} \cdot \frac{\Delta RH_{hyst}}{\Delta RH} \cdot 100$$

The sensitivity of the sensor S was calculated according to the following equation

$$S = \frac{\Delta T}{RH2 - RH1}$$



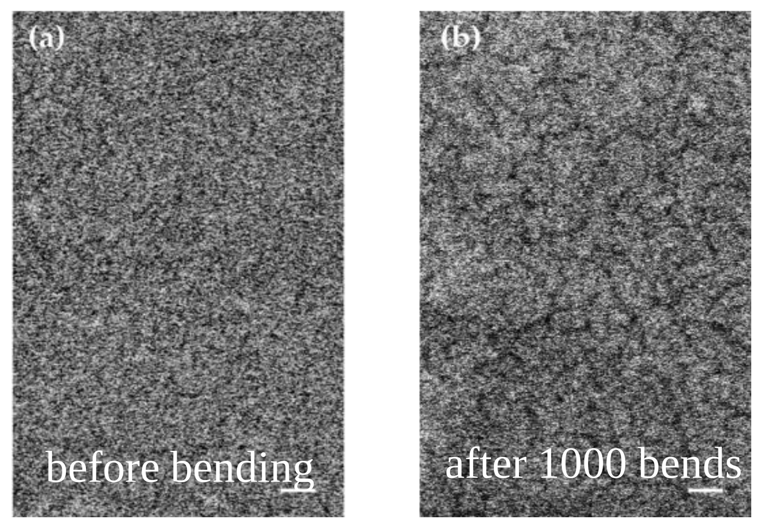
RESULTS & DISCUSSION



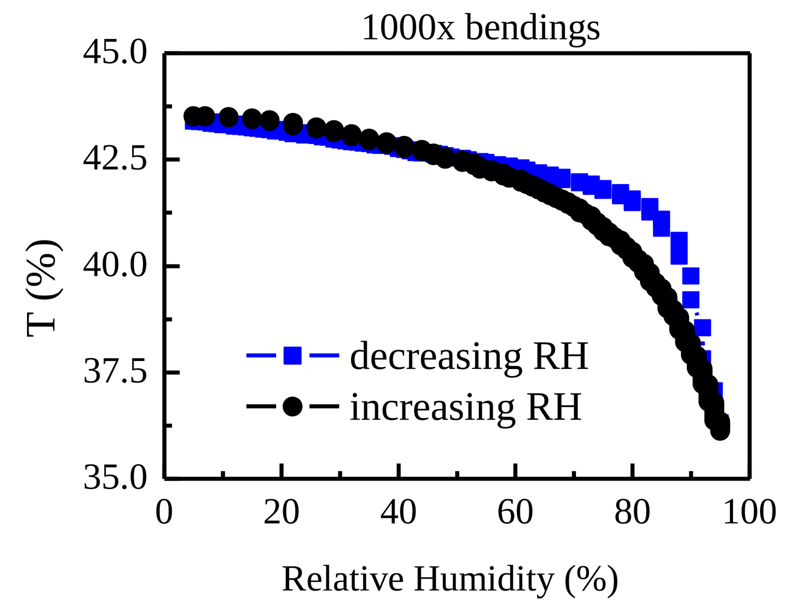
The transmittance coefficient gradually increases after each set of bends

T= 47.6 % before bending

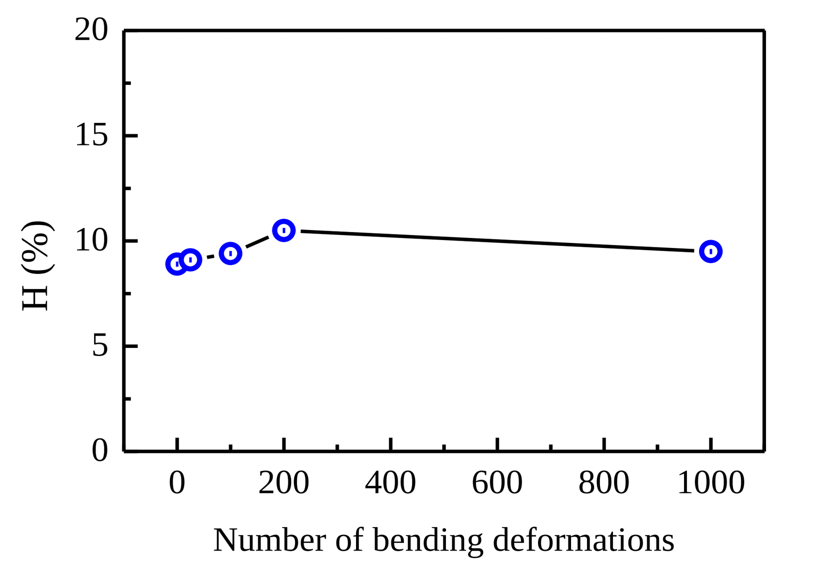
T = 49.1 % after 1000 deformations

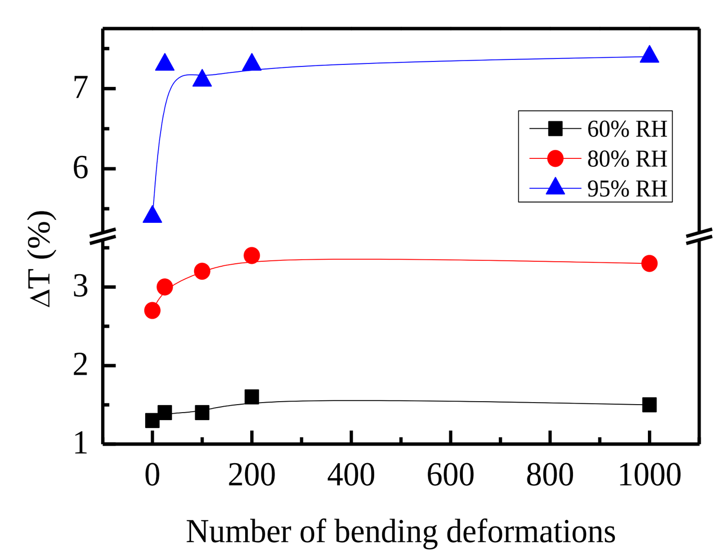


SEM micrographs of the surface of the metallized PET substrate



The generation of fine cracks in the metal film is confirmed by the comparison of surface morphology of metalized PET substrate before bending and after 1000 bends. In the case of bent substrate a network of fine cracks is seen that is responsible for slight increase of transmittance.





Trend of hysteresis and sensitivity with bending deformations:

- both parameters increase at the beginning of the bending test and then reach steady state
  - the effect of bending deformation on ΔT_{max} is stronger for higher humidity levels

Variable/ Number of bending deformations		Before bending	25	100	200	1000
H (%)		8.9	9.1	9.4	10.5	9.5
ΔT for 95 % RH		5.4	7.3	7.1	7.3	7.4
ΔRH	Range 5-75 % RH	3.3	5	2.5	2.5	2.5
	Range 75-95 %RH	0.6	0.6	0.4	0.5	0.4
S	Range 5-75 % RH	0.03	0.02	0.04	0.04	0.04
	Range 75-95 % RH	0.17	0.18	0.23	0.22	0.24

CONCLUSION

- The development of flexible and transparent polymer based optical humidity sensor is demonstrated. The sensor consists of pre-metallized PET substrate covered with spin-coated thin film of poly(vinyl alcohol-co-vinyl acetal) with acetal content of 24 % with thickness of 80 nm.
- The metallization of PET substrate provides sufficient optical contrast between the humidity sensitive film and PET substrate while the small thickness assures fast response.
- A small increase of 1.5 % of transmittance of the sensor is obtained after 1000 bending deformations mostly due to the fine network of cracks appearing in the metal film as a result of bending.
- The influence of bending deformations up to 1000 on the surface morphology and optical quality of the sensor is negligible.
- An enhancement of sensitivity of more than 40 % is observed after bending for relative humidity higher than 75 % resulting in improvement of resolution from 0.6 % RH to 0.4 % RH. It is assumed that weakening of adhesion due to bending is the most probable reason for enhanced polymer swelling.

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