Research on preparation and assessment of a viscose-based humidity sensor

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ABSTRACT

Humidity sensors are extremely significant in measuring and reflecting humidity accurately, consistently and timely. And they are widely applied in various industries including health care, weather forecasting, civil engineering, agriculture care, nuclear reactor control and so on. State-of-art commercial sensors behave some limitation on post-maintenance, sustainability and interference from external factors. Herein, we report a reliable viscose-based humidity sensor with high reaction sensitivity and good repeatability. Viscose, a kind of waste material, was found to gain advantages in terms of cost and sustainability. The results show that viscose carbonized at 600℃ is more suitable for sensors, whereas if it has been sprayed with hydrophobic reagents, it will be less suitable for sensors. We expect this project to bring a sensor to industry that will work properly in a rainy environment.

INTRODUCTION

Humidity sensors have the ability to measure and reflect humidity accurately, consistently and timely. As a result, they are used in a wide range of industries. Industrial automation brought by the popularity of humidity sensors is particularly important in the medical care sector. It not only helps to coordinate the allocation of healthcare resources but also allows for precise 'cloud monitoring' of physical condition with the Internet of Things. Capacitive types of humidity sensors dominates the current market by about 75% of whole sales. Commercial sensors are mainly based on metal oxides, polymers and porous silicon. They have good repeatability within a certain humidity range, but show some disadvantages in terms of post-maintenance, sustainability and interference from external factors. Due to the huge market demand and imbalance between supply and demand sides, the choice of specific materials has to be carefully considered. The transfromation of waste materials such as viscose as a sensing material is a novel and promising option. The advantages of biomass carbon materials include sustainability, greenness, cheapness, large specific surface area, high heteroatomic and high biocompatibility.

METHODOLOGY

The carbonised viscose fabric is cut into 2cm x 3cm and fixed to the plastic sheet with conductive tape. The conductive silver thread is then fixed to the conductive tape with the help of a silver ionic solution. Allow the silver solution to dry before covering the conductive tape once more. When it comes to the performance evaluation, aside from measuring water contact angle at first, the environment of measuring resistance and weight should be controlled well. Furthermore, the resistance changes of the sensor will be determined by the instrument Keithley 2000. Then the test of the resistance-humidity property can be held in a conditioning cabinet. The chamber is able to set a specific humidity and temperature.The testing procedure of the sensor is on the basis of ASTM D1776 and ISO 139 Textile Testing Standard.

The samples are named CF(450), CF(600), CF(700), CF(600)-1 and CF(600)-5 depending on the carbonization temperature and whether they are treated or not.

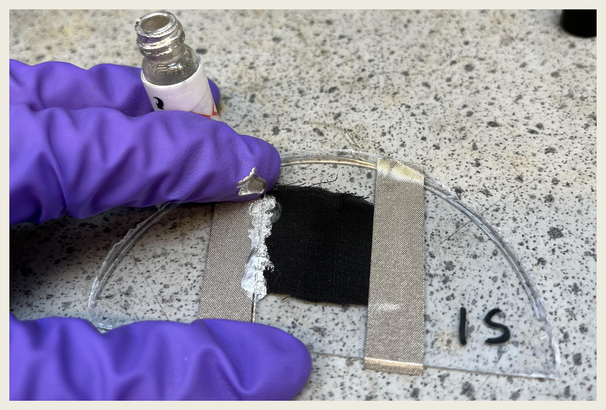

Figure 1. Photograph of sample

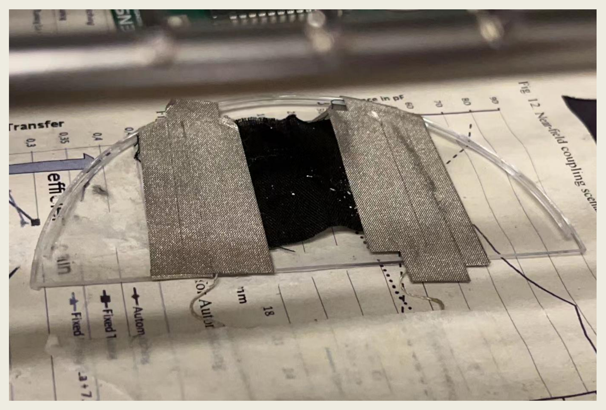

Figure 2. The working environment of the sample

RESULTS

We obtained resistance-humidity curves and weight-humidity curves for all sample groups, which reveal whether the samples are suitable as humidity sensors.

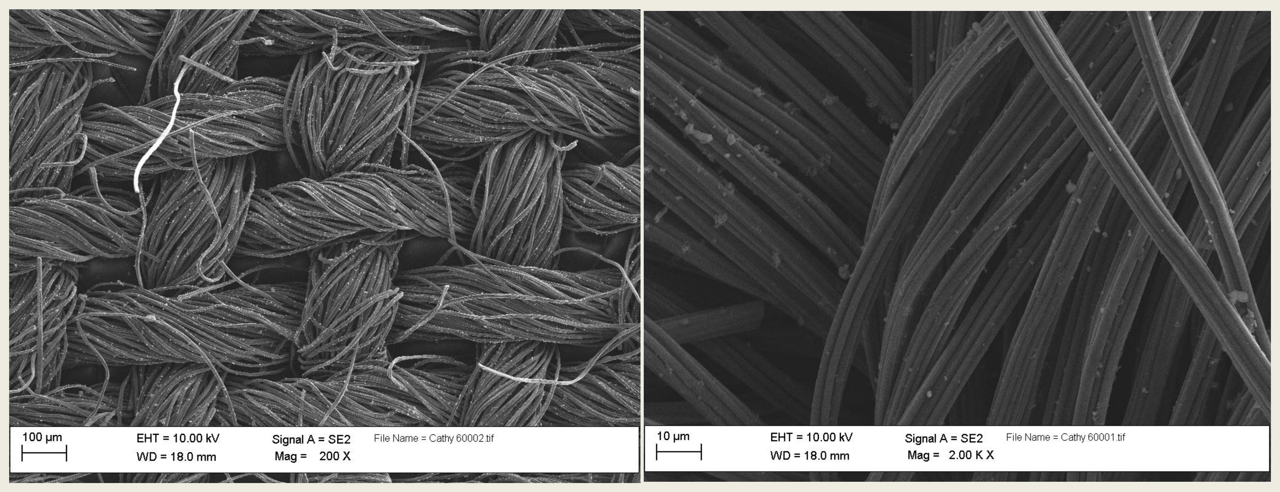

Figure 3. Surface morphology of CF(600)

Sensing material	Substrate	Type	Flexibility	RH range	Response/Recover Time
GO	Coolmax	Resistive	Yes	45%-80%	<0.6s/<0.15s
Carbon Nanocoils	flexible liquid crystal polymer	Resistive	Yes	4%-95%	1.9s/1.5s
2D Ti3C2Tx nanosheets	Cellulose fiber nonwoven fabric via special MXene–cellulose fiber interactions	Resistive	Yes	20%-80%	1.15s/8.71s
Acidified carbon nanotube	Thermoplastic PU nanofiber	Resistive	Yes	11%-95%	Unknown
Multilayer Graphene	Electronspun polyamide (PA) 66	Resistive	Yes	0.1%-90%	Unknown
SWCNT/PVA filaments	SDS	Resistive	No	60%-100%	Unknown/40s
Micro-carbonized bamboo particles	α-lumina substrates with platinum electrodes	Resistive	No	0%-96%	<2 min/<2 min
Two kinds of Biochar/PVP	Ceramic	Resistive	No	5%-100%	1 min/1 min
Porous Ionic Membrane	porous polydimethylsiloxane (PDMS) film	Resistive	Yes	10.89%-81.75%	0.4s/2.6s
GO	Microscale interdigitated electrodes	Capacitive	No	15%-95%	10.5s/41s
Cleancool yarn–shaped sensor with biaxial-sheathed yarn-shaped structure		Capacitive	Yes	6%-97%	3.5s/4s
SnS2/RGO	Flexible PET	Resistive	Yes	0%-97%	33%RH: 4s/3s 87%RH: 6s/15s
PDA	PET	Resistive	Yes	5%-55%	0.15s/0.25s

Table 1. Cross-sectional comparison of different sensing materials in humidity sensor

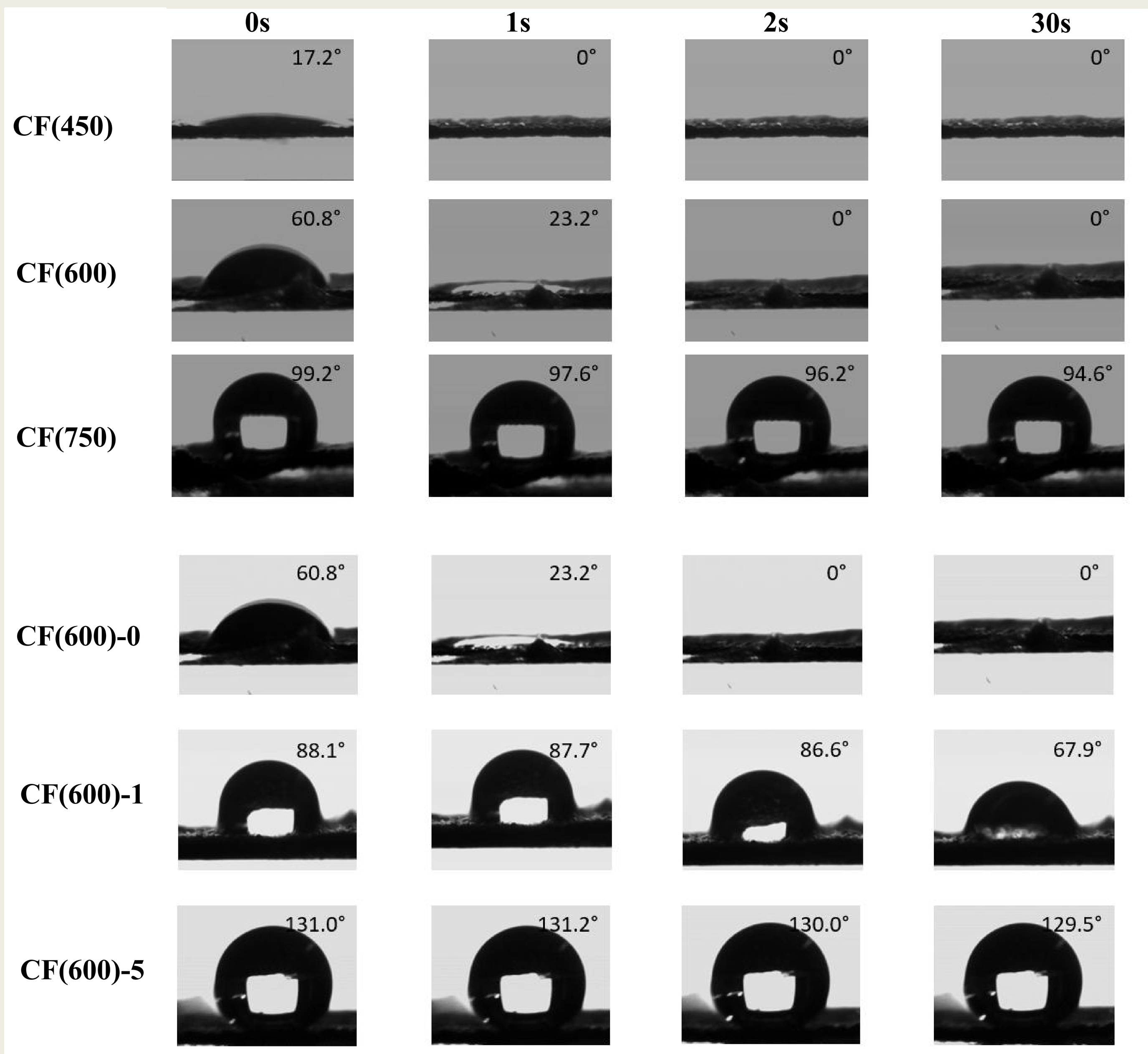

Figure 4. Water contact angle of CF(450), CF(600), CF(750), CF(600)-1 and CF(600)-5 samples

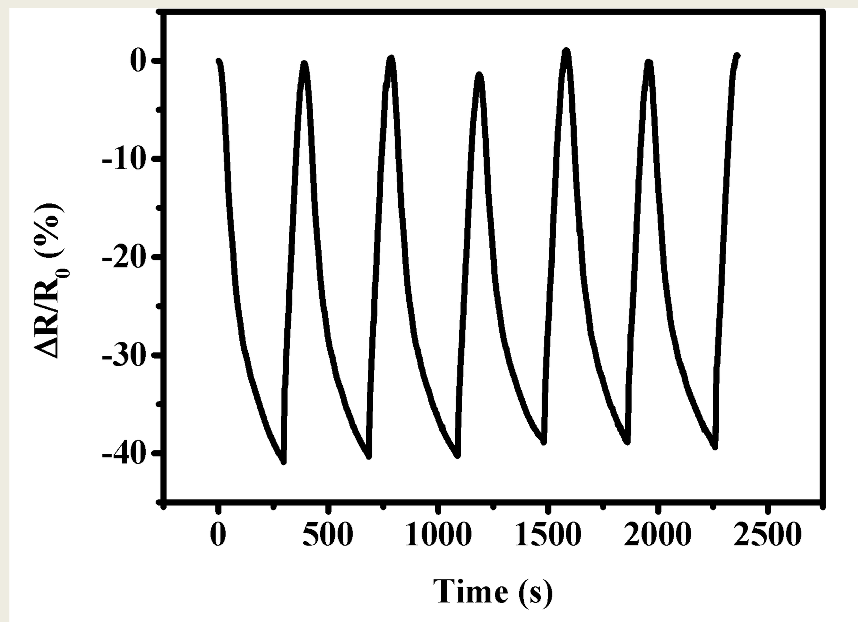

Figure 5. Repeatability test of CF(600) sample

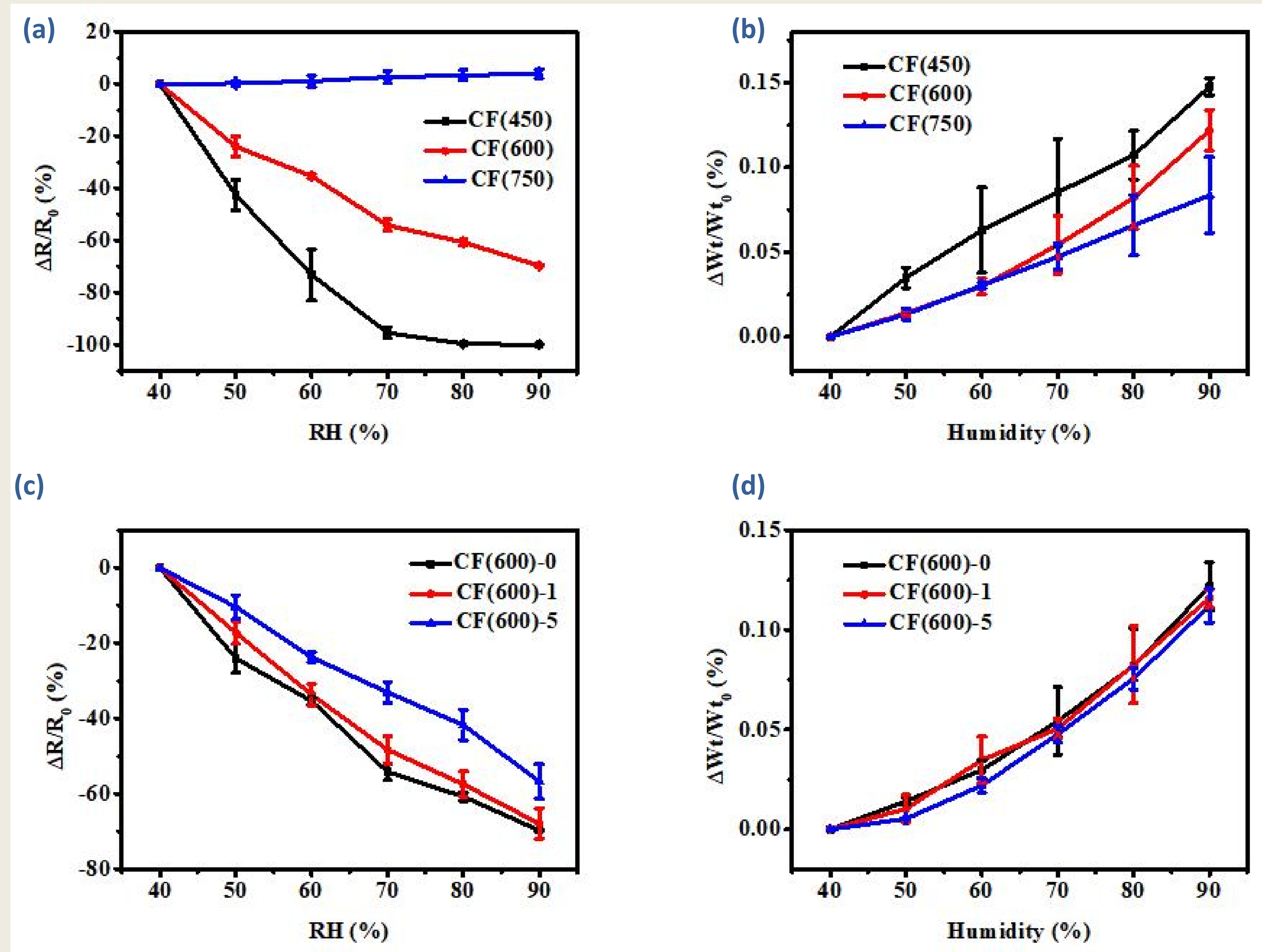

Figure 6. (a)Resistance-moisture curves of CF(450), CF(600) and CF(750) samples. (b)Weight gain with increasing humidity of CF(450), CF(600) and CF(750) samples. (c)Resistance-moisture curves of CF(600)-0, CF(600)-1 and CF(600)-5 samples. (d)Weight gain curves of CF(600)-0, CF(600)-1 and CF(600)-5 samples.

CONCLUSIONS

- Overall, among five samples, CF(450), CF(600), CF(750), CF(600)-1 and CF(600)-5, the highest reaction sensitivity is found in CF(600). It is also most suitable for making humidity sensor. And it is supposed that the reason for the difference of performance is probably linked to oxygen-containing groups of viscose.
- After treatment with hydrophobic reagents, the performance of the samples deteriorates. The longer the hydrophobic reagent is sprayed, the worse the performance of the sample.

Reference

Xu, L. et al., Chemical engineering journal **2021**, 412, 128639./Wu, J. et al., ACS applied materials & interfaces **2019**, 11, 4242/Zhao, X. et al., ACS nano **2020**, 14, 8793./Huang, X. et al., ACS applied materials & interfaces **2019**, 11, 24533./Lu, L. et al., Advanced materials **2021**, 33, 16./Zhou, G. et al., ACS applied materials & interfaces **2017**, 9, 4788./Afify, A.S. et al., Sensors and actuators. B **2017**, 239, 1251./Ziegler, D. et al., Chemosensors **2017**, 5, 35./Li, T. et al., Advanced science **2017**, 4, 1600404./Bi, H. et al., Scientific reports **2013**, 3, 2714./ Ma, L. et al., Advanced functional materials 2019, 29, 1904549./Zhang, D. et al., Nano energy **2020**, 67, 104251./Li, L. et al., Nano letters **2019**, 19, 5544.