

Application of Micro-mass Monitoring in Corrosion of Nanomaterials and its Innovation

Xianjun Rong^{1, a}, Changkun Zhu^{2, b}

¹ School of University of Shanghai for Science and Technology, Shanghai 200082, China

² School of Ningbo University, Ningbo 315000, China

^akrabs0905aaa@163.com, ^b18568285793@163.com

Abstract

In this paper, based on the microscopic mass change monitoring technology, the microscopic mass method was used for the first time to detect the mass change of adsorbed nitrogen dioxide by nanowire materials in real time and to calculate the kinetics of the reaction process of adsorption of acidic gases by its nanomaterials by combining with the Arrhenius equation and adsorption isotherm theory. We conclude that the activation energy of its corrosion process is 75kJ/mol, and we find that it is irrecoverable after adsorption of nitrogen dioxide through multi-concentration real-time monitoring, and the corrosion rate of copper nanowires in nitrogen dioxide is extremely fast, and the corrosion resistance is still a big challenge.

Keywords

Mass Method; Corrosion; Copper Nanowires; Activation Energy.

1. Introduction

With the development of science and technology and the human requirements for visual effects, smart device performance and renewable energy exploration continue to improve, the traditional metal nanowires no longer meet the needs of the science and technology market, so the development of nanomaterials with lower resistance and excellent optical properties is the current science and technology market urgently need to be resolved, in this regard, we found that silver nanowires are due to its unique physicochemical, optical and mechanical properties[1] etc. are widely used as conductive thin-film materials for displays[2-4], solar cell electrodes (SC)[5-8] and chip materials[9-11].

Currently, nanomaterials still face the problem of material corrosion. Corrosion constrains the development of human science and technology, and the global economic losses due to corrosion are huge every year: according to a 2016 study by NACE International, the economic losses caused by corrosion amount to 2.5 trillion dollars per year. The economic loss caused by material atmospheric corrosion accounts for more than half of the total sum of all types of environmental corrosion, and material atmospheric corrosion causes significant economic losses[12]. In addition to this, corrosion also brings a number of safety problems to human beings, such as structural safety problems[13-15], environmental pollution[16-18], resource waste[19-21], and technological development barriers[22].

Therefore, this paper introduces a novel means of testing material corrosion, through which the microscopic corrosion of nanomaterials is studied in depth, this paper is based on the mass change monitor to study the corrosion dynamics of nanomaterials, which will break the traditional means of metal corrosion research, and will be a deeper study of atmospheric corrosion encountered in the process of nanomaterials application, and this technology will definitely point out a clear direction for the exploration of nanomaterial corrosion.

2. Experimental Section

2.1 Material

In this paper, the research object is silver nanowire, Fig. 1a is the SEM picture of nanowire, which was prepared with slender and uniform diameter, Fig. 1b is the transmission electron microscope picture of silver nanowire, whose lattice spacing is 0.238 nm, which corresponds to the XRD in the picture of Fig. 1d to get the {111} crystalline surface, and through the counting of the diameter of the nanowire in the image, the diameter of the nanowire is in the range of 223 nm, and Fig. 1e is the picture of the nanowire before reaction on the cantilever beam. Fig. 1e shows the optical microscope image of the nanowire on the cantilever beam before the reaction, and Fig. 1f shows the optical microscope image of the nanowire on the cantilever beam before the reaction, through the observation, we found that before and after the reaction, the surface of the nanowire appeared black patches, we believe that it is in the nitrogen dioxide atmosphere caused by the morphological changes, so the process of the change is very worthy of study, we will introduce a new corrosion research technology, the micro-mass change monitor to carry out real-time data recording of the quality change of the nanomaterials. In this study, we will introduce a new technique for corrosion research, the micro-mass change monitor, to record the mass change data of nanomaterials in real time, and at the same time, we will calculate the slope of the mass change and the corrosion kinetics by combining with Arrhenius equation.

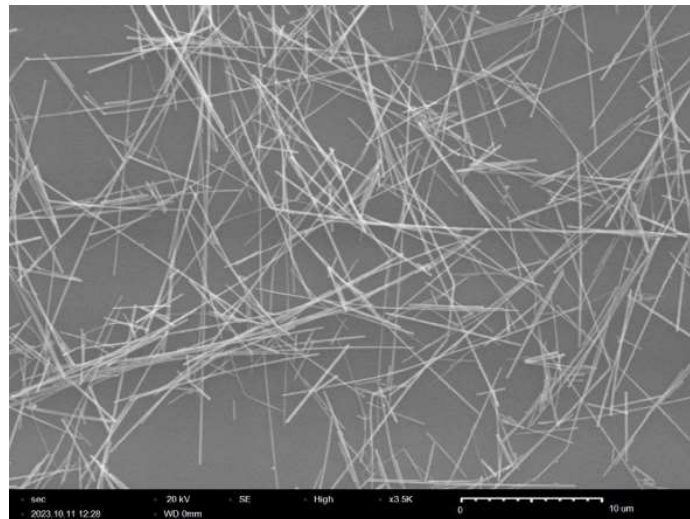


Fig.1 SEM of Cu NWs

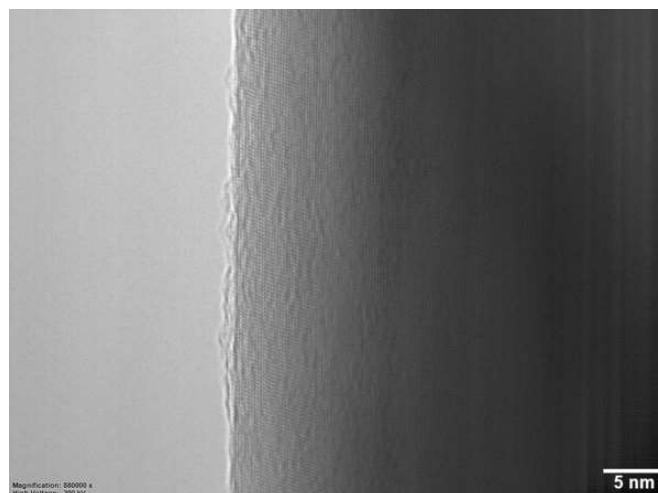


Fig.2 TEM of Cu NWs

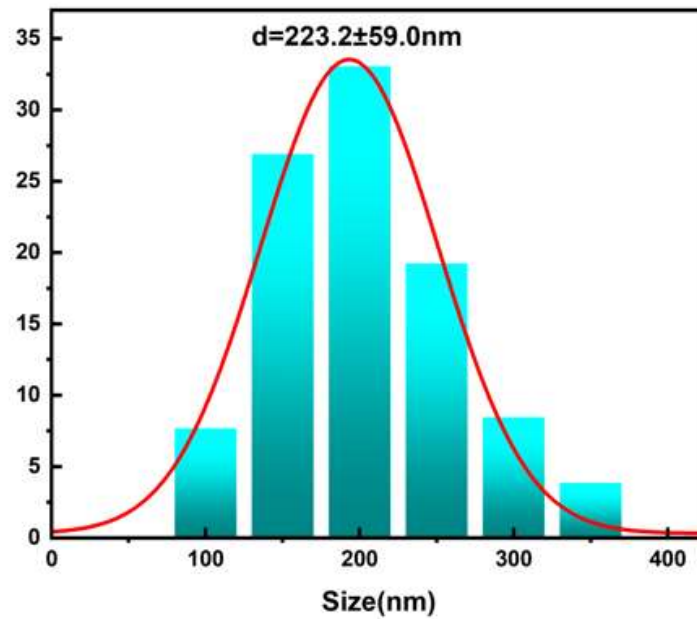


Fig.3 Size of Cu NWs

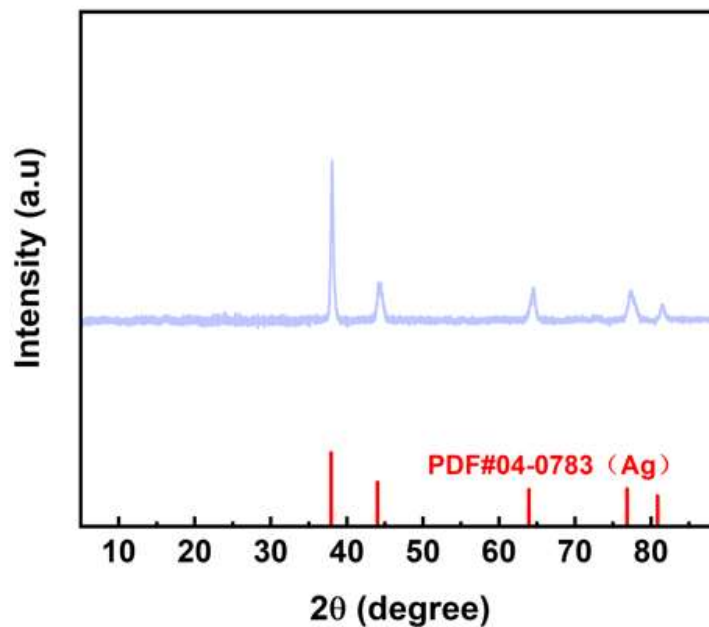


Fig.4 XRD of Cu NWs

2.2 Test

In this paper, through the micro-mass change monitor on the point on the sample to be tested after waiting for its change in the air after the stabilization of the switch to different concentrations of nitrogen dioxide gas, Fig. 2a-e for the different concentrations of the material adsorption of the gas and the reaction to the process of increasing the weight record, which can be observed with the change of concentration, the numerical value of the progress of the reaction Observation of its longitudinal coordinates can be seen as a result of the increase in concentration with the higher the value of the

progress of the reaction. The summary of its adsorption can be seen in Table 1, in addition to this, the gas sensing of nanowires has also been explored, and its corresponding degree of DDVP is detectable, and its response value is 1120s, which is a poor performance, but we provide a new method to study the gas sensitivity, which can be explored through the mass change caused by adsorption of gases on the surface of the material, which is distinctive from the traditional gas sensing. In the future, we will explore the field of gas sensitization by this new test method and open up a new research field of mass-based gas sensitization.

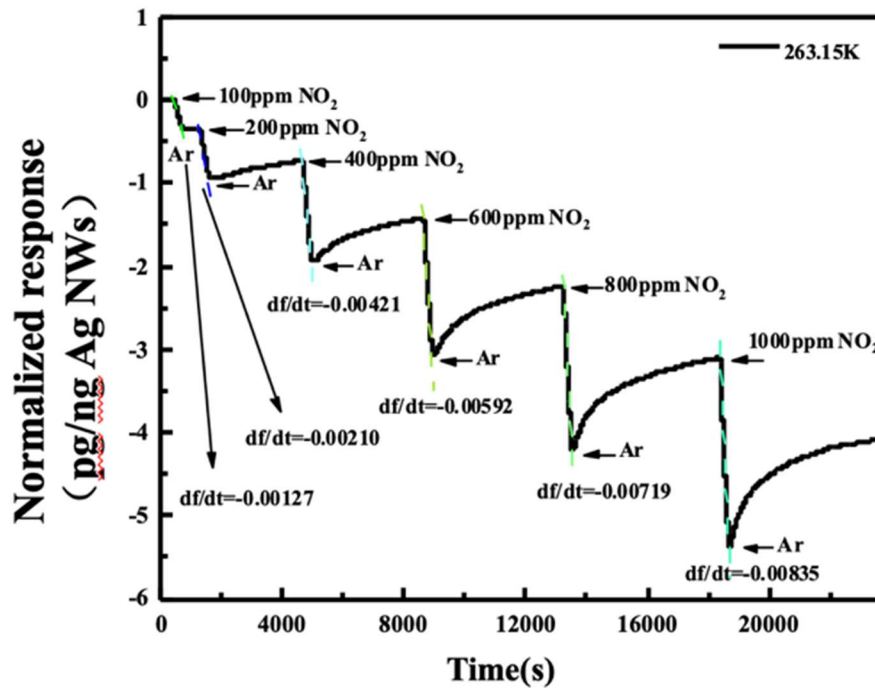


Fig.5 Response of Cu NWs with different concentration NO in 263K

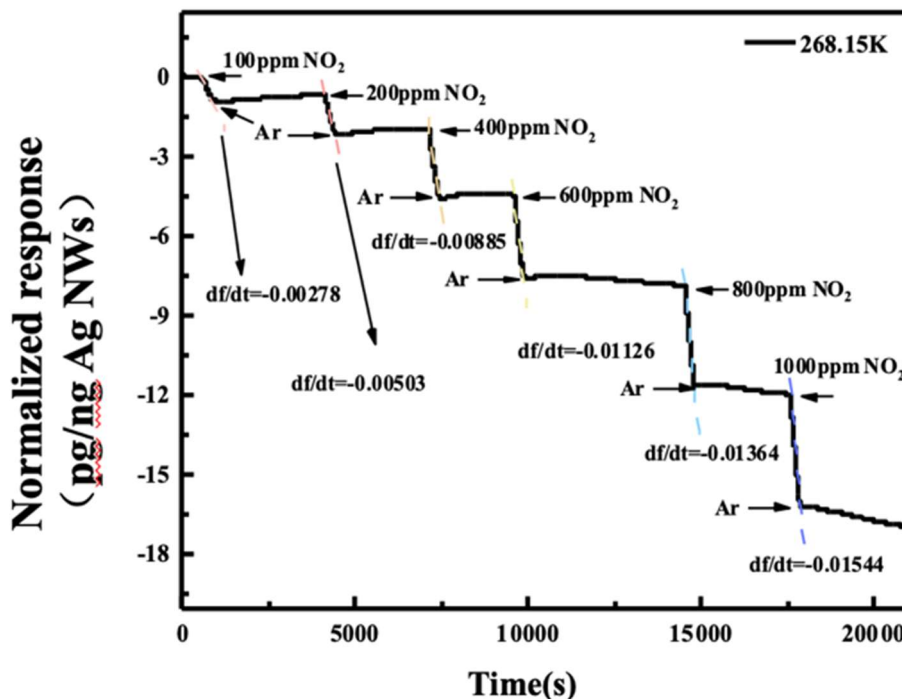


Fig.6 Response of Cu NWs with different concentration NO in 268k

We through the same material to different temperatures under the material adsorption rate curve calculation, we through the different point sample mass monitor into different temperatures for the same concentration of nitrogen dioxide gas probe its corrosion rate, and ultimately the resulting data through the normalization of the mass number processing, the final reaction rate are in a benchmark unit and ultimately combined with the Arrhenius equation calculating the activation energy, which 268k temperature The reaction rate is -0.01761 at 268k and -0.02644 at 263k, resulting in an activation energy of $E_a = 47.6855$ KJ/mol.

In addition to explore the concentration of silver nanowires adsorption effect, more probe its corrosion process in the initial corrosion rate, and through the corrosion rate combined with the Arrhenius equation to calculate the activation energy, the activation energy calculation significance mainly lies in the ability to intuitively see the reaction speed as well as the material at different temperatures under the reaction rate of the probe, which brings a new measure of nanomaterials working temperature.

Table 1. Summary E_a of different concentration NO in 263k/268k, respectively

Concentration(ppm)	Temperature(k)	Slope	Activation energy(kcal/mol)
100	263	-0.00127	91.9
	268	-0.00278	
200	263	-0.00210	102.5
	268	-0.00503	
400	263	-0.00421	87.2
	268	-0.00885	
600	263	-0.00719	75.4
	268	-0.01126	
800	263	-0.00719	75.1
	268	-0.01364	
1000	263	-0.00835	72.1
	268	-0.01544	

3. Conclusion

Copper nanowire material in the atmosphere is more prone to be corroded by nitrogen dioxide gas molecules, so this paper investigates its activation energy in the corrosion process, by calculating its adsorption isotherm, as well as its activation energy, its activation energy in the 75kcal/mol or so, this paper and carried out a gas-sensitive test of the DDVP, and found that the response is slower, but has a certain potential for the gas-sensitive research materials, and finally, this paper's means of research will be a new direction for future research on activation energy.

Acknowledgments

Natural Science Foundation.

References

- [1] Ha, H.; Amicucci, C.; Matteini, P.; Hwang, B. Mini review of synthesis strategies of silver nanowires and their applications. *Colloid and Interface Science Communications* 2022, 50, 100663.

- [2] Kwak, I. C.; Cho, W. H.; Kwon, T. H.; Kim, M. J.; Lee, J. I.; Roe, D. G.; Ho, D. H.; Jo, S. B.; Kang, M. S.; Kim, B.; et al. Allrounder Strategy for Photopatterning Silver Nanowire Network Electrodes. *Chemistry of Materials* 2023, 35 (1), 71-80.
- [3] Wang, W.; Yang, Z.; Gu, Y.; Wu, Z.; Wang, G.; Chen, G.; Huang, M.; Xu, C.; Ye, C.; Zhang, W.; et al. Enhanced stability of silver nanowire transparent conductive films against ultraviolet light illumination. *Nanotechnology* 2021, 32 (5), 055603.
- [4] Kim, H.; Seo, M.; Kim, J.-W.; Kwon, D.-K.; Choi, S.-E.; Kim, J. W.; Myoung, J.-M. Highly Stretchable and Wearable Thermo-therapy Pad with Micropatterned Thermochromic Display Based on Ag Nanowire–Single-Walled Carbon Nanotube Composite. *Advanced Functional Materials* 2019, 29 (24), 1901061.
- [5] Fu, Q.; He, J.; Zheng, J.; Xing, Y.; Wang, Q.; Xiong, J.; Zhu, W.; Xuan, R.; Fu, A.; Gan, X.; et al. Robust transparent Ag nanowire electrode for bifacial perovskite solar cells. *Journal of Alloys and Compounds* 2024, 1001, 175058.
- [6] Wu, J.; Que, X.; Hu, Q.; Luo, D.; Liu, T.; Liu, F.; Russell, T. P.; Zhu, R.; Gong, Q. Multi-Length Scaled Silver Nanowire Grid for Application in Efficient Organic Solar Cells. *Advanced Functional Materials* 2016, 26 (27), 4822-4828.
- [7] Wu, J.; Que, X.; Hu, Q.; Luo, D.; Liu, T.; Liu, F.; Russell, T. P.; Zhu, R.; Gong, Q. Organic Solar Cells: Multi-Length Scaled Silver Nanowire Grid for Application in Efficient Organic Solar Cells (*Adv. Funct. Mater.* 27/2016). *Advanced Functional Materials* 2016, 26 (27), 4806-4806.
- [8] Lee, E.; Ahn, J.; Kwon, H.-C.; Ma, S.; Kim, K.; Yun, S.; Moon, J. Solar Cells: All-Solution-Processed Silver Nanowire Window Electrode-Based Flexible Perovskite Solar Cells Enabled with Amorphous Metal Oxide Protection (*Adv. Energy Mater.* 9/2018). *Advanced Energy Materials* 2018, 8 (9), 1870037.
- [9] Karimi-Chaleshtori, R.; Nassajpour-Esfahani, A. H.; Saeri, M. R.; Rezai, P.; Doostmohammadi, A. Silver nanowire-embedded PDMS with high electrical conductivity: nanowires synthesis, composite processing and electrical analysis. *Materials Today Chemistry* 2021, 21, 100496.
- [10] Yang, P.; Peng, J.; Chu, Z.; Jiang, D.; Jin, W. Facile synthesis of Prussian blue nanocubes/silver nanowires network as a water-based ink for the direct screen-printed flexible biosensor chips. *Biosensors and Bioelectronics* 2017, 92, 709-717.
- [11] Yang, C.; Gu, H.; Lin, W.; Yuen, M. M.; Wong, C. P.; Xiong, M.; Gao, B. Silver Nanowires: From Scalable Synthesis to Recyclable Foldable Electronics. *Advanced Materials* 2011, 23 (27), 3052-3056.
- [12] XU Di, Y. X., LI Qing, CHENG Xuequn, LI Xiaogang. Review on Corrosion Test Methods and Evaluation Techniques for Materials in Atmospheric Environment. *Journal of Chinese Society for Corrosion and protection* 2022, 42 (3), 447-457.
- [13] Yu, S.; Liu, Y.; Chen, Q.; Yu, X.; Hyun, G.; Wang, S.; Ye, Y.; Feng, J.; Chen, Z.; Jiang, F.; et al. Damage-Tolerant Wood Layers for Corrosion Protection of Metal Structures. *Nano Letters* 2024, 24 (1), 245-253.
- [14] Adedipe, O.; Brennan, F.; Kolios, A. Review of corrosion fatigue in offshore structures: Present status and challenges in the offshore wind sector. *Renewable and Sustainable Energy Reviews* 2016, 61, 141-154.
- [15] Wang, C.; Elsayed, E. A. Stochastic modeling of corrosion growth. *Reliability Engineering & System Safety* 2020, 204, 107120.
- [16] Ruiz Muñoz, G. A.; Sørensen, J. D. Probabilistic inspection planning of offshore welds subject to the transition from protected to corrosive environment. *Reliability Engineering & System Safety* 2020, 202, 107009.
- [17] Hussain, R. R.; Al-Negheimish, A.; Alhozaimy, A.; Singh, D. D. N. Corrosion characteristics of vanadium micro-alloyed steel reinforcement bars exposed in concrete environments and industrially polluted atmosphere. *Cement and Concrete Composites* 2020, 113, 103728.
- [18] Dong, Y.; Song, G.-L.; Zhang, J.; Gao, Y.; Wang, Z. M.; Zheng, D. Biocorrosion induced by red-tide alga-bacterium symbiosis and the biofouling induced by dissolved iron for carbon steel in marine environment. *Journal of Materials Science & Technology* 2022, 128, 107-117.
- [19] Shokri, A.; Sanavi Fard, M. Corrosion in seawater desalination industry: A critical analysis of impacts and mitigation strategies. *Chemosphere* 2022, 307, 135640.
- [20] Xu, Y.; Huang, Y.; Cai, F.; Lu, D.; Wang, X. Study on corrosion behavior and mechanism of AISI 4135 steel in marine environments based on field exposure experiment. *Science of The Total Environment* 2022, 830, 154864.

- [21] Sukanya, R.; Barwa, T. N.; Luo, Y.; Dempsey, E.; Breslin, C. B. Emerging Layered Materials and Their Applications in the Corrosion Protection of Metals and Alloys. *Sustainability* 2022, 14 (7), 4079.
- [22] Liu, X.; Lei, X.; Wang, Y.-G.; Ding, Y. Prevention of Na Corrosion and Dendrite Growth for Long-Life Flexible Na–Air Batteries. *ACS Central Science* 2021, 7 (2), 335-344.