Water-processable polyaniline as versatile polymer sensing material for ultrasensitive and highly reversible detection of ammonia

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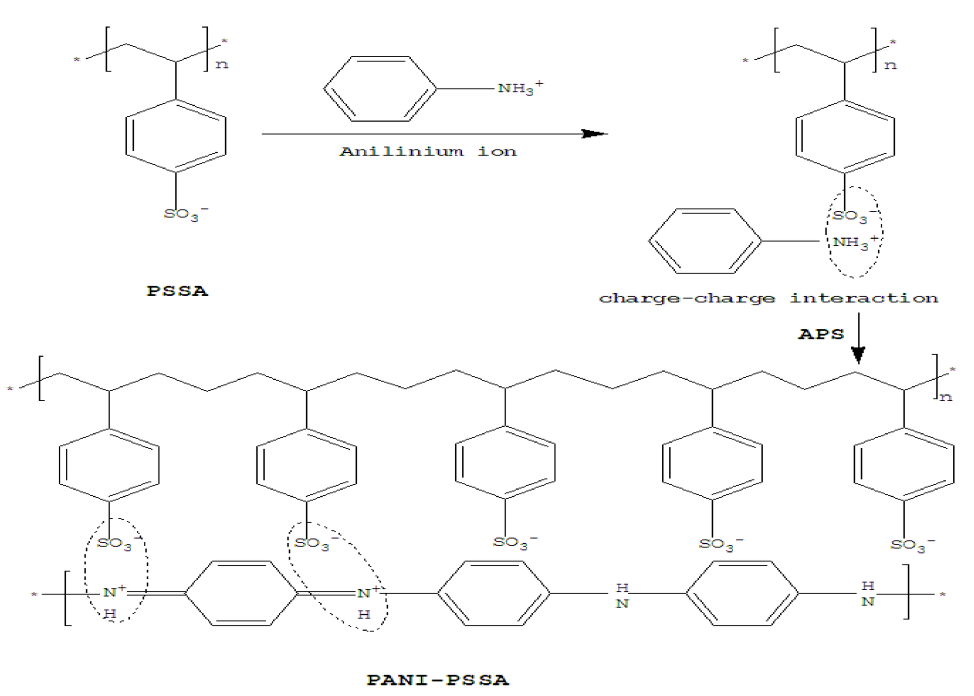
Introduction

NH_3 is a common poisonous gas with a threshold limit of 25 ppm for exposure of 8 h. High performance NH_3 sensors with high sensitivity, fast response, good reversibility and stability are highly desired. Polyaniline (PANI) is a versatile polymeric sensing material responsive to acid/base and reducing/oxidizing gases, such as NH_3, HCl, NO_2. However, its poor processibility hinders the applications. Here we report water-processable PANI prepared with polyacid template which is featured with ultrasensitive and highly reversible detection of NH_3.

Experimental



Scheme 1 Preparation of water-soluble PANI-PSSA.

Processable PANI-PSSA was synthesized by solution polymerization of aniline with ammonium persulfate as an oxidant and poly(styrene sulfonic acid) (PSSA) as a soft template [1]. The molar ratio of PSSA /aniline was controlled at 0.5/1;1/1; 2/1; 3/1; 4/1, denoted as Sample 0 to Sample 4, respectively. Gas sensors were fabricated by dip coating the polymer solution on interdigital gold electrodes.

Characterization of PANI-PSSA

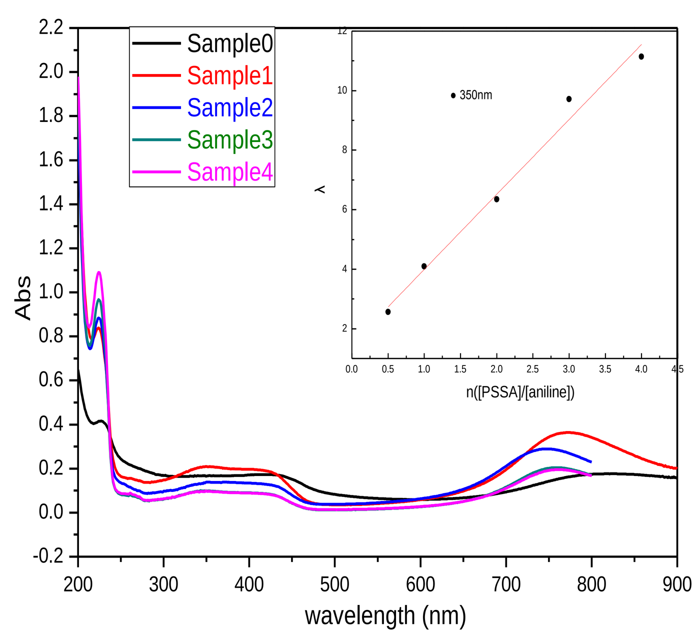


Figure 1. UV-vis spectra of PANI-PSSA

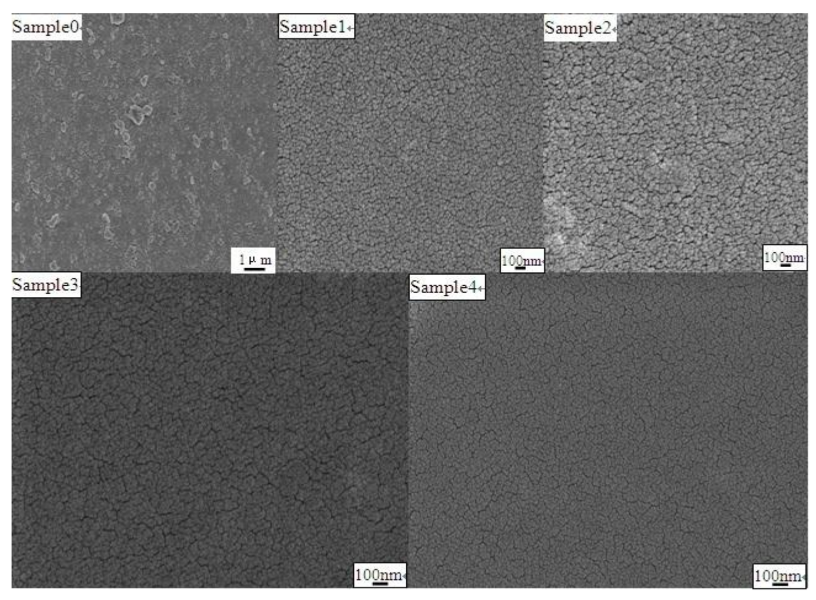


Figure2. SEM images of PANI-PSSA

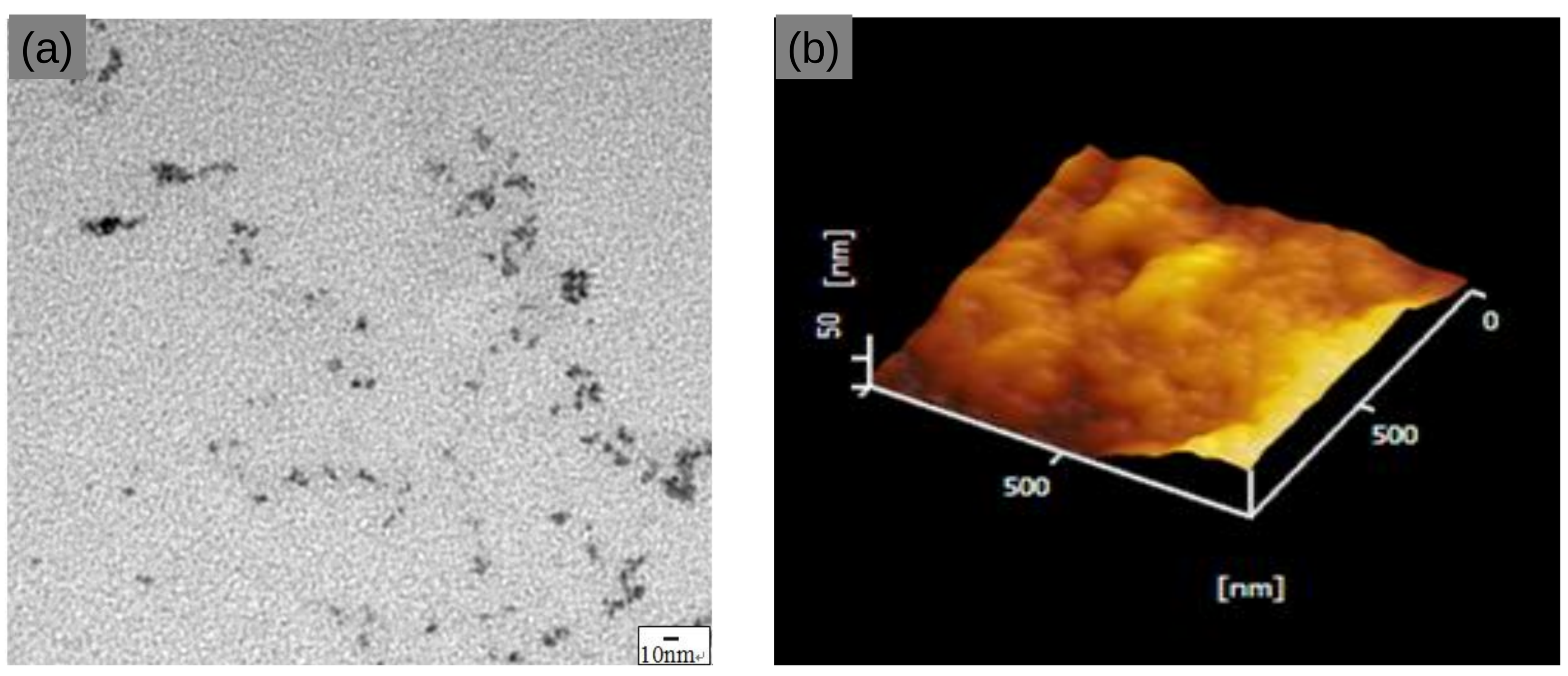


Figure3. TEM(a) and AFM (b) images of PANI-PSSA

UV–vis spectra show that PANI-PSSA is in doping state. Uniform and smooth films composed of water-soluble PANI-PSSA nanoparticles sizing ~ 20nm are obtained as revealed by SEM, TEM observations and AFM measurements.

NH_3 sensing properties of PANI-PSSA

1. Electrical response to NH_3 and interference of humidity

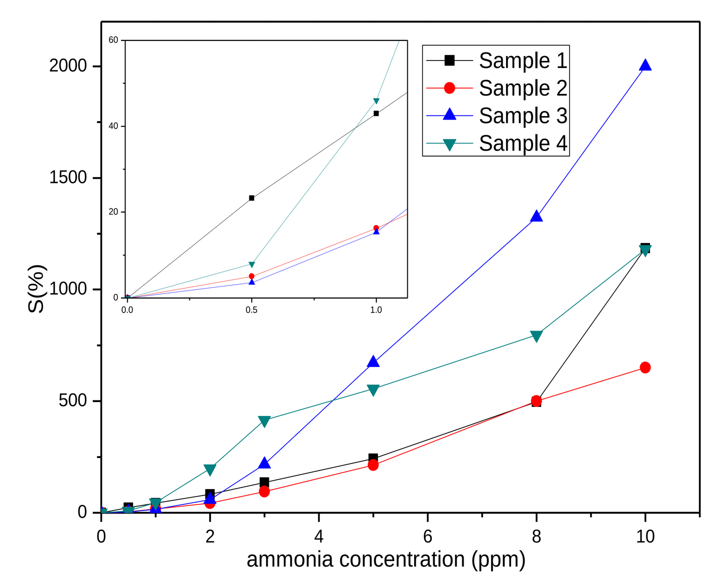


Figure 4. Sensitivity vs [NH_3] of sample 1-4

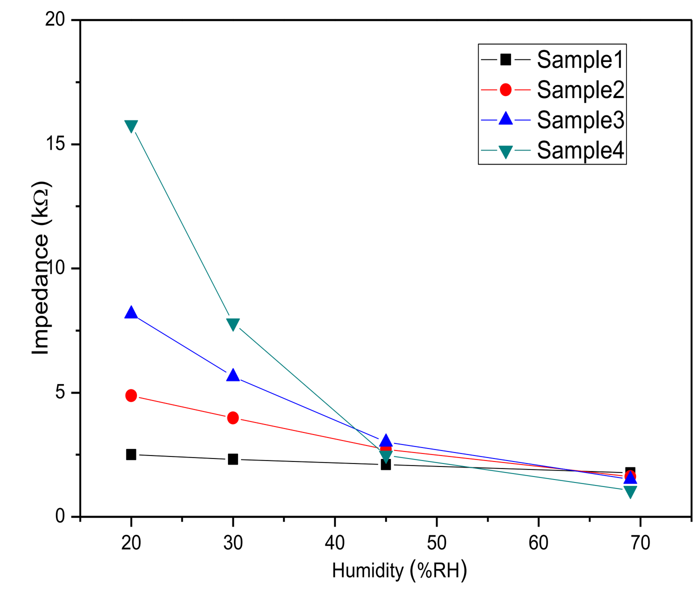


Figure 5. Humidity response to Sample 1-4

Sample 1 showed the highest sensitivity to 0.5 ppm NH_3 and was almost free from the interference of humidity, thus was employed for the following investigations.

2. Effect of [PANI-PSSA] on its sensitivity to NH_3 and selectivity of PANI-PSSA

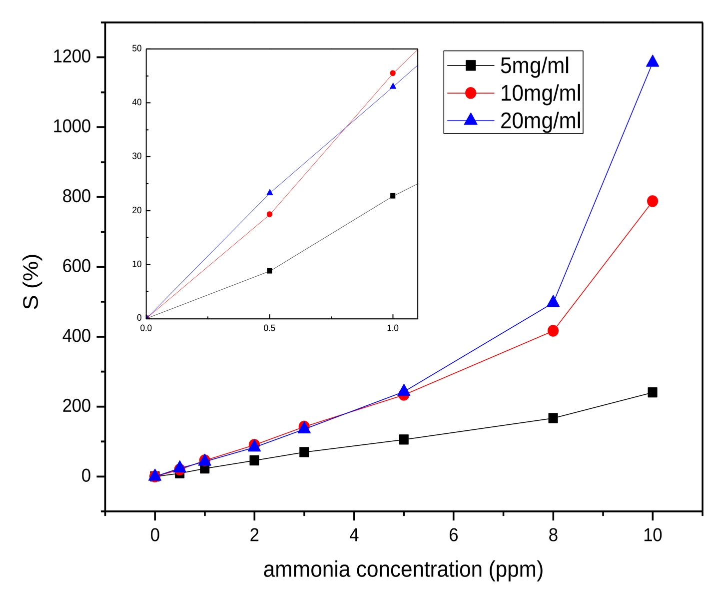


Figure 6. Effect of PANI-PSSA concentration on its sensitivity to NH_3

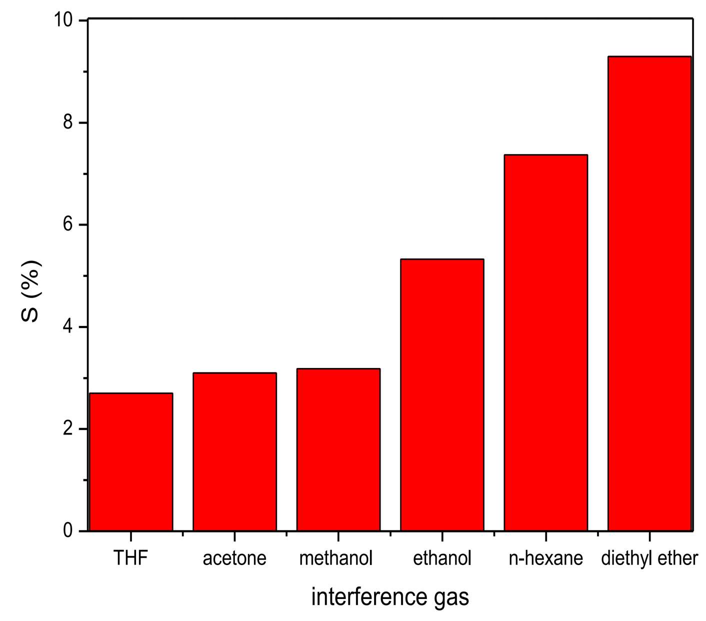


Figure 7. Sensitivity of PANI-PSSA to interference gases of 5000 ppm

A positive correlation between PANI-PSSA concentration and sensitivity was found. The sensor showed low sensitivity (less than 10%) to various interference gases of high concentration (5000 ppm), suggestive of its good selectivity.

3. Reversibility and Repeatability

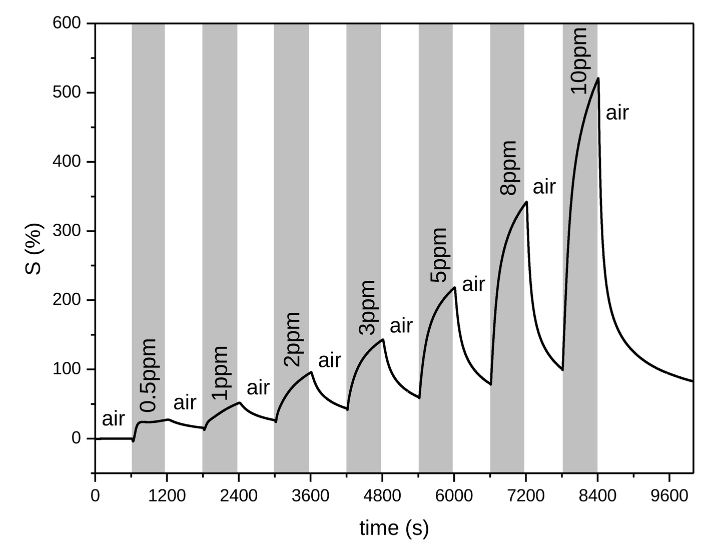


Figure 6. Dynamic response to NH_3

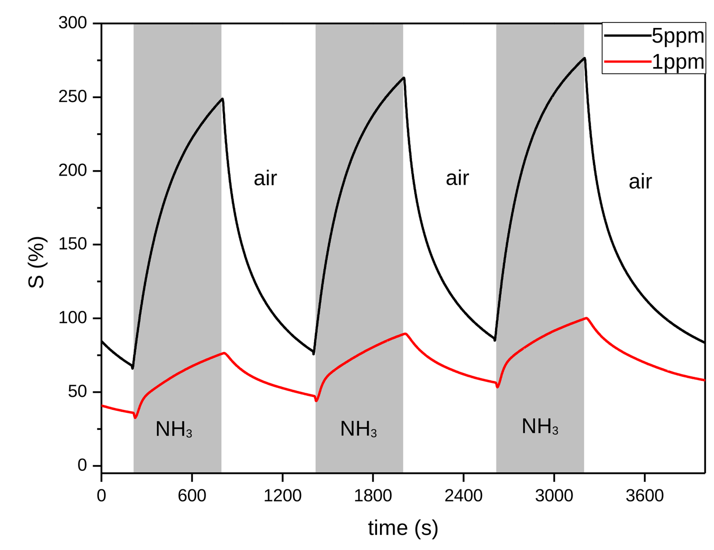


Figure 7. Cyclic tests of dynamic responses to NH_3

PANI-PSSA exhibited rapid response, fast and reversible recovery. In addition, it revealed very good repeatability to 1 ppm NH_3.

Conclusions

Water-processable PANI could be facilely prepared with PSSA as the dopant and template, and employed to construct thin film gas sensor. Under optimal conditions, it is featured with ultrahigh sensitivity (23.3% towards 0.5 ppm NH_3 , with a theoretical limit of detection of 200 ppb), high reversibility and good repeatability even to NH_3 as low as 1 ppm.

Acknowledgements

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References

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