An enhanced MEMS-based gas ionization sensor by seedless growth of ZnO nanowires

S.Bakhshi Sichani[1,2], A.Nikfarjam[1], and H.Hajghassem[1]

[1] MEMS & NEMS Laboratory, Faculty of New Sciences & Technologies, University of Tehran, P.O. Box 14395-1561, Tehran, 33316-196363, Iran

[2] Laboratory for Soft Matter and Biophysics, Department of Physics and Astronomy, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium

In the present research, a planar MEMS-based gas ionization sensor based on the seedless growth of zinc oxide nanowires is reported. Selective and seedless Zinc Oxide nanowires were grown on lithography based gold electrodes by the hydrothermal method. As a planar gas ionization sensor (GIS), low operating voltage with fast response and recovery times were achieved for argon, helium, air + 32 % RH, nitrogen, dry air, oxygen, and carbon dioxide. Sharp tips of ZnO nanowires reduce the breakdown voltage by local field emission enhancement as represented for Helium and Argon to about 115 V and 85 V respectively.

Introduction

Gas Ionization Sensors (GISs) as a physical gas sensor represent superior responses for several gases including noble ones with poor adsorption energy that chemical gas sensors are incapable to detect. Although GISs suffer from low sensitivity, they are insensitive to environmental changes and demonstrates ultra-short response and recovery times at room temperature [1]. To reduce the operating voltage of GIS we can either reduce the gap distances between electrodes or increase the field emission phenomenon by using sharp-tip electrodes by employing nanostructures. The high local electric field at the sharp-tips expels some electrons via tunneling process which can facilitate the ionization process [2].

ZnO Nanowire as a one-dimensional nanostructure is widely employed in GISs to enhance the local electric field to reduce the gas breakdown voltage. Zinc oxide nanowire with wurtzite lattice structure is an important n-type semiconductor with a wide band gap (3.7 eV), which has prominent applications in electronics, photonics, piezotronics, biology, and energy harvesting. ZnO nanowire growth via hydrothermal method is a very cost-effective and low-temperature mechanism which can be used on a wide variety of substrates such as polymers, silicon, glass, quartz, etc. Normally, a pre-deposited ZnO thin film as a seed layer is essential in hydrothermal approach to facilitate the nucleation and subsequent growth of ZnO nanowires. However, in this study, without any seeding layer, the roots of ZnO nanowires fuse together due to the initial growth of ZnO thin film on the surface of the patterned gold layer [3]. The novel introduced GIS in this research is a MEMS-based physical gas sensor, which is consisted of two planar single triangular gold electrodes facing each other with desired gap distance. The electrodes are modified by selective and seedless growth of Zinc oxide nanowires to enhance the local electric field at their sharp tips, as well as to protect the gold electrodes against sputtering in gas ionization process [4].

Results and Discussion

The fabricated GIS at this research was tested in a cylindrical sealed chamber in atmospheric pressure at room temperature. Several gases such as noble ones were introduced to the sensor chamber and the breakdown voltage of the sensor was measured by a Keithley 6487 source and measurement unit. The GIS with 10 µm gap distance was tested by argon, helium, air + 32 % relative humidity, nitrogen, dry air, carbon dioxide, and oxygen. The breakdown voltages of 280 V, 360 V, 390 V, 440 V, 460 V, 510 V, and 530V were achieved, respectively. Figure 1 demonstrates different breakdown voltages for various gases. Sharp tip ZnO nanowires made a significant decrease in breakdown voltage of Helium from 465 V to 350 V and argon from 395 V to 310 V by field emission enhancement.

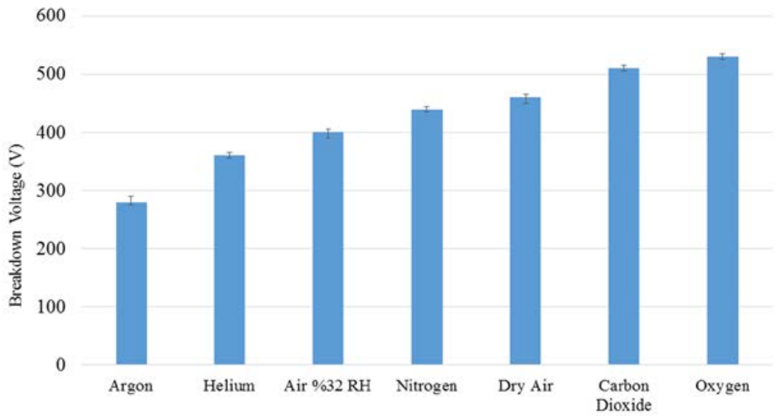

Figure 1: breakdown voltages for several gases with 10µm gap inter-electrodes GIS.

Conclusions

In this work, a novel planar gas ionization sensor (GIS) based on selective and seedless growth of ZnO nanowires on Au electrodes with 10 µm inter-electrode gap distance was presented. The novel GIS exhibited excellent sensitivity, selectivity, and reliability especially for gases with low adsorption energy. Sharp-tip ZnO nanowires would not only reduce the working voltage of the sensor (about115 V for He) but also protect Au planar electrodes against sputtering and deformation in gas ionization atmosphere.

References

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