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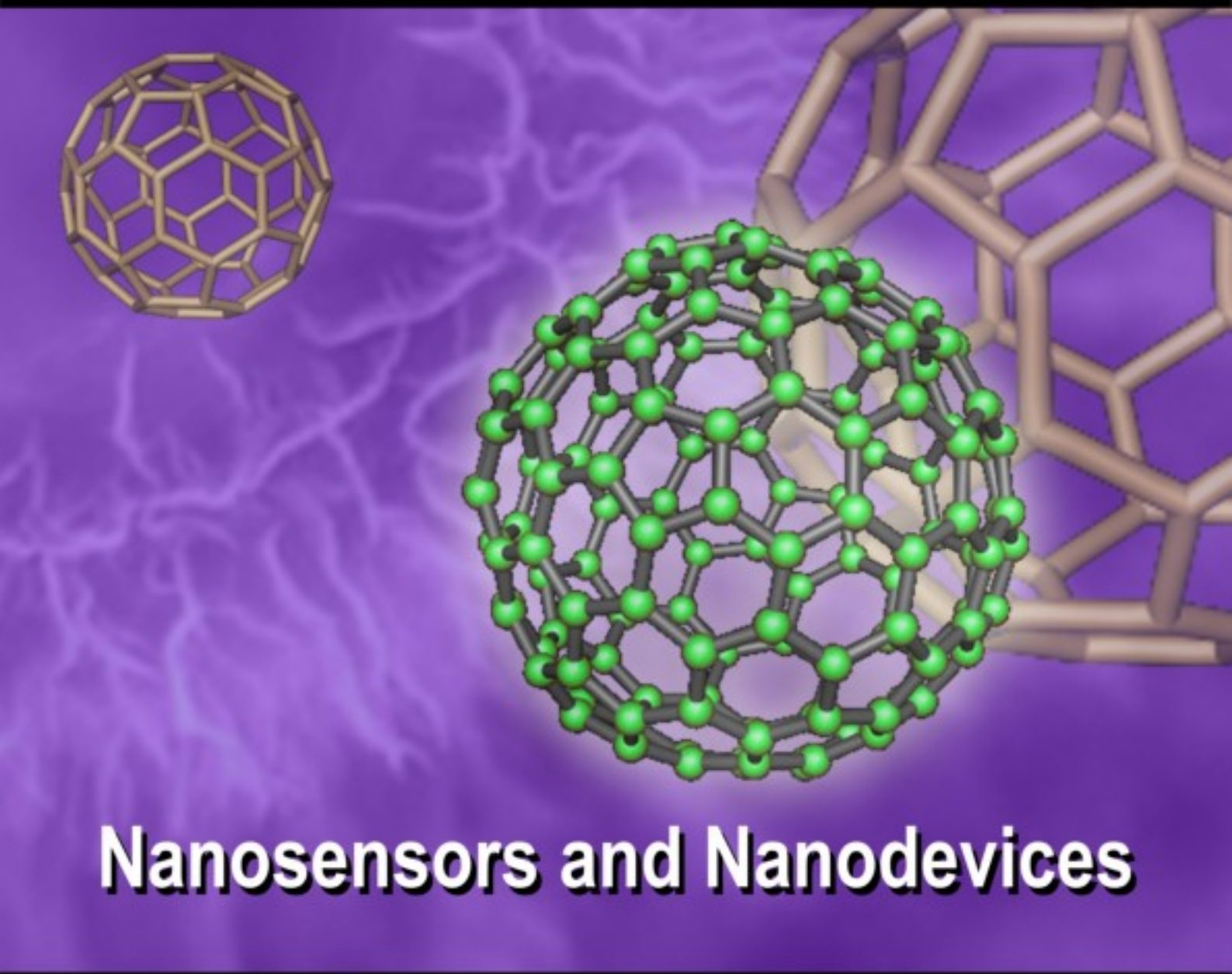

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Hydrogen Sensor Based on Carbon Nano-tube Fortified by Palladium

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Abstract: In this paper single-wall carbon Nano-tubes (SWNT) were prepared by using chemical – Thermal vapor deposition method and utilizing molybdenum and iron catalysts and silica alumina – base. Methane was passed over catalyst in optimum condition including passing speed equal to 4 lit/min and pressure of 1.27 bar for 2-25 minutes and temperature of furnace was equal to 980 °C and prepared carbon Nano-tubes were sublimated in 1600 °C to achieve 70 % yields. Diameter and specific area of Nano-tubes were 2-15 nm and 400-560 m^2/g respectively. Various quantities of palladium chloride were inserted in carbon used for prepared Nano-tubes by utilizing vacuum evaporation which its optimum quantity was 0/10 g in order to enhance sensitivity of carbon Nano-tubes relative to hydrogen to make sensors appropriate for low temperatures. For investigation instruments and determining physical properties, XRD, AFM, SEM and TEM equipments have been applied and prepared. Hydrogen sensor is simple, low cost and ready to use in various environment.

Keyword: Hydrogen sensor, Carbon Nanotube and Palladium.

1. Introduction

By discovering carbon Nano-tubes (CNT) during 1991-1993, a nonstop investigation was initiated on chemical and physical properties of this type of carbon Nano-tubes by studying *Raman* spectrum of carbon Nano-tubes. However, based on vibration and electronic characteristics on hybrid allotropy (pure sp2 and sp3) basis of graphite and diamond was cried out. Nevertheless, issues relevant to strong

and special vibration of Raman have been studied. In addition to Raman spectroscopy, several microscopic efforts may be beneficial for determining selective properties of carbon Nano-tubes including TEM (transmission electron microscopy), SEM (scanning electron microscopy) which are applied for determining carbon morphology of single-wall carbon Nano-tubes (SWNT) (2-5).In this paper, we used evaporation method for penetrating palladium in carbon Nano-tubes. Increasing palladium in carbon Nano-tubes results in enhancing sensor sensibility to hydrogen gas, and also it's utilization in low temperatures. Concentration of penetrated palladium in carbon Nano-tubes is proportional to sensibility of sensor toward hydrogen gas.

2. Experimental

After growing single-walled carbon Nano-tubes with chemical vapor deposition (CVD), we took (TEM) and found diameter of tubes are about 1-15 nm, then we examine Raman Spectroscopy and compared it with other references and found that it have 3-4 peaks and compared it with graphite Raman Spectroscopy and found that graphite has only one peak in 1582 cm^{-1} but single-walled carbon nanotubes have two peaks in this region one in 1573 cm^{-1} and one in 1573 cm^{-1} the first one corresponds to D mode and second corresponds to P mode completely conformed with single-walled carbon nanotubes (SWNT) and then we made one cylinder bulk of single-walled carbon nanotubes.

All the common chemicals were on analytically grade and were commercially available. The water used in all experiments was twice distilled with quartz heating tube. A model Cambridge stereo scan 360 scanning electron microscopy (SEM) of nanotubes. A model Philips FEG 200 kv transmission electron microscope (TEM) was used to take photo of nanotubes fragments. A model Hall Effect Oxford Instruments-august 1992, A model Raman spectroscopy Almega Dispersive Raman manufactory Thermo Nicollet Made in USA, was used.

Chemical vapor deposition method involves thermal decomposition of hydrocarbons (usually CH_4) at temperatures ranging form 500 to 1000 °C in the presence of a catalyst containing transition metals such as Fe and Mo. This process, which is more energy efficient that the electric arc-discharge and laser ablation methods, is ideal to generate well-defined structure of nanotubes. The yield and structure of nanotubes are affected by the type, purity and porosity of the catalyst. It has been shown that methane CVD process can be used to obtain ca. 200 % yield (2 g of SWNT s/g catalyst) of high quality carbon nanotubes. The methane CVD process shows promises for long-scale production of defect free carbon nanotubes.

Carbon nanotubes produced in a typical process are closed ended and are usually associated with other carbonaceous species such as nanoparticles, fullerenes and catalyst.

After preparing single walled carbon nanotubes in order to mounting palladium and increasing sensibility of carbon nanotubes relative to hydrogen gas in low temperatures, palladium chloride was applied.

Palladium chloride was selected in various quantity and mounted by certain amounts of carbon of single wall nanotubes by using vacuum evaporation, and then were investigated by utilizing metallurgic optical microscope and SEM and optimum quantity of palladium chloride required to be mounted on carbon nanotubes found to be 0.1 g.

3. Results and Discussion

Single-walled carbon nanotubes provided from CVD and used from them for review of sensitivity properties in SEM spectrum observed and clearly have seen exist of single-walled carbon nanotubes under 50 nm, since SEM device in researchment is in limit of 50 nm then we can not used from it for determine of correct dimension and done reviews. TEM spectrum sample of single-walled carbon nanotubes and anything reason is more observed that carbon nanotubes have provided in about 8 nm for next studies and reviews (12).

Note that have seen obviously on different sample by TEM that seed scales of catalyst have essential role in status and grow of single-walled carbon nanotubes. Anything seed scales of catalyst from Gel-cell way are smaller and about nanometer, provided single-walled carbon nanotubes samples will be desirable by scale. In image clearly scale of single-walled carbon nanotubes is about 8 nm.

XRD of carbon nanotubes that curve show carbon nanotubes with seed scales about nanometer.

Raman spectrum of carbon nanotubes that review of it determines curves of type D that first state is related to single-walled carbon nanotubes and next curve is marker of acidic corrosion in surface of carbon nanotubes (12).

The scanning electron microscopy (SEM) photograph of the sensor materials sintered at 980 °C and sublimated at 1600°C indicated that the prosity and grain size of carbon nanotubes significant increases.(SEM) photograph revealed (Fig. 1) qualitative the carbon nanotubes with palladium has greater and larger number of pores. The AFM Photograph (Fig. 2) from the AFM image of carbon nanotubes with palladium in the layer. By taking image from different parts of the surface and driving the average size of carbon nanotubes with palladium particles in each image by foregoing software and average size particles in each sample was calculated, and the mean particle size is about 20 nm. The particle are packed closely and well distributed on the disk. The size and morphology of the particles were characterized by TEM as shown in (Fig. 3) the uniformly of nano powder was confirmed by TEM observation.

The evaluation of the response and recovering characteristics has been carried out. The dc resistance in hydrogen gas alternatively helped to establish the response and recovering characteristics. The result (Fig. 4) show that the invariant resistance in hydrogen gas with time (s).Response and recovering times are 95 (s) and 130 (s) respectively.

4. Conclusion

In this paper, a summary of single walled carbon nanotubes provided and prepared by CVD method in area of 2-15 nm based on Sol-Gel catalyst. Device studies show desirability of sintered materials and ability applications, In review of provided Raman, XRD spectrums, study of Hall effect phenomena and conductivity of provided single-walled carbon nanotubes that can have very well of repeatability, high-level purity of material and development and bring ability of application in most of industries. Carbon nanotubes were activated by palladium through utilizing vacuum evaporation. AFM photo shows grain size of particles that rang 15-30 nanometers. Studying and investing carbon particles and sensor sensibility and AFM photo shows that decreasing grain size of carbon in nanotubes and palladium amounts leads to increase grain size of particles and sensibility of sensors (13-15).

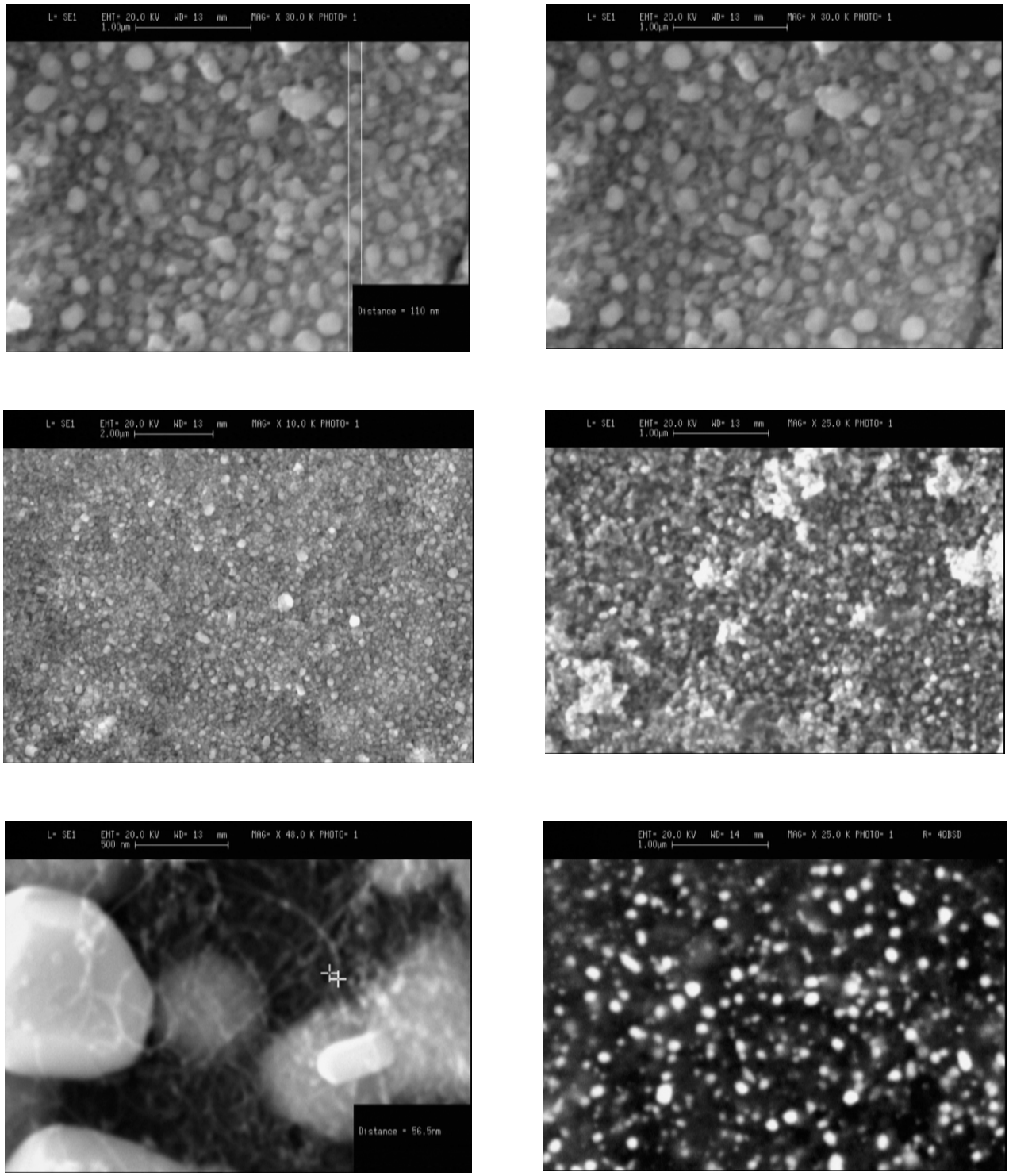

Fig. 1. SEM Photograph before and after adding palladium.

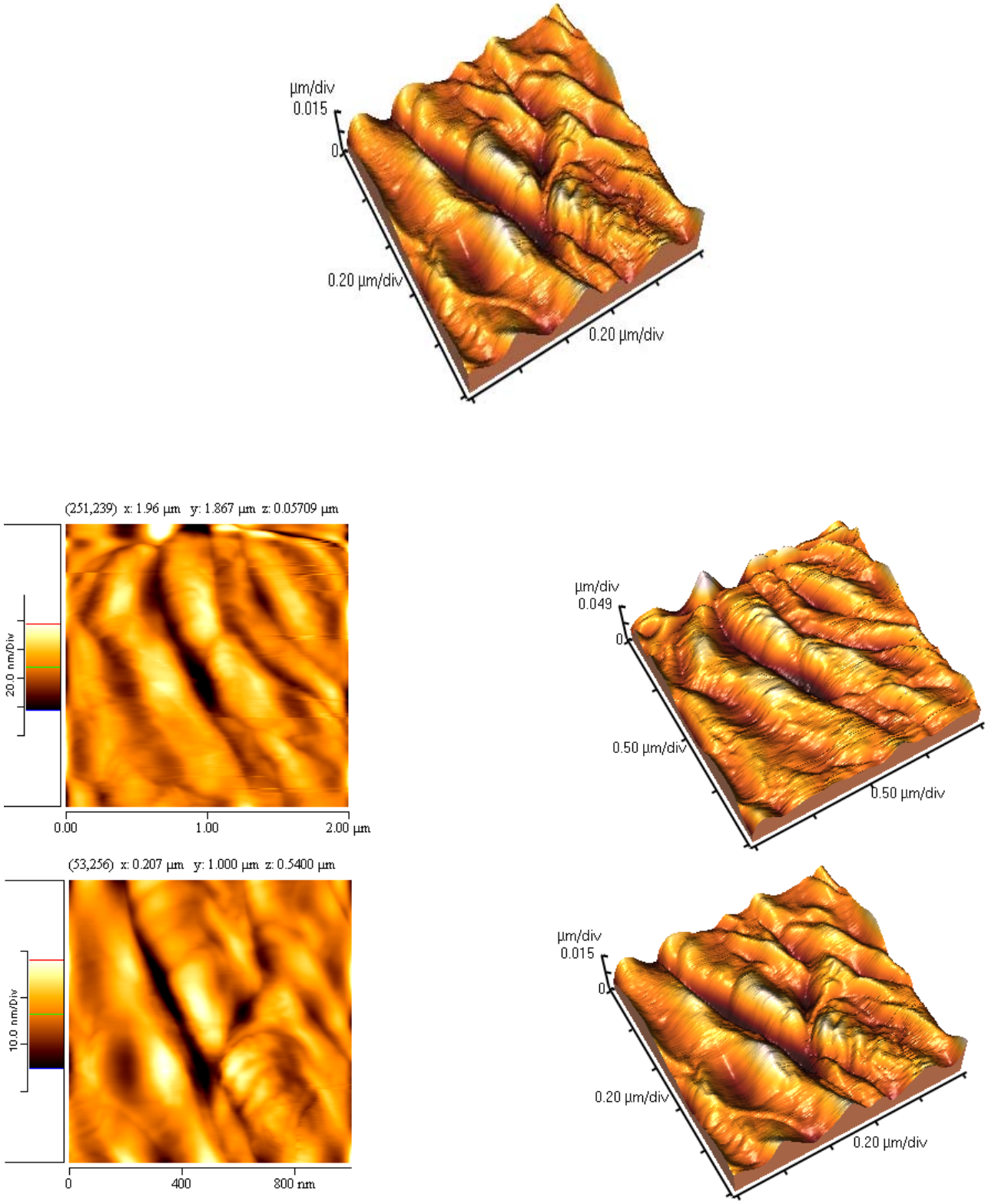

Fig. 2. AFM photograph of carbon nanotube with palladium.

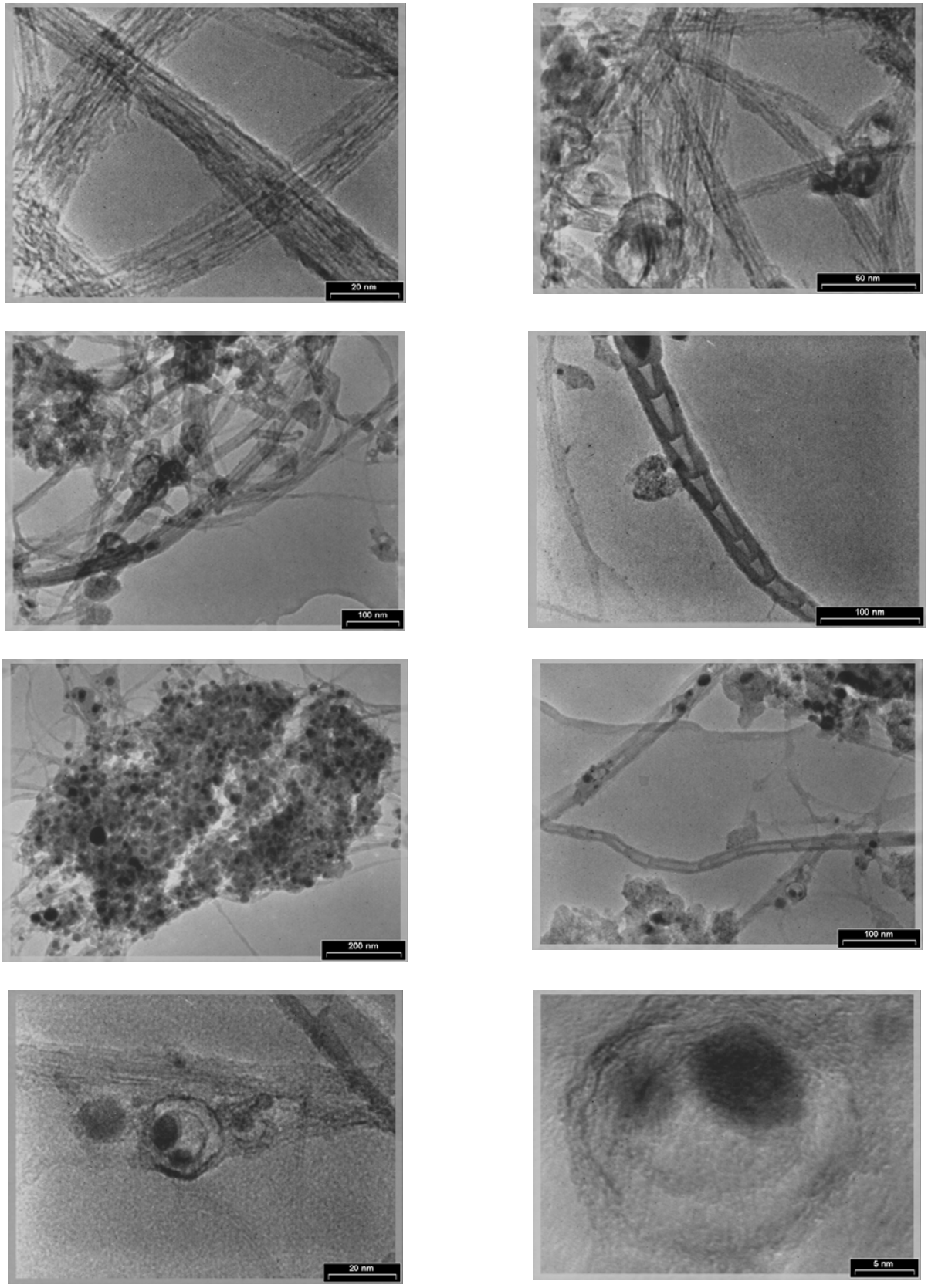

Fig. 3. TEM photograph of carbon nanotyube with palladium.

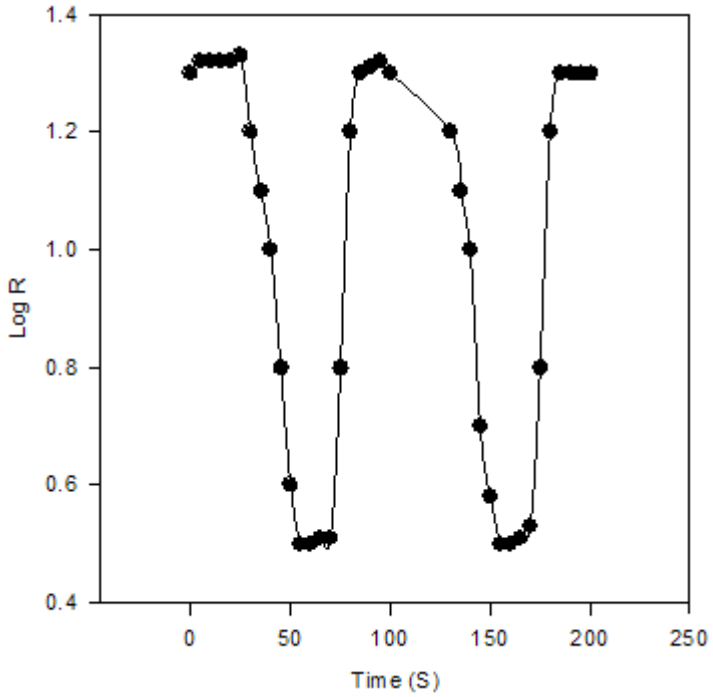

Fig. 4. Invariant resistance in 20000 ppm of hydrogen.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
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