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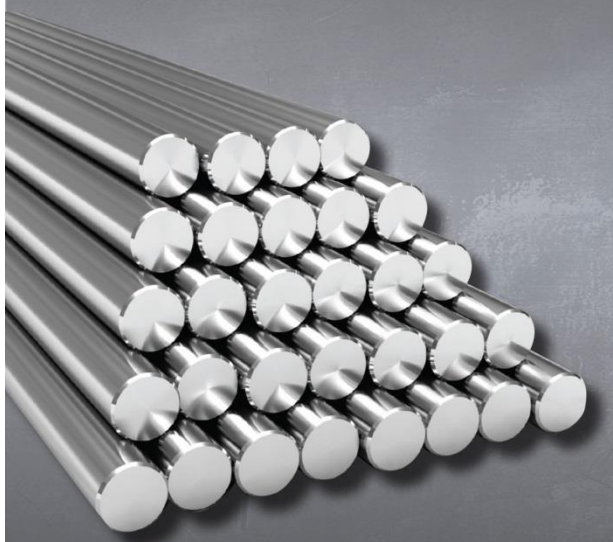
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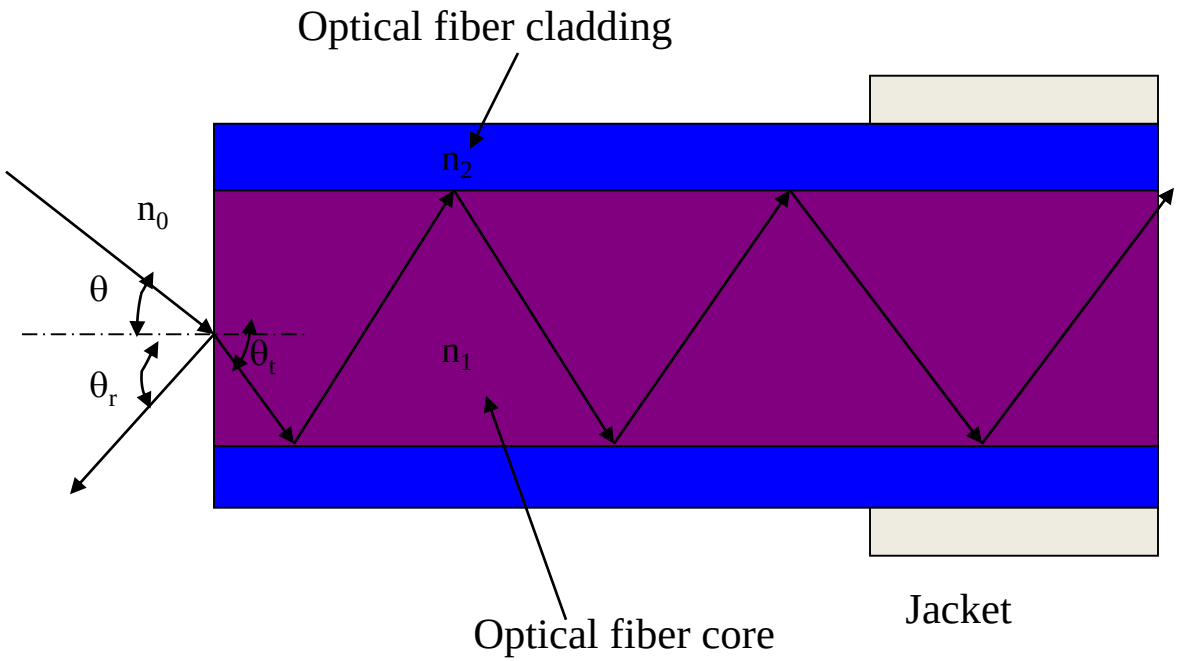
Sol-gel Derived Nanomaterials for Designing Fiber Optic Gas Sensors

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Department of Chemistry and Physics
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Outline

- Optical fiber, light guiding and optical fiber chemical sensors
- Sol-gel process for making nanomaterials for hydrogen gas sensing
- Sensor structure
- Examples of optical fiber gas sensors
- Conclusions and further work
- Acknowledgement

The structure of a typical optical fiber

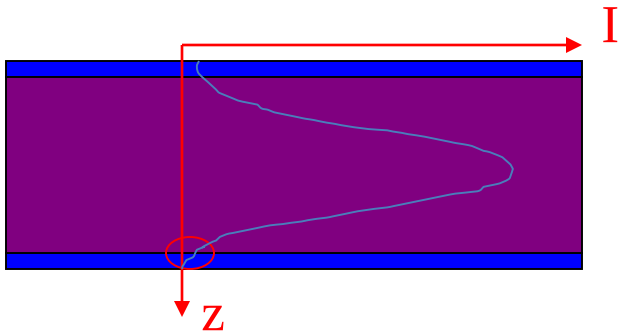


A light beam is guided inside an optical fiber through a series total internal reflections, which requires:

$$\theta<\theta_c = \mathrm{Sin}^{-1}(n_1^2-n_2^2)^{1/2}$$

Light power distribution inside an optical fiber

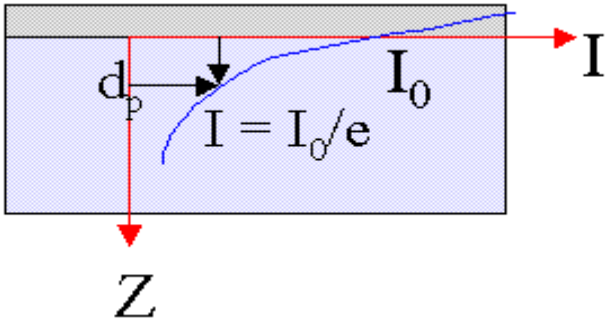
Light power distribution in an optical fiber



- >90% of light power is distributed inside the optical fiber core for multimode optical fiber
- ca. 50% of power can be distributed in cladding in single mode optical fibers

Evanescent wave

An evanescent wave is a near-field standing wave formed at each point of total internal reflections



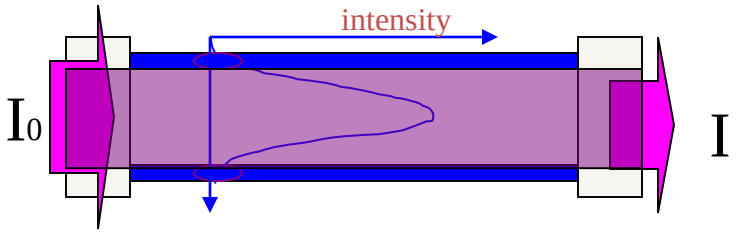
$$I = I_0 \exp(-z/d_p)$$

$$d_p = \lambda/2n_1[\sin^2\theta - (n_2/n_1)^2]^{1/2}$$

*A. Katzir, et al., Appl. Opt., **35**, 2274 (1996)*

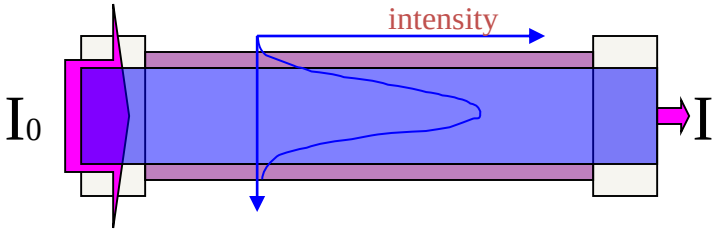
OFCS classification

Evanescent wave (EW) sensor



- Interaction inside the cladding
- Can use low cost fibers
- Fast response
- Limited sensitivity

Active core (AC) sensor

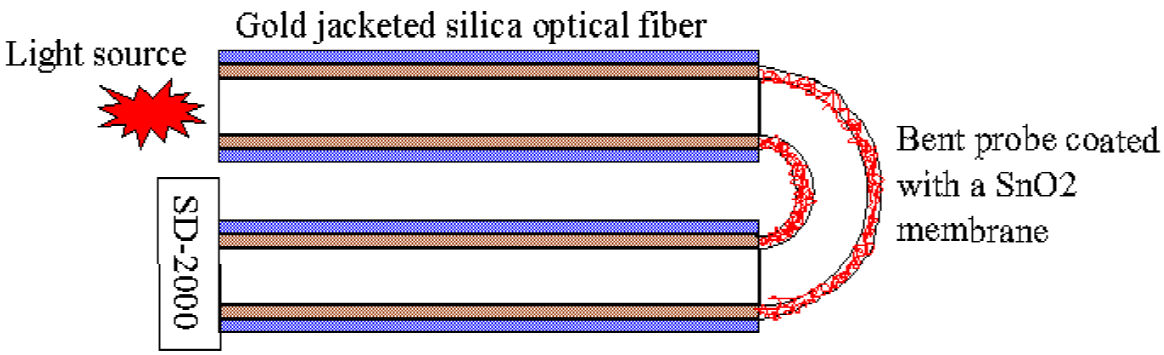


- Interaction inside the fiber core
- Need specially tailored fibers
- High sensitivity

S. Tao, "Fiber optic chemical sensors for environmental monitoring", in "Encyclopedia of Sensors", C. A. Grimes, E. C. Dickey and M. V. Pishko, eds., Vol. 3, pp. 449-474, American Scientific Publishers, Stevenson Ranch, CA, 2006.

A selective high temperature H_2 sensor

I: Structure

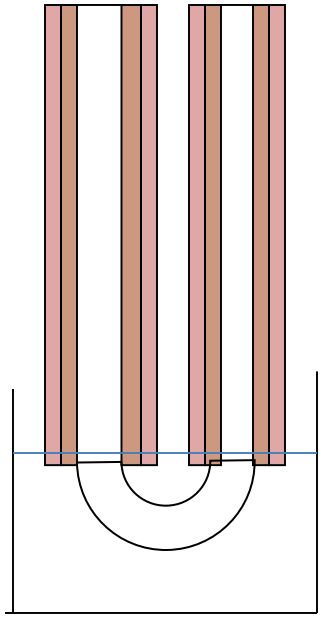


II: Principle

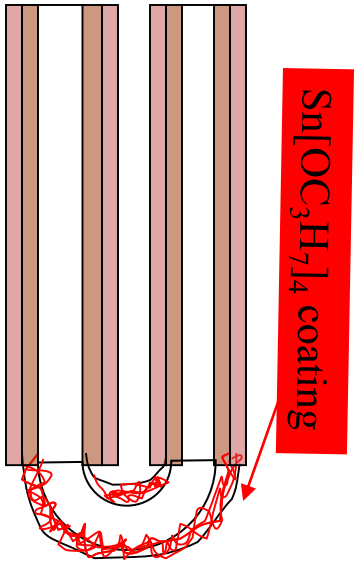
- A reducing gas (H_2, CO, organic compound) reacts with SnO_2 nanoparticles changes oxygen ion concentration on particle surface
- SnO_2 membrane EW optical spectrometry → selective sensing

Q. Yan, S. Tao and H. Toghiani, *Talanta*, **77**, 953-961 (2009)

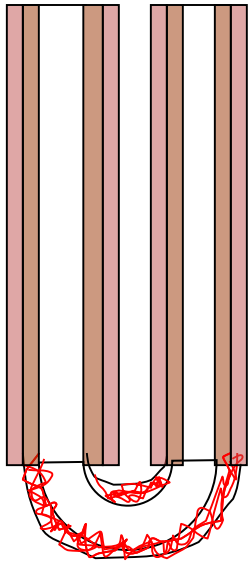
Sensor probe preparation



$Sn[OC_3H_7]_4$ in isopropanol/toluene

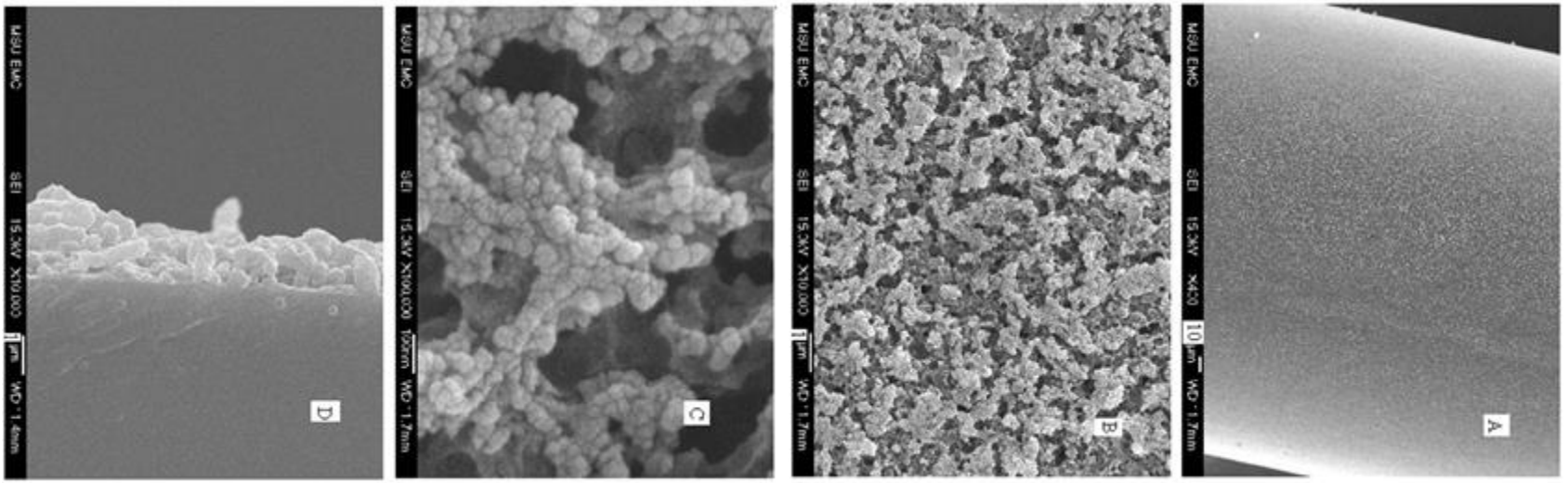


($Sn[OC_3H_7]_4$ is hydrolyzed in air

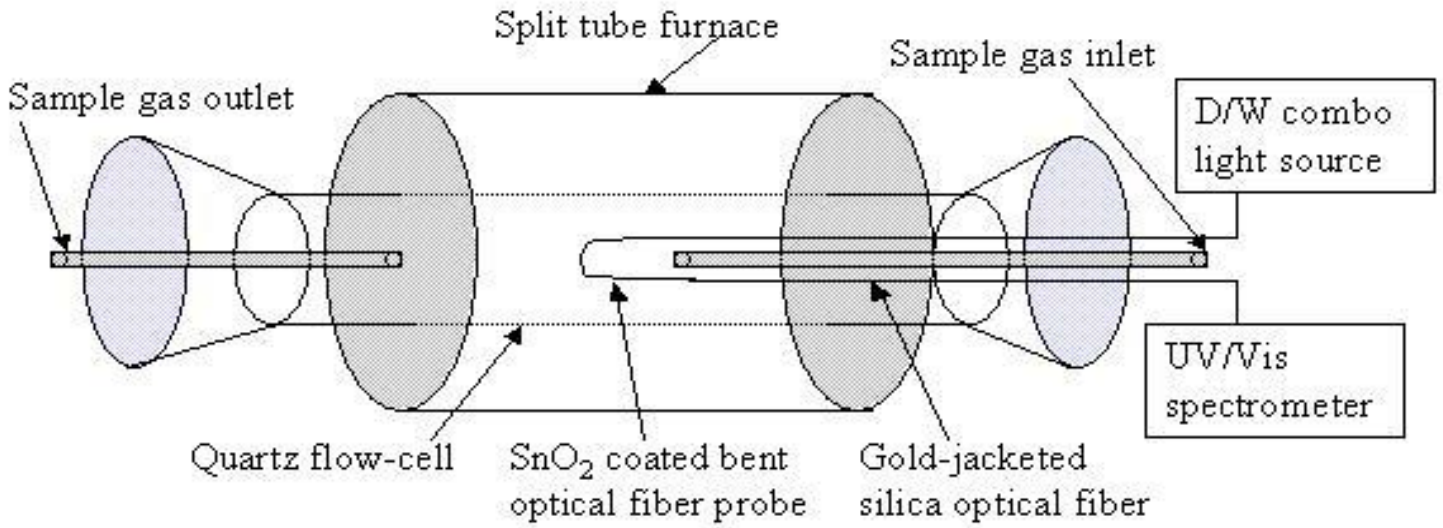


Heat treatment (600 ^oC for 1 hour)

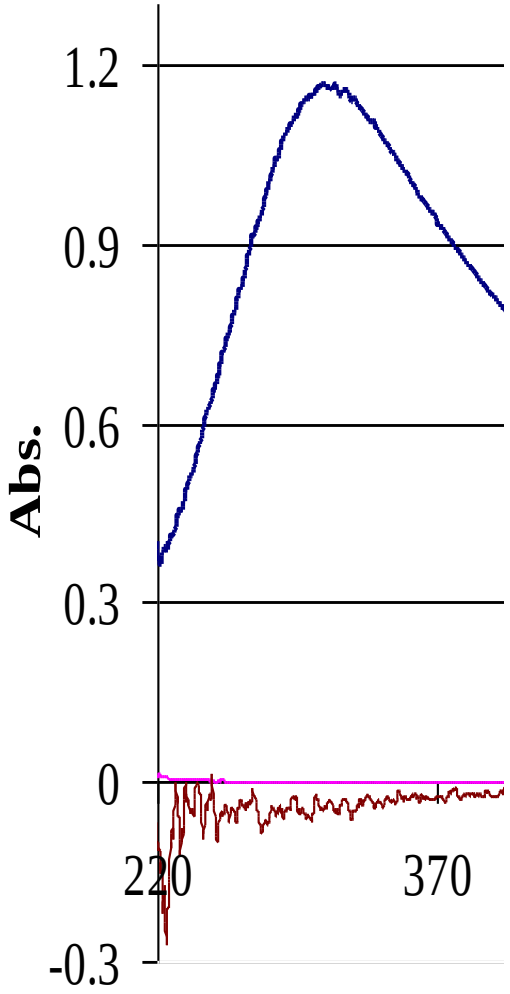
SEM images of SnO2 coating on fiber core surface

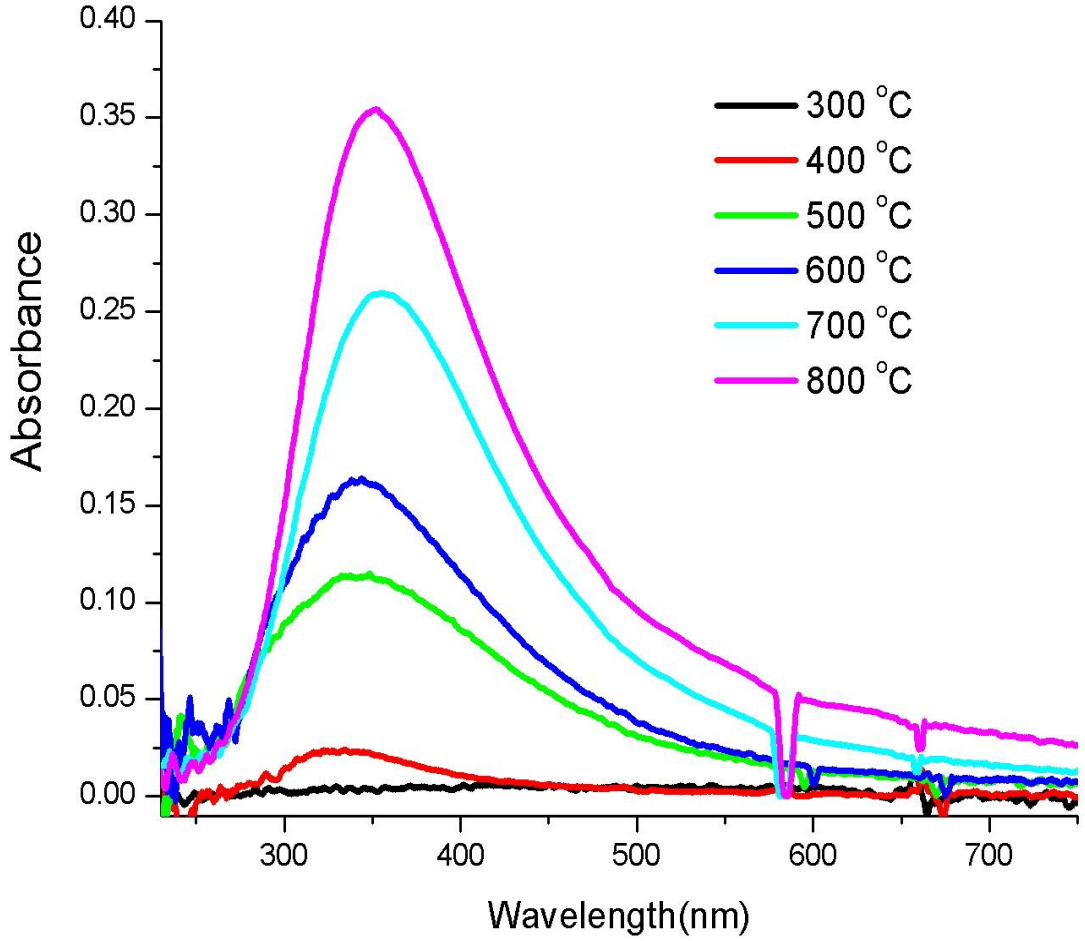


Test the sensor for detecting hydrogen in gas sample

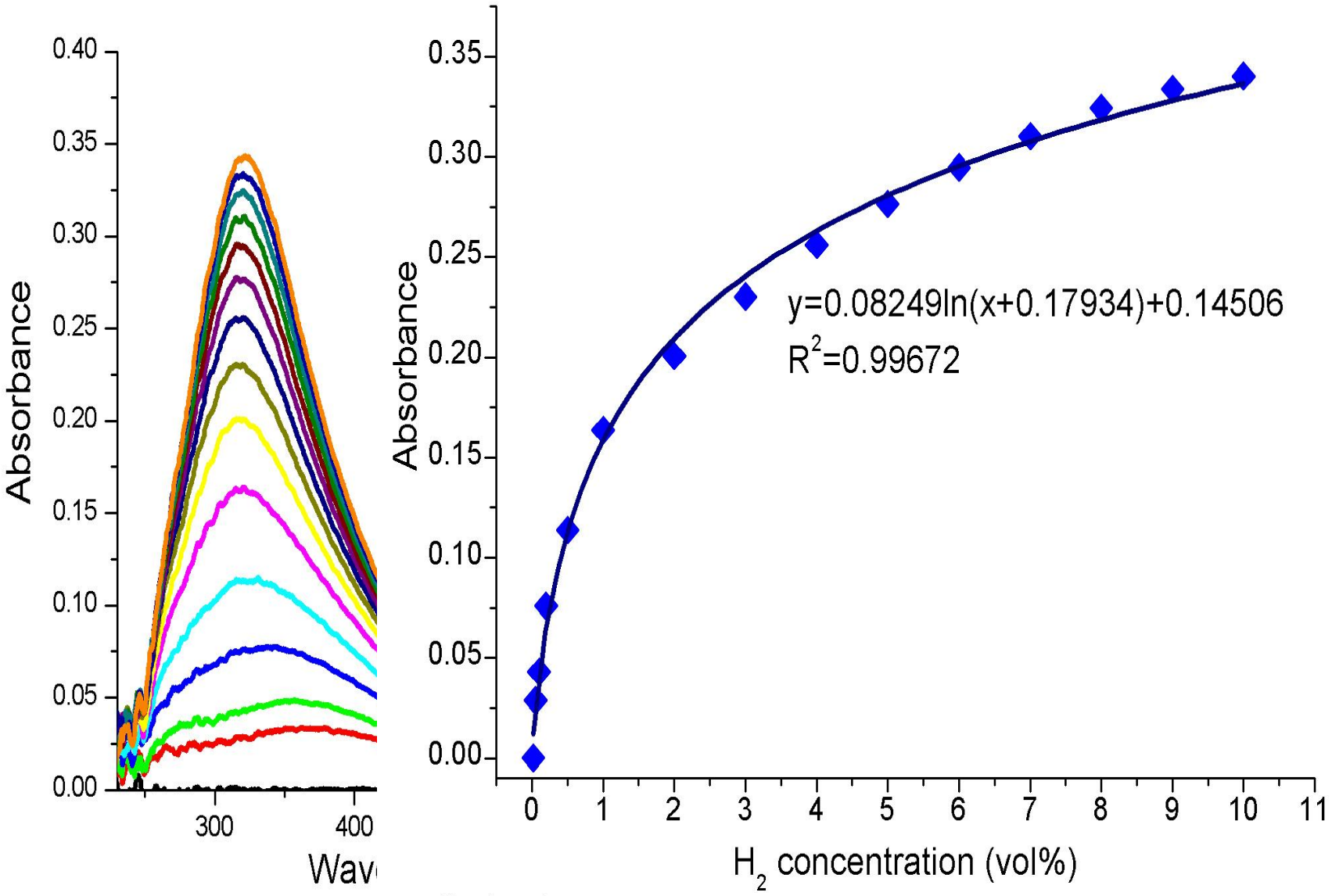


Test result

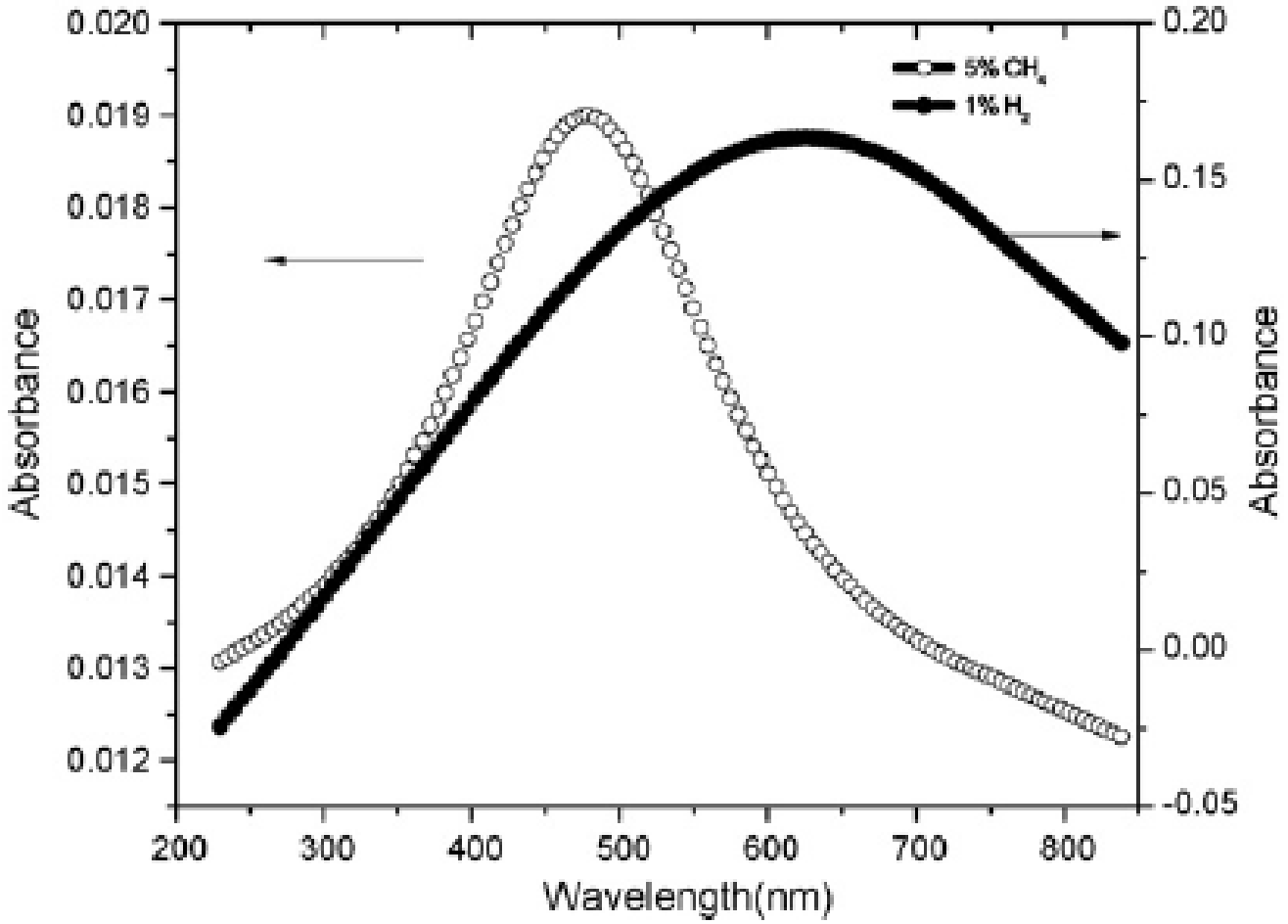

1.2
0.9
0.6
0.3
0
-0.3
Abs.
220
370


0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Absorbance
300
400
500
600
700
Wavelength(nm)
300 °C
400 °C
500 °C
600 °C
700 °C
800 °C

Test result

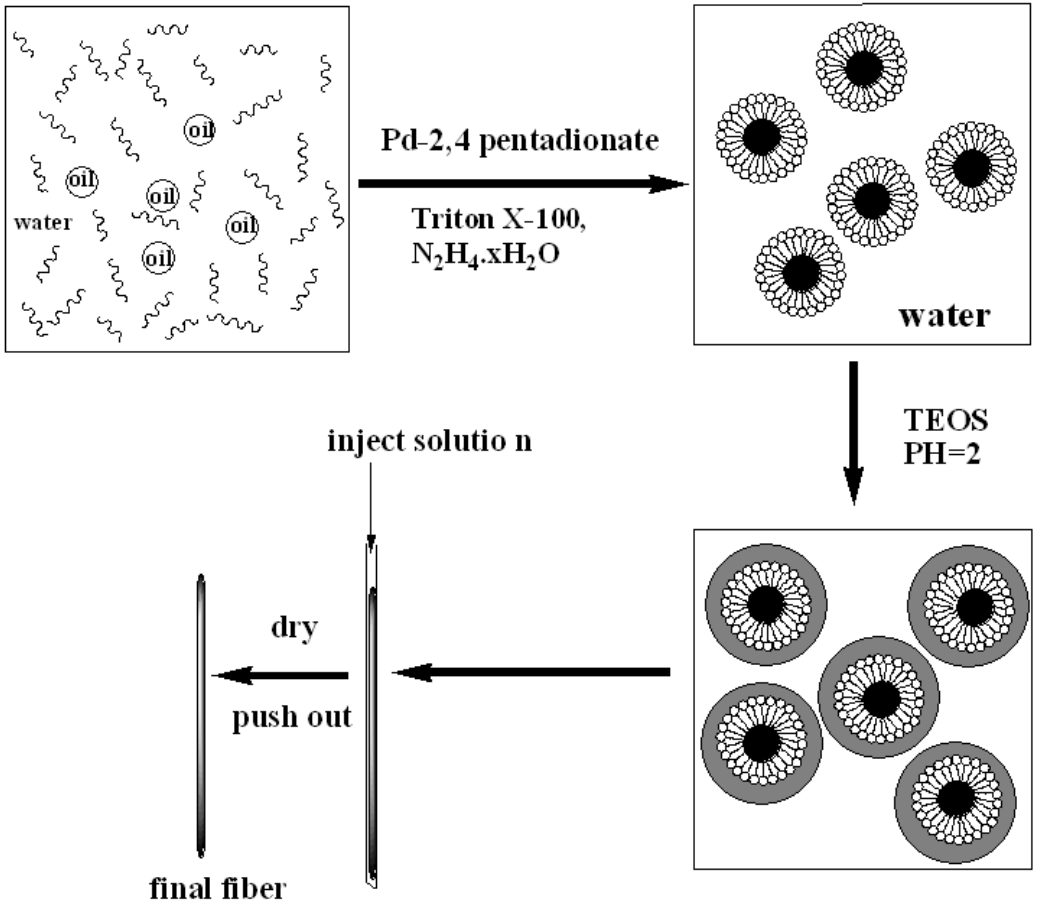

Absorbance
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
300
400
Wav
Absorbance
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
y=0.08249ln(x+0.17934)+0.14506
R2=0.99672
0
1
2
3
4
5
6
7
8
9
10
11
H2 concentration (vol%)

Improve selectivity by incorporating reactions to cladding (1 wt% Pt doped SnO_2)

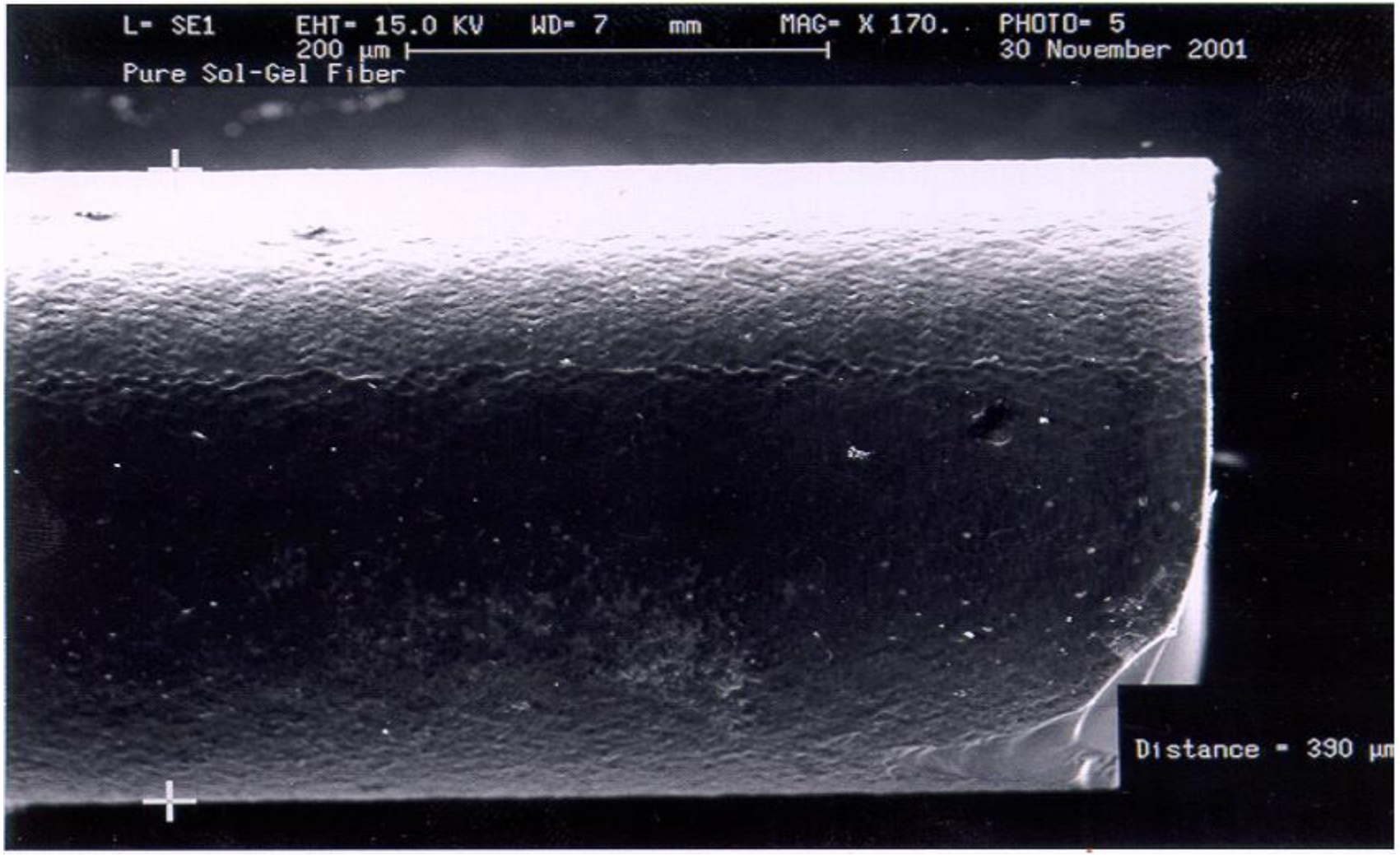


A palladium doped sol-gel silica optical fiber for detecting hydrogen at ambient temperature

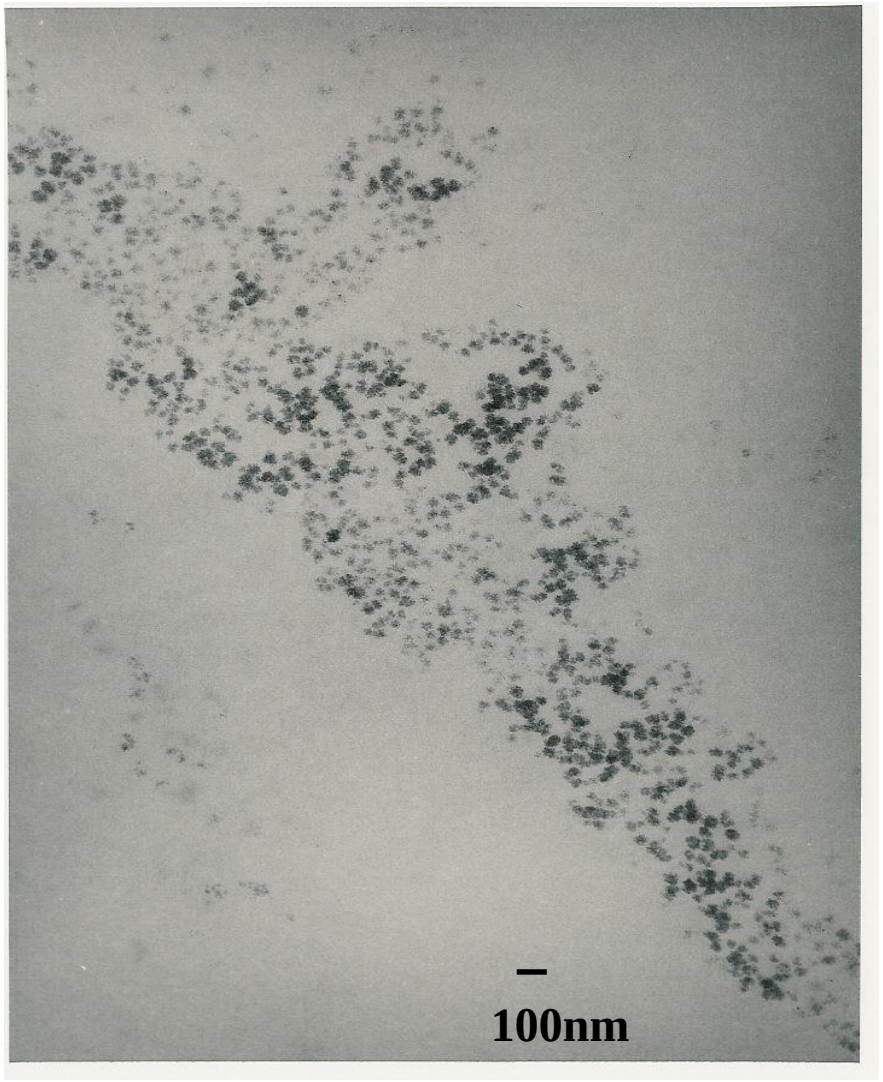
I: The process for making palladium nanoparticles doped sol-gel silica optical fiber



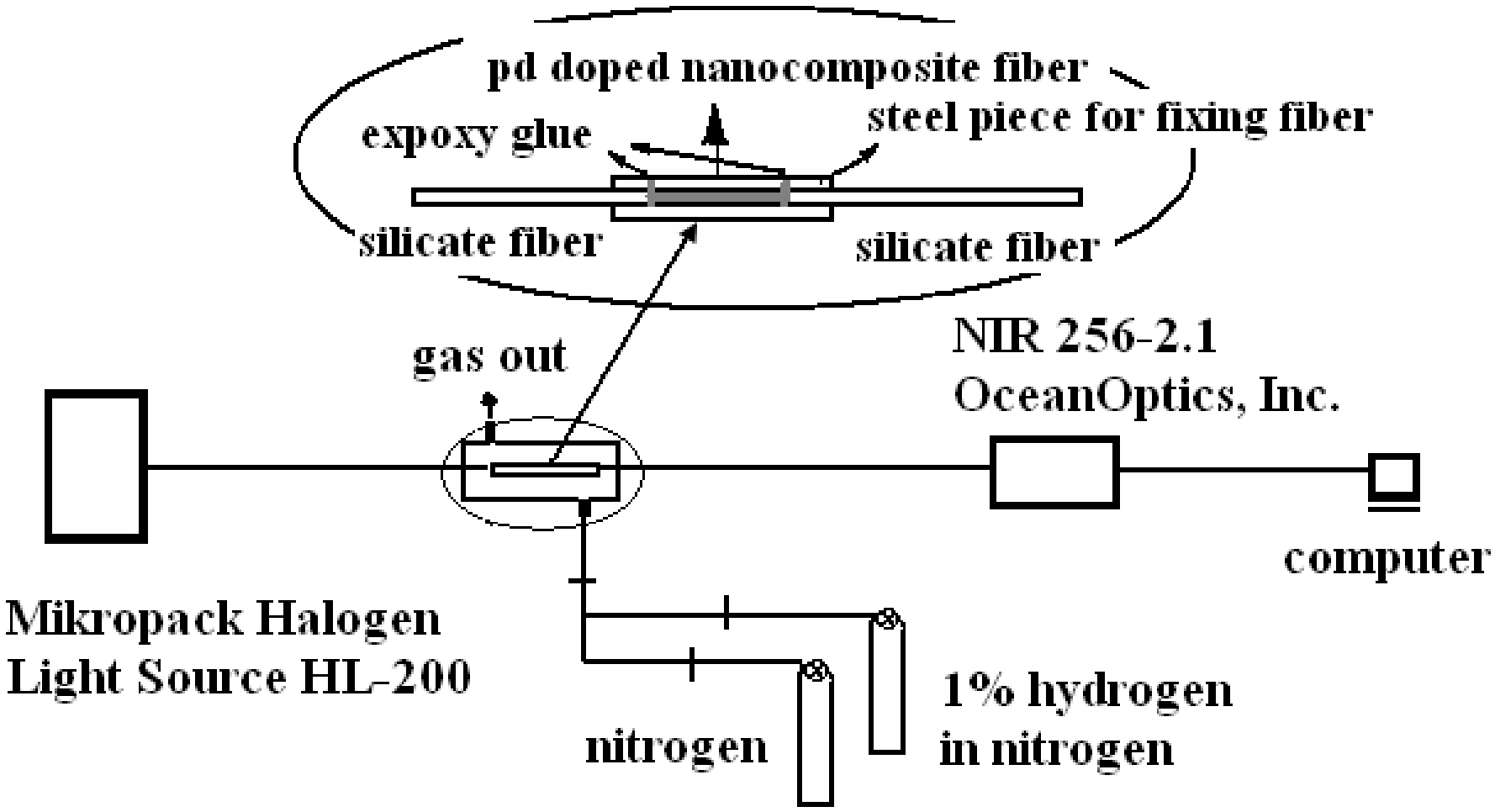
II A SEM image of a sol-gel derived porous silica optical fiber



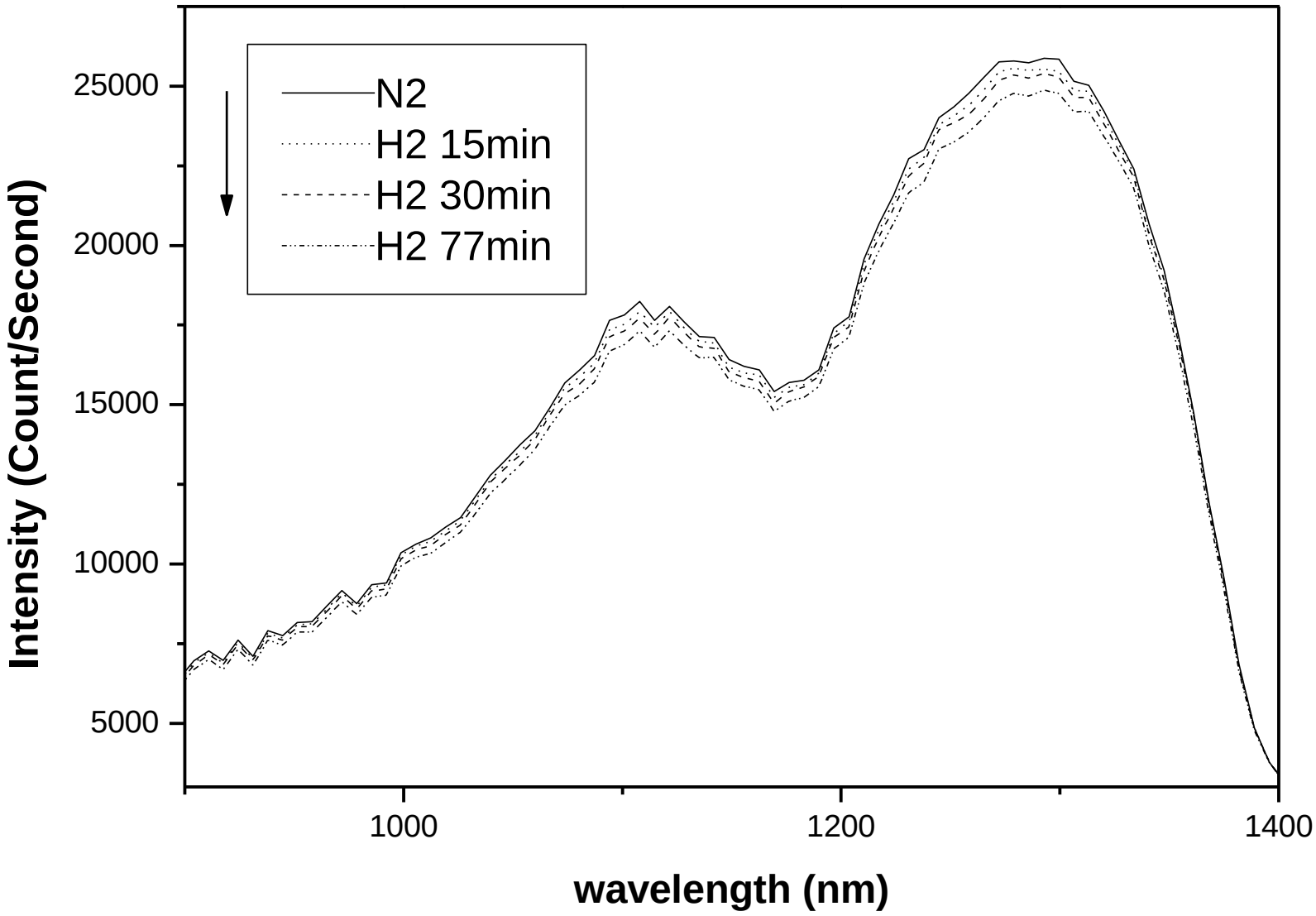
III A SEM image of palladium particles in sol-gel derived porous silica



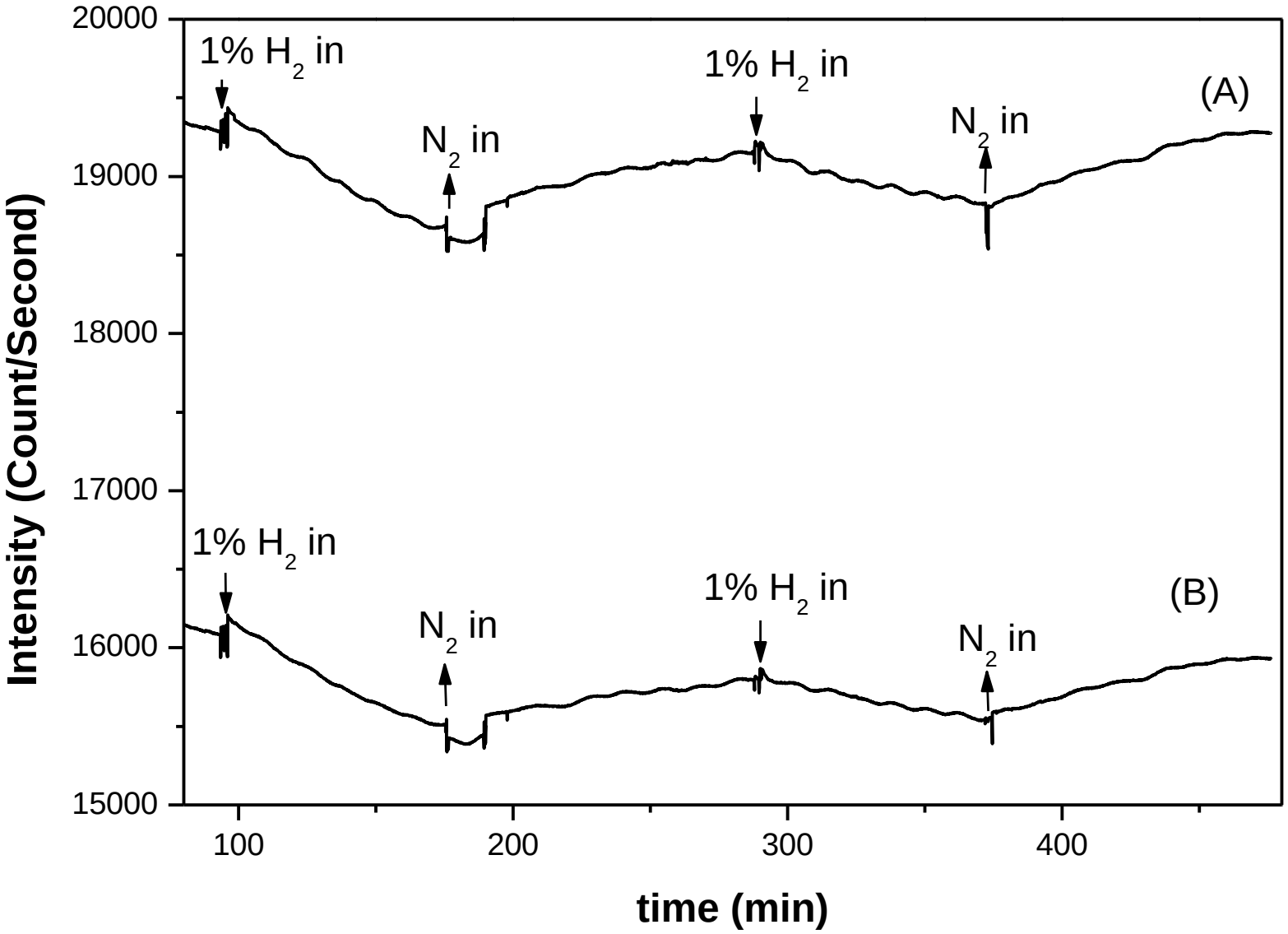
IV Test the sensor for detecting hydrogen in gas sample



V: Test result



V: Test result



Conclusions and further work

- Nanocompiste materials have been synthesized with sol-gel or sol-gel/micelle techniques
- The nanocomposite materials can be coated on surface of optical fiber core or be made into the form of optical fibers for designing gas sensors
- Trace hydrogen in gas samples of different temperature has been detected with developed sensor techniques
- Chemical reactions can be integrated into sensing element to achieve selective sensing
- Further work will be focused on integrating optical spectroscopy and electrochemical methods for developing selective and multi-components sensing techniques.

Acknowledgement

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