

Miażem wyrabane i nie przyszedłem.

Czujnik

- Czujnik jest instrumentem, który reaguje na bodźce fizyczne (takie jak ciepło, światło, dźwięk, ciśnienie, magnetyzm lub ruch)
- Zbiera i mierzy dane dotyczące niektórych właściwości danego materiału
- Czujniki są ważną częścią każdej aplikacji pomiarowej i automatyki.
- Czujnik jest odpowiedzialny za przekształcenie pewnego rodzaju zjawisk fizyko-chemicznych w ilość mieralną poprzez system gromadzenia danych
- Czujnik musi być skalibrowany i posiadać swoją dokładność

Dlaczego nanoczujniki

- Cząsteczki, które są mniejsze od charakterystycznych długości związań z konkretnymi zjawiskami często prowadzą do nowych właściwości, które zależą od wielkości materiału
- Gdy rozmiar struktury/materiału jest zmniejszany, wzrasta stosunek powierzchni do objętości, a zjawiska powierzchniowe przeważają w porównaniu do materiałów objętościowych.
- Zmniejszenie wielkości części czujnikowej i / lub przetwornika w czujniku jest ważne, aby lepiej zminiaturyzować urządzenia.
- Nauka nano materiałów dotyczy nowych zjawisk i właściwości, a nowe urządzenia czujnikowe są budowane, które wykorzystują te zjawiska.
- Czułość może wzrosnąć dzięki lepszym właściwościom przewodzenia, granice wykrywania mogą być niższe, można badać bardzo niewielkie ilości próbek (analitu), można wykryć wiele substancji i wielkości bez stosowania skomplikowanej chemii i odczynników.

Nanomaterials in Lithium-Ion Batteries and Gas Sensors

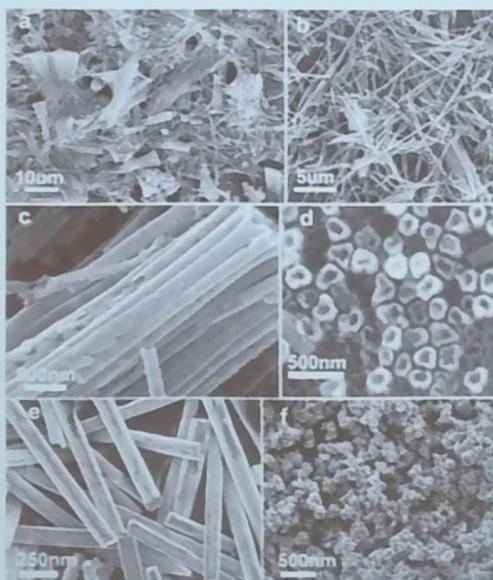


Figure 2. SEM images of the as-prepared Co_3O_4 samples: a,b) nanotubes at low magnification; c) walls of nanotube bundles; d) tips of nanotube bundles; e) nanorods; and f) nanoparticles.

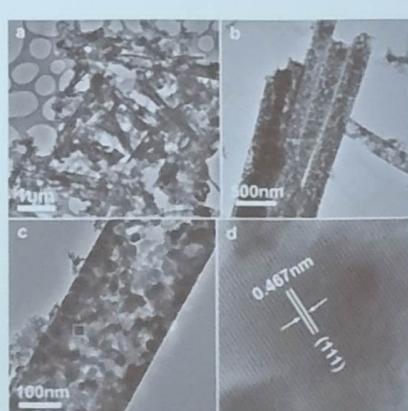


Figure 3. Representative TEM images of the as-prepared Co_3O_4 nanotubes: a) prepared with 0.5 M Co^{2+} nitrate solution; b,c) prepared with 2 M Co^{2+} nitrate solution; and d) HRTEM image of the square marked in (c).

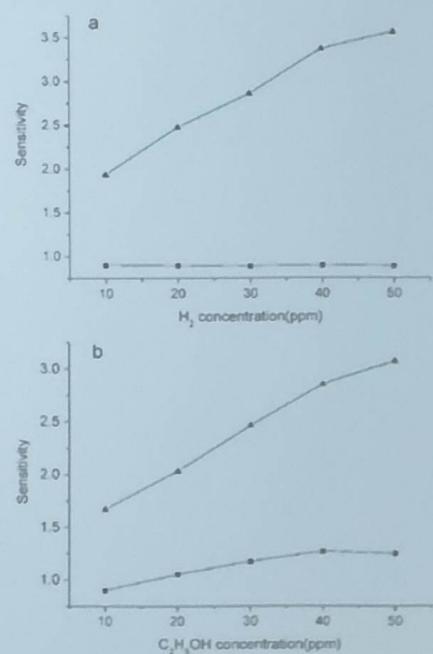


Figure 8. Sensitivity to a) H_2 and b) $\text{C}_2\text{H}_5\text{OH}$ of the sensors made by the as-prepared Co_3O_4 nanotubes (triangles) and nanoparticles (squares) at room temperature.

Co_3O_4 electrode	Potential values [V]			Current densities [mA cm^{-2}]		
	$E_{\text{a}1}$	$E_{\text{a}2}$	E_{o}	$I(E_{\text{a}1})$	$I(E_{\text{a}2})$	$I(E_{\text{o}})$
Nanotubes	1.31	0.70	2.15	5.35	4.30	4.20
Nanorods	1.26	0.69	2.12	3.60	2.90	3.65
Nanoparticles	1.31	0.75	2.13	3.65	3.90	3.70

Gas sensors using carbon nanomaterials: A review

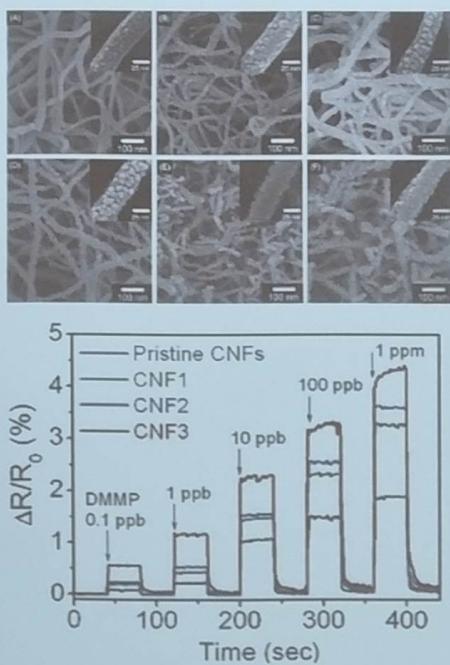


Fig. 8. Upper plots: low- and high-resolution (inset) SEM images of carbon nanofibers (CNF) that is composed of various concentrations of ZnO_{x}/SiO_2 in the PVP solution (A) 0.5 wt%, (B) 0.75 wt%, (C) 1 wt%, (D) 1.25 wt%, (E) 1.5 wt%, and (F) 2 wt% with a diameter of 40 nm. Lower plot: normalized resistance changes upon sequential exposure to various DMMP vapor concentrations (black, pristine CNF; green, CNF1 with 1 wt% ZnO ; blue, CNF2 with 1 wt% SiO_2 ; and red, CNF3 with 1 wt% ZnO and SiO_2). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.) Adapted from Ref. [43], © American Chemical Society, with permission.

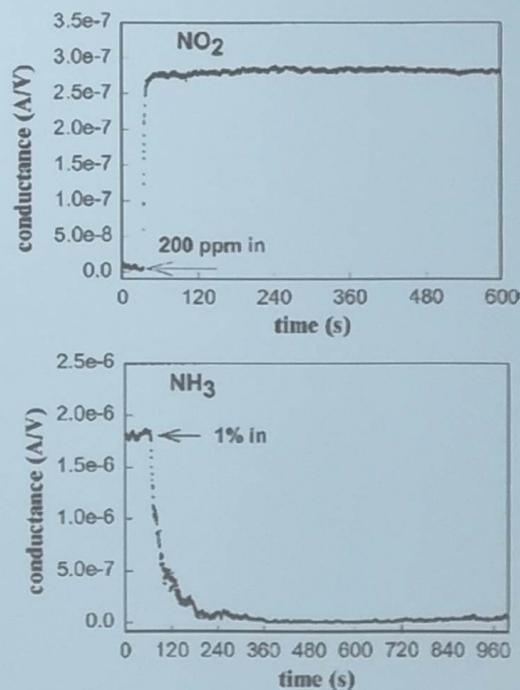


Fig. 9. Electrical response of a semiconducting SWNT to gas molecules. Conductance (under $V_g = +4$ V) versus time in a 200-ppm NO_2 flow (upper subplot). Conductance (under $V_g = 0$ V) versus time recorded with the same S-SWNT sample in a flow of Ar containing 1% NH_3 (lower subplot).

Sensors and Actuators B 179 (2013) 32–45

Gas sensors using carbon nanomaterials: A review

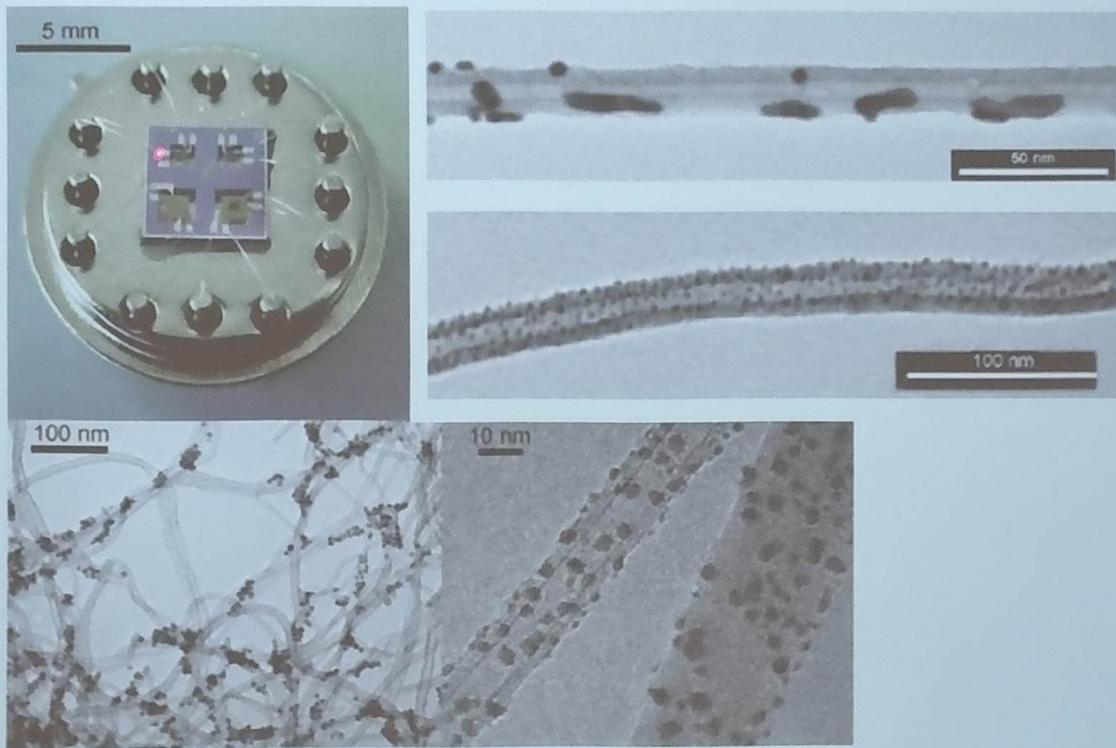
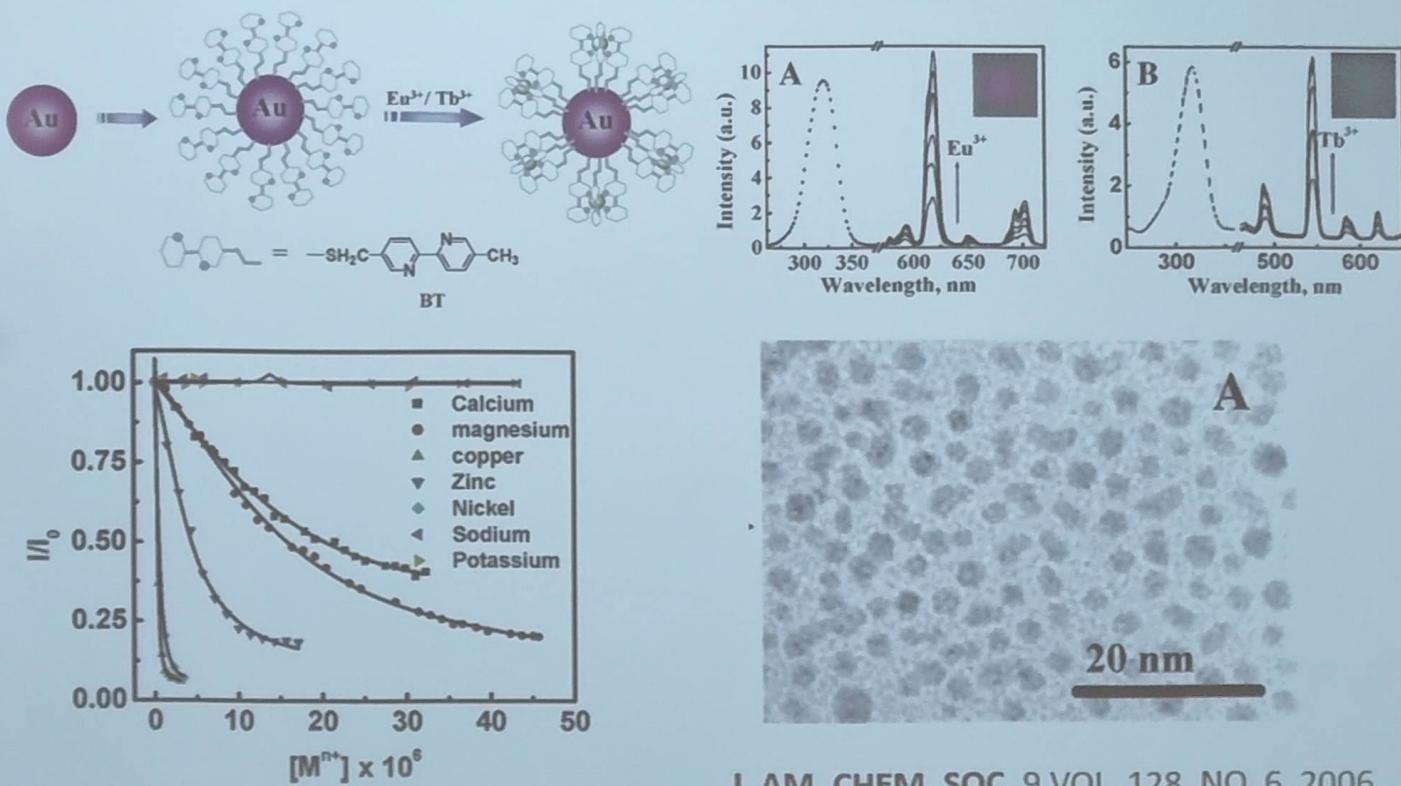


Fig. 12. Optical microscope image of the 4-element sensor array (upper left), SEM image of the electrode area showing that the CNT mat bridges electrode gap (upper right), TEM image of Pd-decorated CNTs (lower right), TEM image of Rh-decorated CNTs (lower left).

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Sensors and Actuators B 179 (2013) 32–45

Functionalized Gold Nanoparticles as Phosphorescent Nanomaterials and Sensors



J. AM. CHEM. SOC. 9 VOL. 128, NO. 6, 2006

Optical Sensor Based on Nanomaterial for the Selective Detection of Toxic Metal Ions

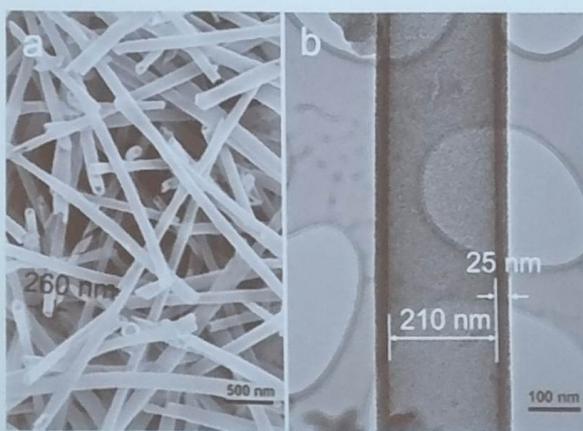


Figure 1. a) SEM and b) TEM images of SNT-1.

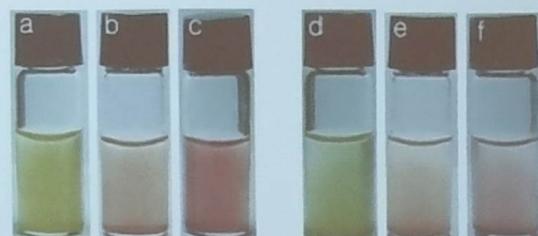
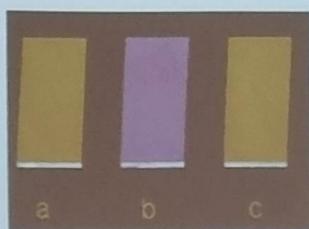


Figure 3. Pictures of the suspensions of a) SNT-1, b) SNT-1 + 0.01 mM Hg(NO₃)₂, c) SNT-1 + 1.0 mM Hg(NO₃)₂, d) SSP-1, e) SSP-1 + 10.0 mM Hg(NO₃)₂, and f) SSP-1 + 100.0 mM Hg(NO₃)₂ in water.



Figure 4. Color changes for isolated SNT-1 with different metal anions in water: a) free-SNT-1, b) Hg(NO₃)₂-loaded SNT-1, c) Hg(ClO₄)₂-loaded SNT-1, d) HgCl₂-loaded SNT-1, e) HgBr₂-loaded SNT-1, f) HgI₂-loaded SNT-1, g) Hg(SCN)₂-loaded SNT-1, and h) HgSO₄-loaded SNT-1.

Amperometric glucose sensor based on platinum–iridium nanomaterials

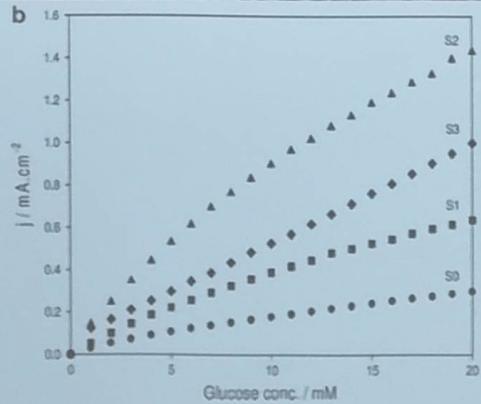
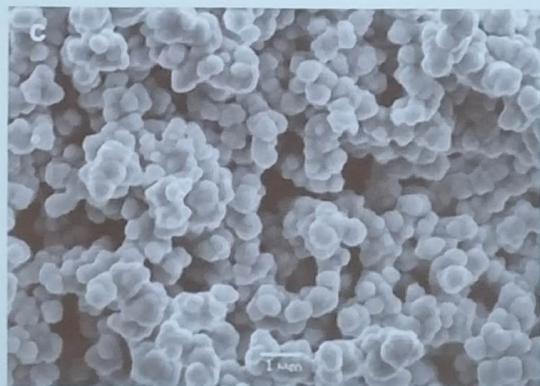


Fig. 3. (a) Chronoamperometric responses of S0, S1, S2 and S3 measured at 0.1 V in 0.1 M PBS (pH 7.4) + 0.15 M NaCl with successive additions of 1 mM glucose (0–20 mM). The scan rate was 20 mV/s.

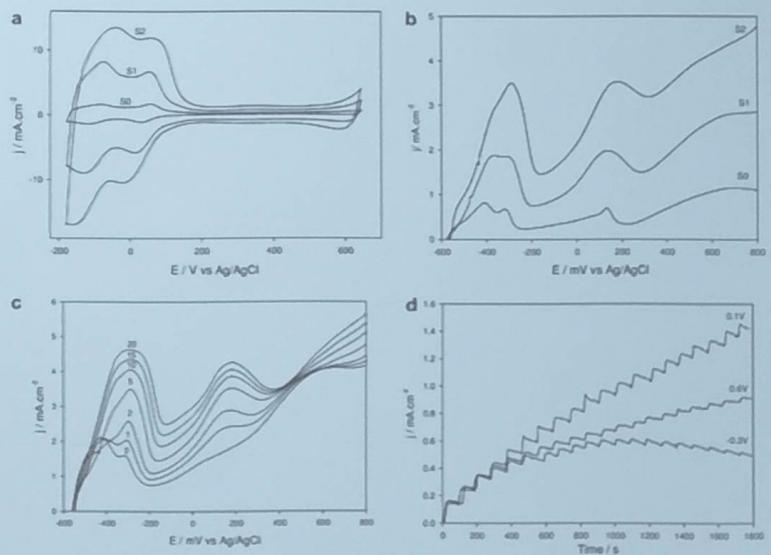


Fig. 2. (a) Cyclic voltammograms of S0, S1, and S2 recorded in 0.5 M H_2SO_4 at a scan rate of 20 mV/s. (b) Linear voltammograms of S0, S1, and S2 measured in 0.1 M PBS (pH 7.4) + 0.15 M NaCl + 5 mM glucose at 10 mV/s. (c) Linear voltammograms of S2 recorded at 10 mV/s in 0.1 M PBS (pH 7.4) + 0.15 M NaCl + x mM glucose where x was varied from 0 to 20. (d) Chronoamperometric curves of S2 at -0.3 V, 0.1 V and 0.6 V with successive additions of 1 mM glucose (0–20 mM) to 0.1 M PBS (pH 7.4) + 0.15 M NaCl.

Electrochemistry Communications 10 (2008) 1438–1441

Highly sensitive wireless H_2S gas sensors at room temperature based on CuO-SWCNT hybrid nanomaterials

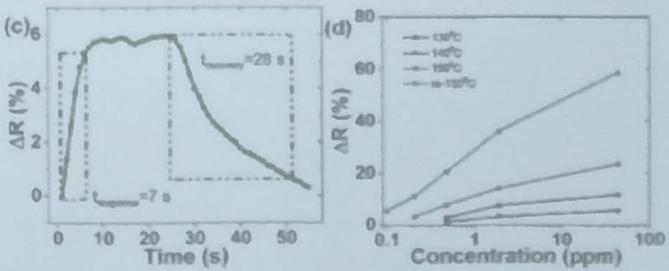
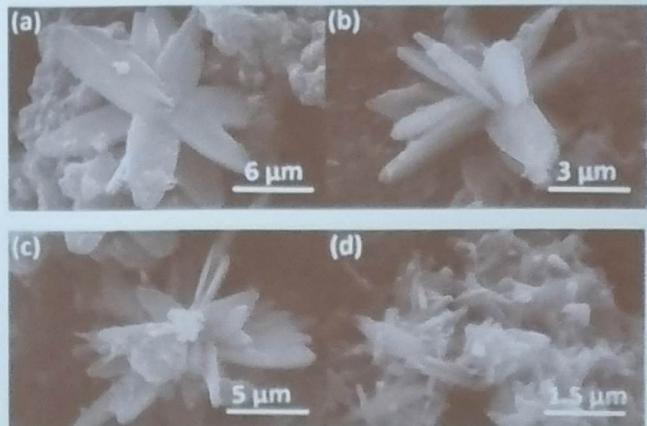
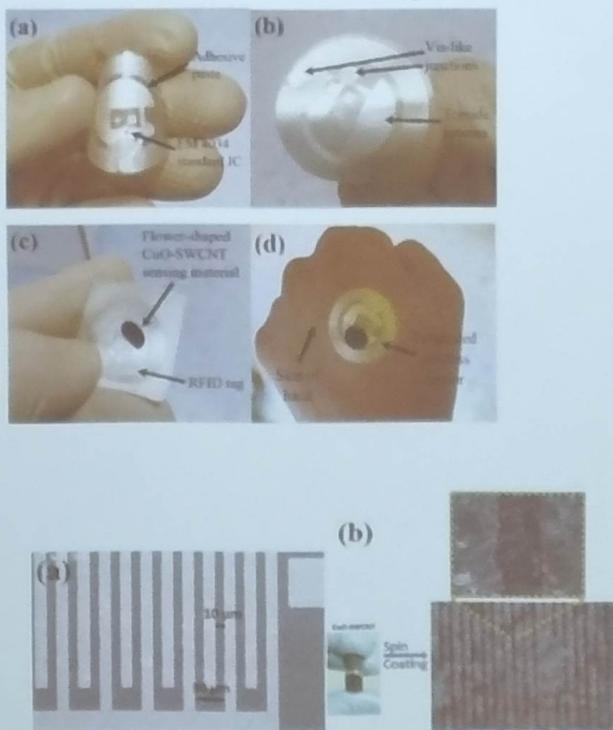


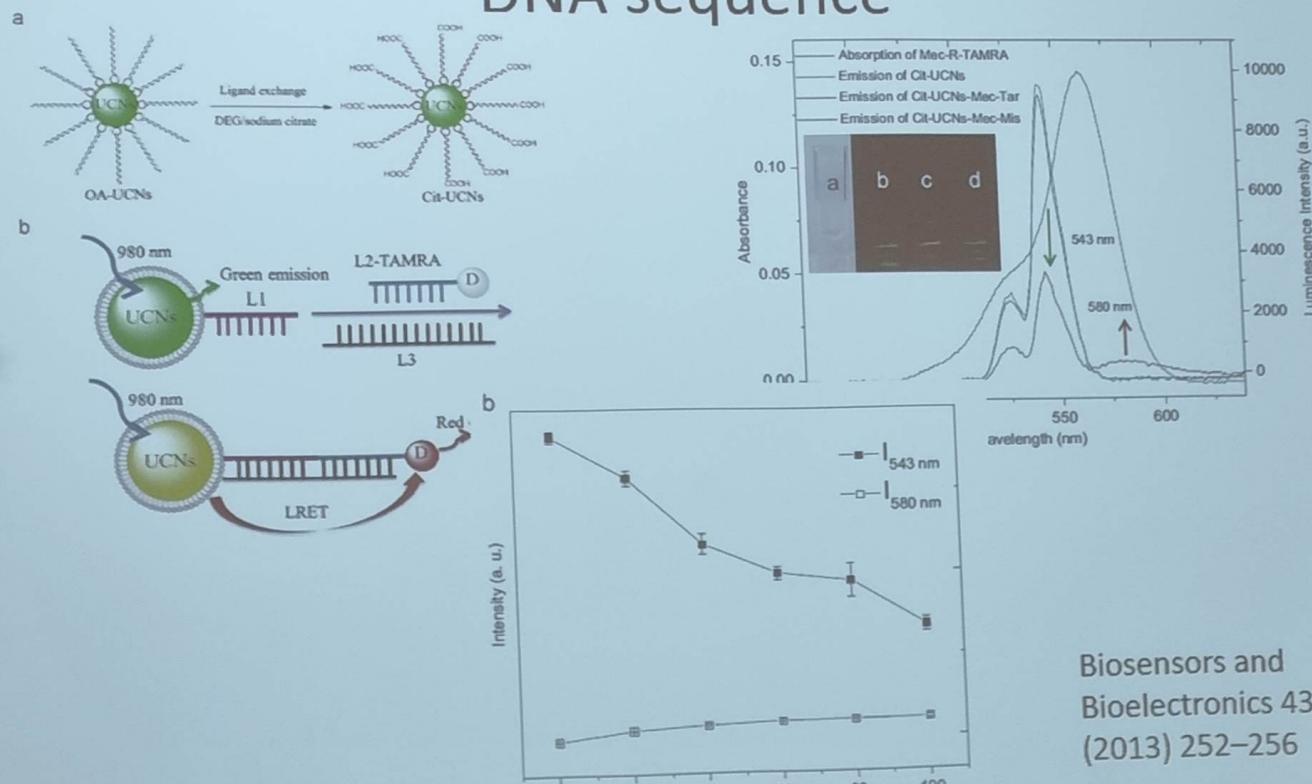
Fig. 4. (a) Cold interdigitated array (IDA) fabricated on SiO_2/Si . (b) Fabricated device after spin coating of CuO-SWCNT sensitive film on IDA.

Sensors and Actuators B 231 (2016) 474–483

CNT based Nano Sensors

System	Target species	Salient feature	Reference
Single wall nanotubes (SWNT)	NH ₃ and NO ₂	Sensitive to 200 ppm of NO ₂ , and 1% of NH ₃ .	Science 287 (2000) 1801.
Single wall nanotubes (SWNT)	N ₂ , He, O ₂ , and Ar	Gas concentrations as low as 100 ppm can be detected	Appl. Phys. Lett. 83 (2003) 2280.
Multi-wall carbon nanotubes (MWCNTs)	NH ₃	Gas concentrations as low as 10 ppm can be detected. The sensor showed a reversible response of few minutes.	J. Phys. D: Appl. Phys. 36 (2003) L109.
Poly(o-anisidine) (POAS) coated CNT	HCl	Nine times increase in sensitivity compared to uncoated CNT	Chemical Physics Letters, Volume 383(5-6) (2004) 617.
MWNT-SiO ₂	CO ₂ , O ₂ and NH ₃	Sensor response time is approximately 45 s, 4 min, and 2 min for CO ₂ , O ₂ , and NH ₃ , respectively. The sensor response is reversible for O ₂ and CO ₂ , but irreversible for NH ₃	IEEE Sens. J. 2 (2002) 82.
Single-walled carbon nanotube (SWNT)	β-D-glucose	Senses β-D-glucose in solution phase by two distinct mechanisms of signal transduction: fluorescence and charge transfer.	Nat. Mater. 4 (2005) 86.
Poly(vinylferrocene) (PVF) derivatised MWCNTs	Glucose	Glucose concentration in real blood sample can be determined.	The Analyst 131 (2006) 670.

Upconversion nanoparticle based LRET system for sensitive detection of MRSA DNA sequence



High-performance surface-enhanced Raman scattering sensors based on Ag nanoparticles-coated Si nanowire arrays for quantitative detection of pesticides

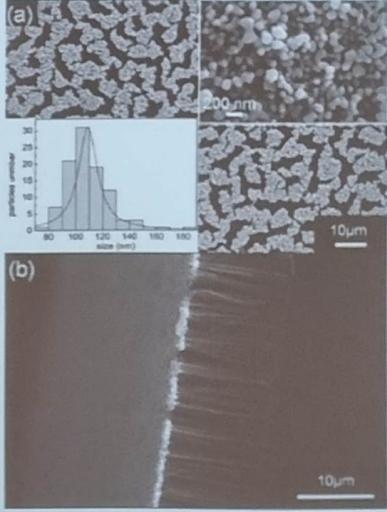


FIG. 1. SEM images of the top view (a) and the side view (b) of the substrate of the SiNW arrays coated with Ag nanoparticles. Inset: high magnification SEM image of Ag nanoparticles and Histograms of the size of Ag nanoparticles.

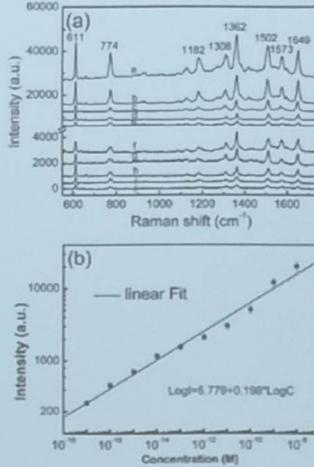


FIG. 2. (a) SERS spectra of R6G obtained at different concentrations, curve a (10^{-8} M), curve b (10^{-9} M), curve c (10^{-10} M), curve d (10^{-11} M), curve e (10^{-12} M), curve f (10^{-13} M), curve g (10^{-14} M), curve h (10^{-15} M), curve i (10^{-16} M), and curve j (10^{-17} M). (b) The linear relationship between the logarithmic intensities (1362 cm^{-1}) and the concentrations. Each datum indicated an average from five samples, and each error bar indicated the standard deviation.

Appl. Phys. Lett. **96**, 053104 2010

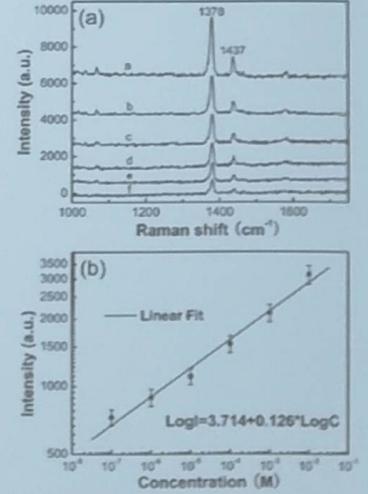


FIG. 3. (a) SERS spectra of Carbaryl obtained at different concentrations, curve a (10^{-2} M), curve b (10^{-3} M), curve c (10^{-4} M), curve d (10^{-5} M), curve e (10^{-6} M), and curve f (10^{-7} M), (b) the linear relationship between the logarithmic intensities (1378 cm^{-1}) and the concentrations. Each datum indicated an average from five samples, and each error bar indicated the standard deviation.

Nanocrystalline NIR-to-NIR luminescent thermometer based on Cr³⁺,Yb³⁺ emission

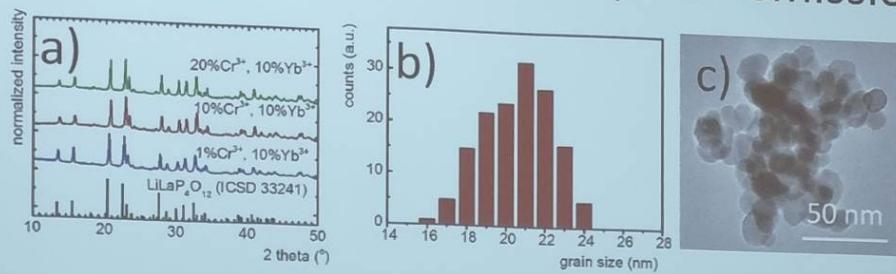
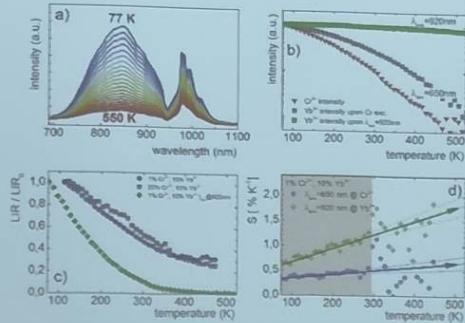


Fig. 1. XRD spectra for LiLaP₄O₁₂:Cr,Yb nanocrystals, and distribution of the grain size of LiLaP₄O₁₂:10%Cr³⁺, 10%Yb³⁺ nanocrystals – b with representative TEM image – c.



Sensors and Actuators B 243 (2017) 388–393

Quantum Dots-Based Optical Fiber Temperature Sensors Fabricated by Layer-by-Layer

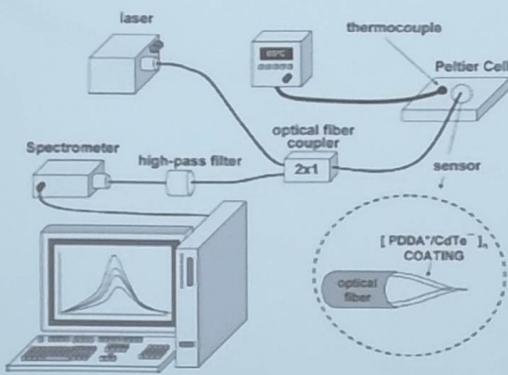


Fig. 1. Experimental setup.

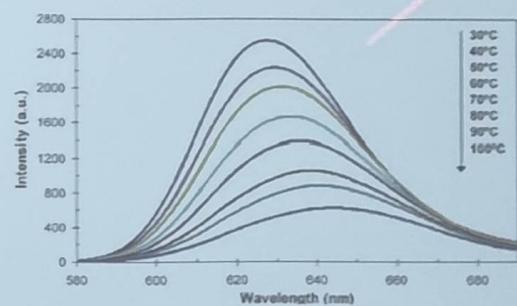


Fig. 3. Spectrum of the red QD $[PDDA/CdTe]_{20}$ sensor at different temperatures.

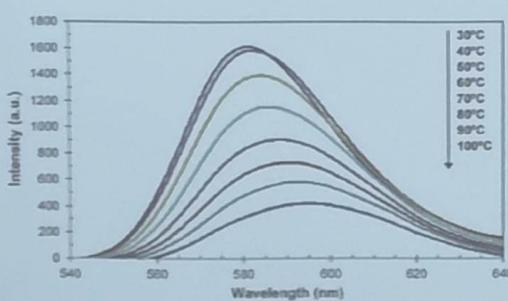


Fig. 2. Spectrum of a green QD $[PDDA/CdTe]_{20}$ sensor at different temperatures.

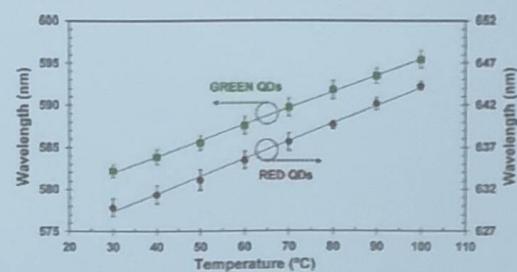
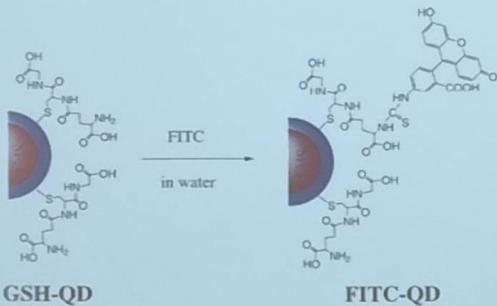


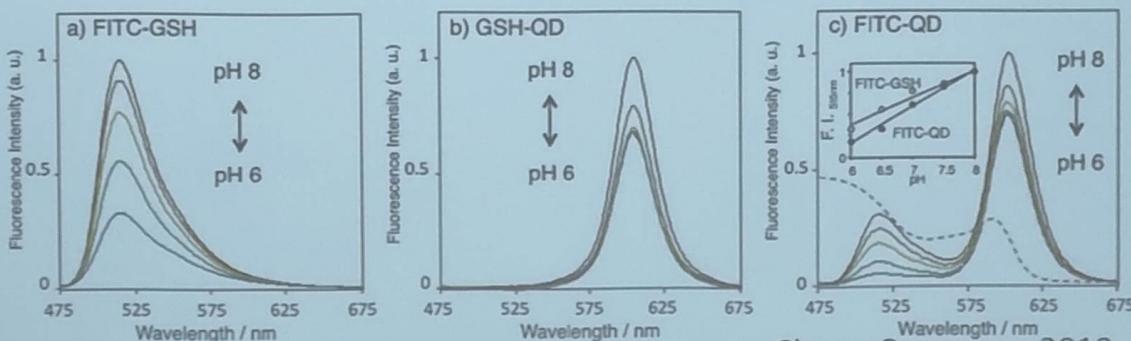
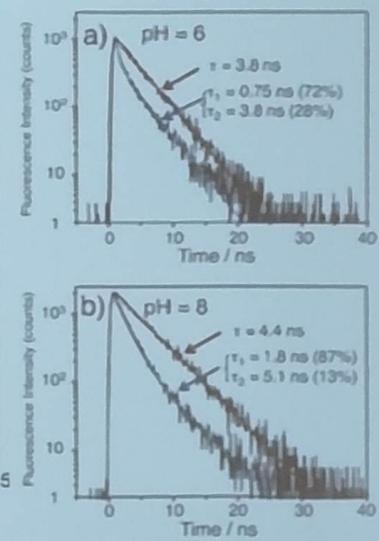
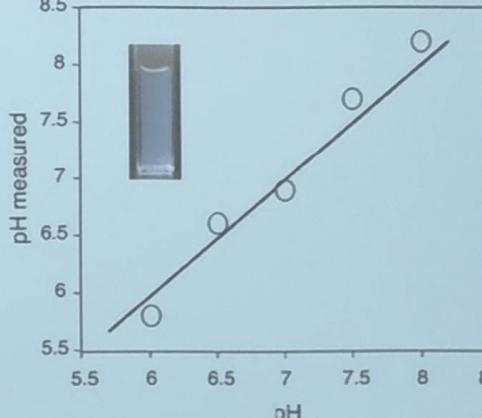
Fig. 4. Dependence of the emission-peak wavelength with respect to the temperature (sensors of Figs. 2 and 3). The sensors were submitted to three complete cycles of heating and cooling.

IEEE SENSORS JOURNAL, VOL. 6, NO. 6, DECEMBER 2006

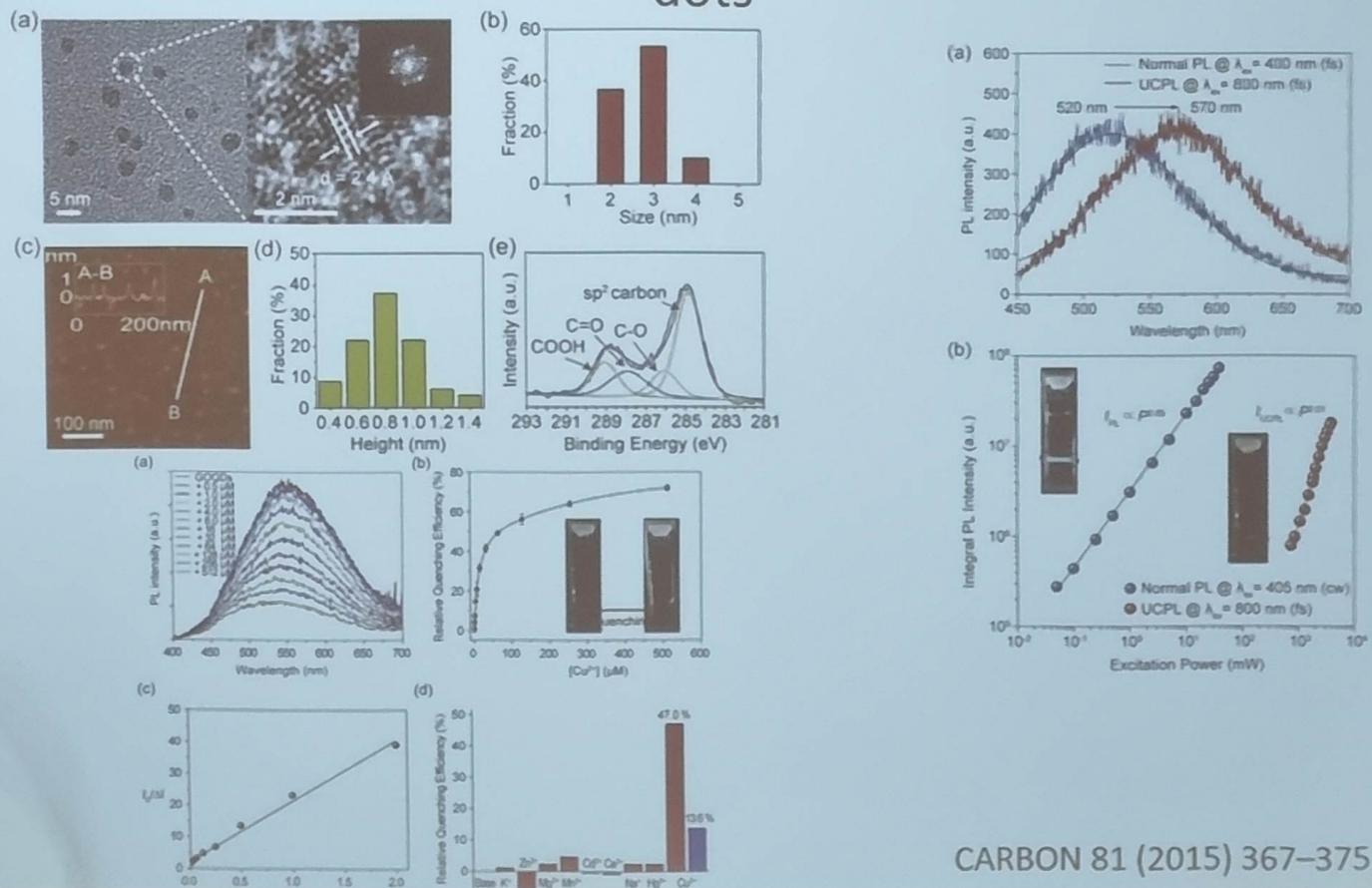
A quantum dot-based ratiometric pH sensor



Scheme 1 Schematic representation of the preparation of FITC (fluorescein isothiocyanate)-QD by the conjugation of FITC to GSH (glutathione)-QD in water. When the conjugation reaction is performed in buffer solutions such as PBS, the coupling efficiency is significantly decreased.



Up-conversion photoluminescent metal ion sensors via two photon absorption in graphene oxide quantum dots



CARBON 81 (2015) 367–375

High-Sensitivity Humidity Sensor Based on a Single SnO₂ Nanowire

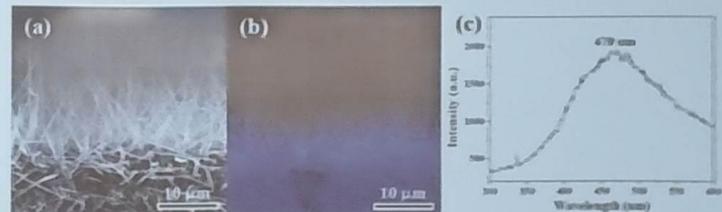
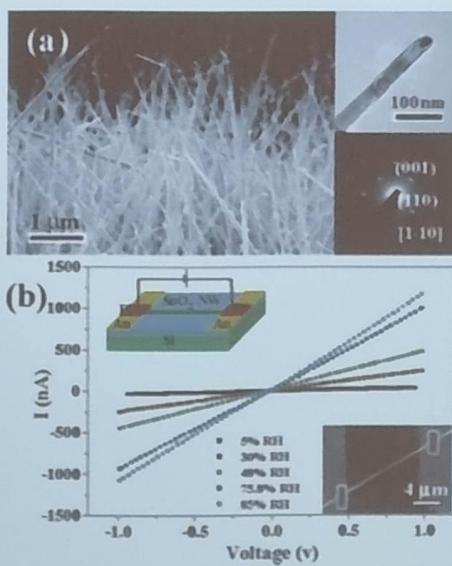


Figure S3. (a) Secondary electron image, (b) panchromatic CL image and (c) corresponding CL spectrum of single SnO₂ nanowire. CL spectrum of SnO₂ nanowire is dominated by a broad emission centered at 470. And panchromatic CL image shows that blue luminescence is uniformly emitted from every SnO₂ nanowire.

RH of air	Resistance of SnO ₂ NW
5%	$2.80 \times 10^7 \Omega$
30%	$4.06 \times 10^6 \Omega$
48%	$2.00 \times 10^6 \Omega$
75.8%	$1.00 \times 10^6 \Omega$
85%	$0.859 \times 10^5 \Omega$

Oxide based Nanosensors

Metal oxide	Target species	Salient features	Reference
V ₂ O ₅ nanofibres	1-Butylamine, toluene, propanol	Extremely high sensitivity was measured for 1-butylamine (below 30 ppb) and moderate sensitivity for ammonia. In contrast, only very little sensitivity was observed for toluene and 1-propanol vapours.	Sens. Actuators B 106 (2005) 730.
SnO ₂ nanobelts	CO, NO ₂ , ethanol	Sensitivity at the level of a few ppb	Appl. Phys. Lett. 81 (2002) 1869.
In ₂ O ₃ nanowires	NH ₃ , NO ₂	The response times have been determined to be 5 s for 100-ppm NO ₂ and 10 s for 1% NH ₃ , and the lowest detectable concentrations are 0.5 ppm for NO ₂ and 0.02% for NH ₃	Appl. Phys. Lett. 82 (2003) 1613.
ZnO nanowires	Ethanol	Sensitive to ethanol concentration is in the range of 1–100 ppm. Sensitivity increases sharply as the temperature is raised from 200 to 300 °C	Appl. Phys. Lett. 84 (2004) 3654.
MoO ₃ nanorods	Ethanol and CO	The detection limit for ethanol and CO is lower than 30 ppm	Chem. Phys. Lett. 407 (2005) 368
Cd-doped ZnO nanowire	Relative humidity	Cd-doped ZnO nanowires show a clear positive temperature coefficient of resistance effect, which is quite abnormal as compared to pure ZnO nanowires	Appl. Phys. Lett. 84 (2004) 3085.
SnO ₂	Dimethyl methylphosphonate (DMMP)	Sensitive to 53 ppb DMMP and can be improved via doping nanobelts with catalytic additives.	Appl. Phys. Lett. 86 (2005) 063101.

Lanthanide doped nanoparticles as remote sensors for magnetic fields

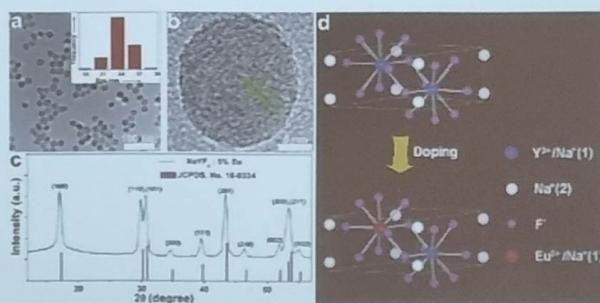


Fig. 1 (a) Low-resolution TEM image of NaYF₄:5% Eu NPs (inset: the size distribution of NPs). (b) HRTEM image of NaYF₄:5% Eu NPs. (c) XRD pattern of NPs. (d) Crystal structure of NaYF₄ and Eu³⁺ doped NaYF₄.

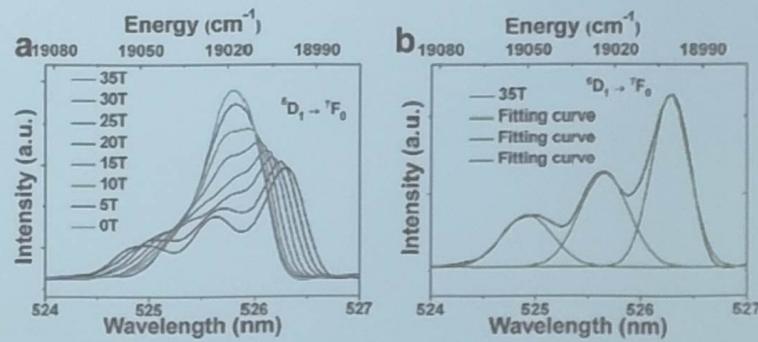
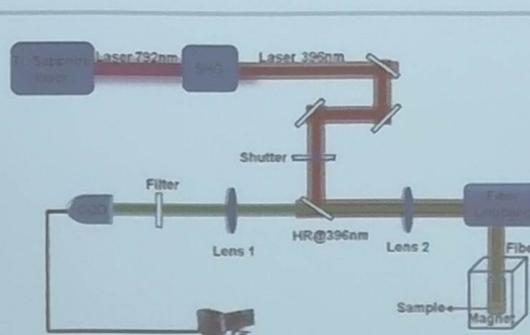
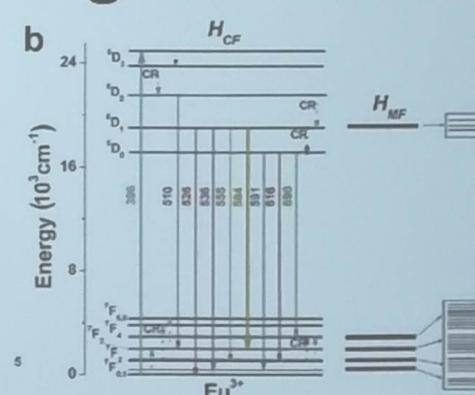
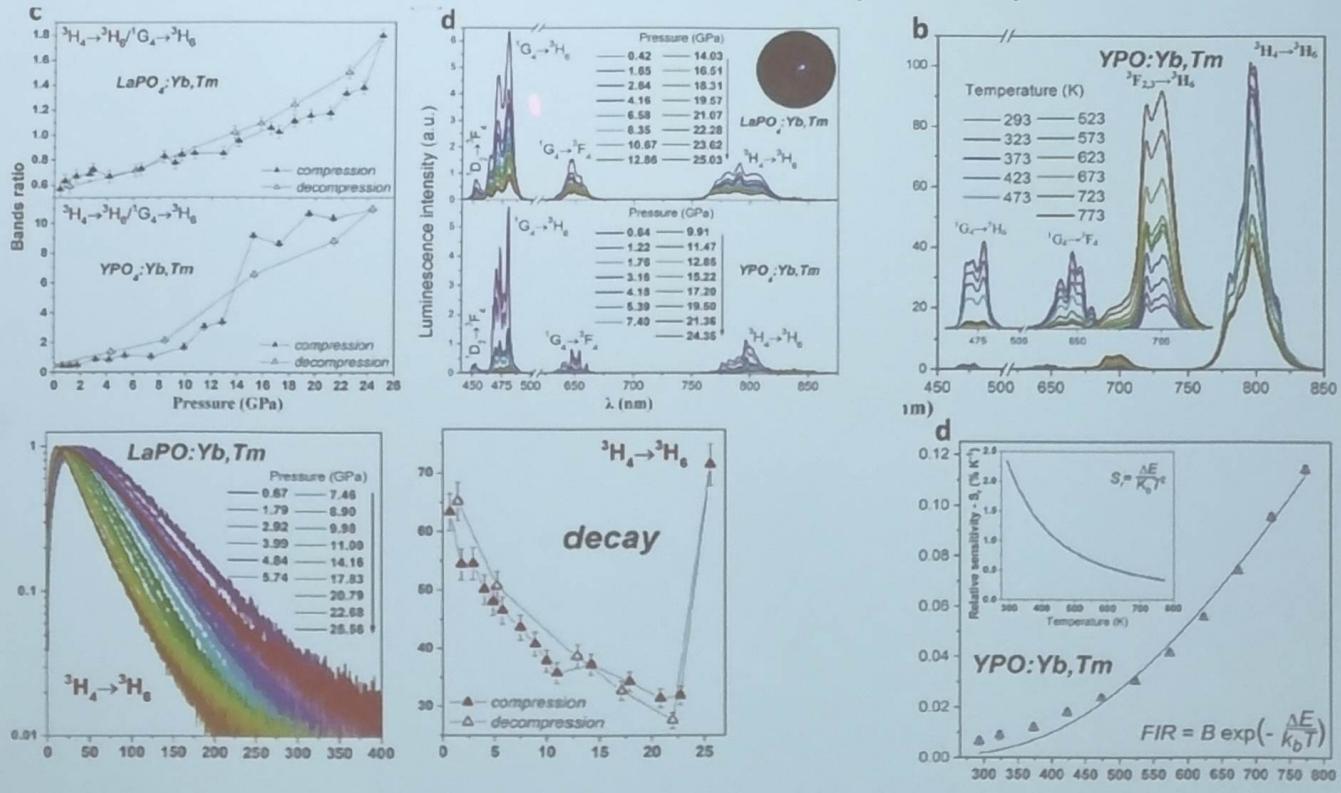


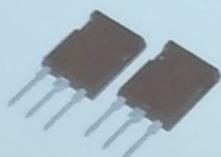
Fig. 2 Schematic diagram of the luminescence spectroscopy test system equipped with a pulsed MF.

Multifunctional Optical Sensors for Nanomanometry and Nanothermometry $\text{LaPO}_4/\text{YPO}_4:\text{Yb}^{3+}-\text{Tm}^{3+}$



ACS Appl. Mater. Interfaces 2018, 10, 17269–17279

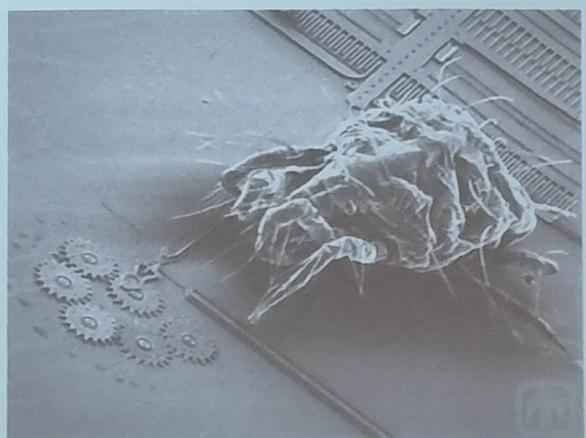
Nanoelektronika w czujnikach



W 2002 roku zaczęto wytwarzać bramki w technologii 90nm, w 2010 roku wytwarzane już były procesory w technologii 35nm. Według firmy Intel, wielkości charakteryzujące układy elektroniczne produkowane seryjnie to 22nm, 16nm od 2013 roku oraz 11nm od roku 2015. Wielkość 8nm będzie kresem miniaturyzacji układów elektronicznych opartych na krzemie z powodu kwantowego zjawiska tunelowego.

MEMS (micro elektro- mechanical systems). Z tego typu układami można spotkać się w głowicach drukarek atramentowych i rzutnikach wideo (zwierciadła), w przemyśle motoryzacyjnym (czujniki przyspieszenia), elektronice użytkowej (mikrozyroskop) oraz przemyśle medycznym (Bio-MEMS, Lab-On-Chip).

Miniaturyzacja zmienia układy MEMS w NEMS (nano elektro- mechanical systems). Układy te mogą być używane w przyszłych urządzeniach do przechowywania danych. Materiałami mającymi olbrzymie możliwości jako materiały konstrukcyjne układów NEMS są nanorurki węglowe i grafen



Skaningowy Mikroskop Jonowy (FIB-Focused Ion Beam)

Skaningowy Mikroskop Jonowy (FIB-Focused Ion Beam) umożliwia przygotowanie i wstępную obserwację preparatów przeznaczonych do prowadzenia badań z wykorzystaniem TEM (Transmisyjny Mikroskop Elektronowy) i SEM (Skaningowy Mikroskop Elektronowy). W urządzeniu tym wykorzystuje się do wycinania próbek zogniskowaną wiązkę jonów o grubości ok. 6 nm i o określonej energii, którą można dobrać w zależności od obrabianego materiału. Ze względu na bardzo małe rozmiary próbki, urządzenie jest również mikroskopem, który umożliwia obserwację i kontrolę procesu wycinania próbki. Urządzenie posiada specjalny system do przenoszenia i mocowania próbki na element nośny.

