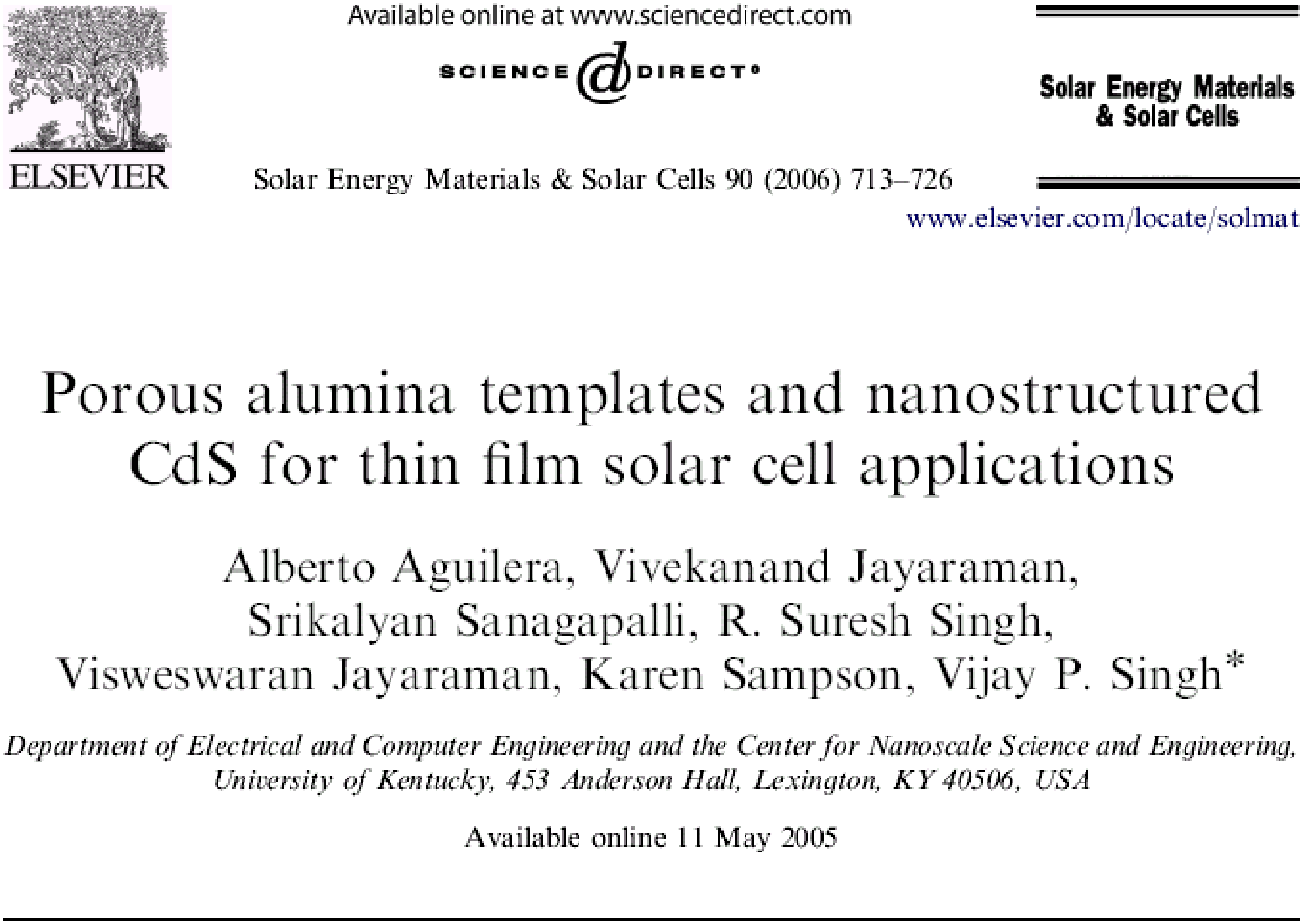
Nanomaterials

for high tech applications

Applications overview

- PAA
  - Energy, biosensors
- PAT
- NW
- NP

Energy



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Solar Energy Materials & Solar Cells 90 (2006) 713–726

Solar Energy Materials & Solar Cells

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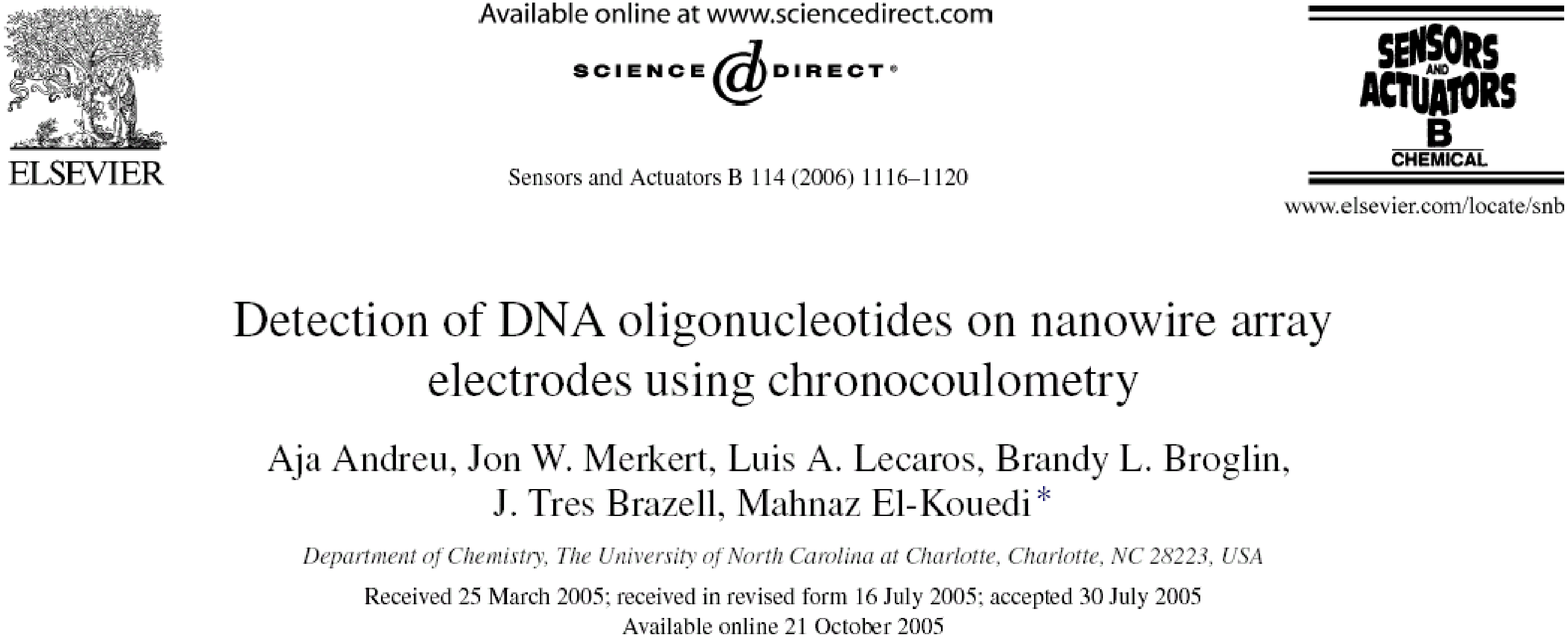
Porous alumina templates and nanostructured CdS for thin film solar cell applications

Alberto Aguilera, Vivekanand Jayaraman,
Srikalyan Sanagapalli, R. Suresh Singh,
Visweswaran Jayaraman, Karen Sampson, Vijay P. Singh*

*Department of Electrical and Computer Engineering and the Center for Nanoscale Science and Engineering,
University of Kentucky, 453 Anderson Hall, Lexington, KY 40506, USA*



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Sensors and Actuators B 114 (2006) 1116–1120
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SENSORS AND ACTUATORS B CHEMICAL
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Detection of DNA oligonucleotides on nanowire array electrodes using chronocoulometry

Aja Andreu, Jon W. Merkert, Luis A. Lecaros, Brandy L. Broglin,
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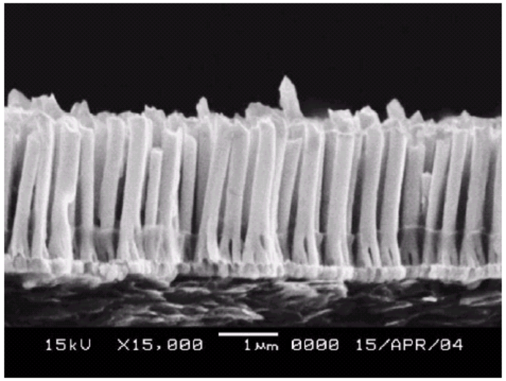
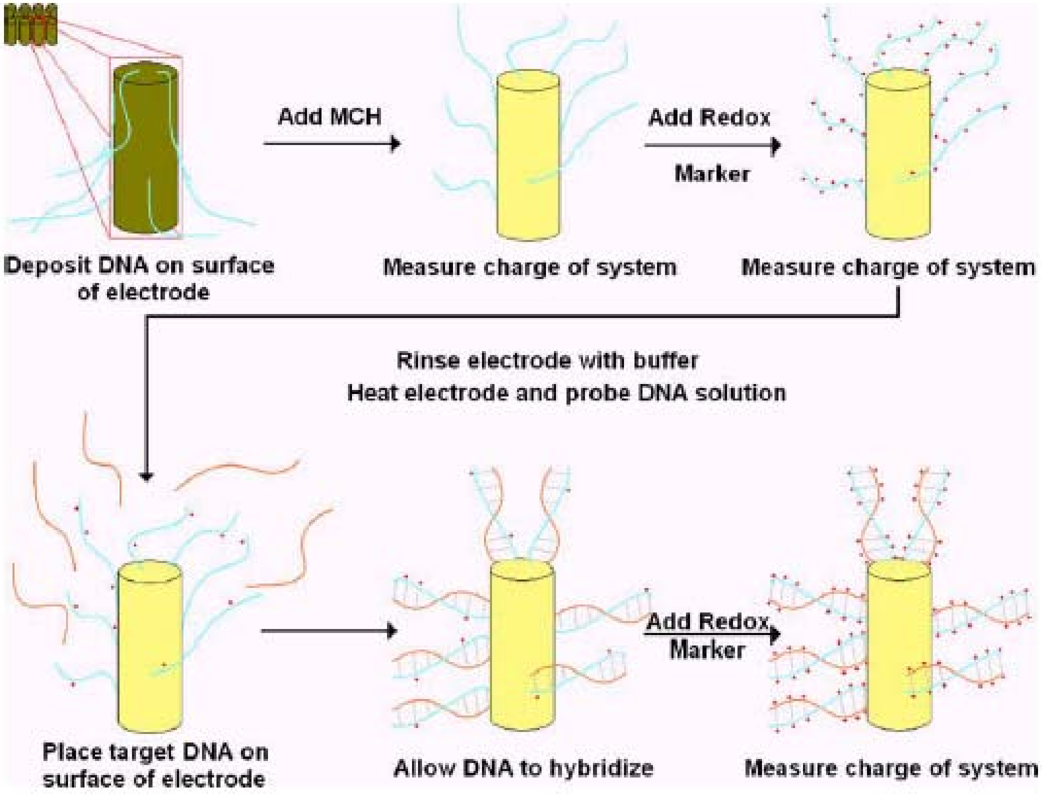
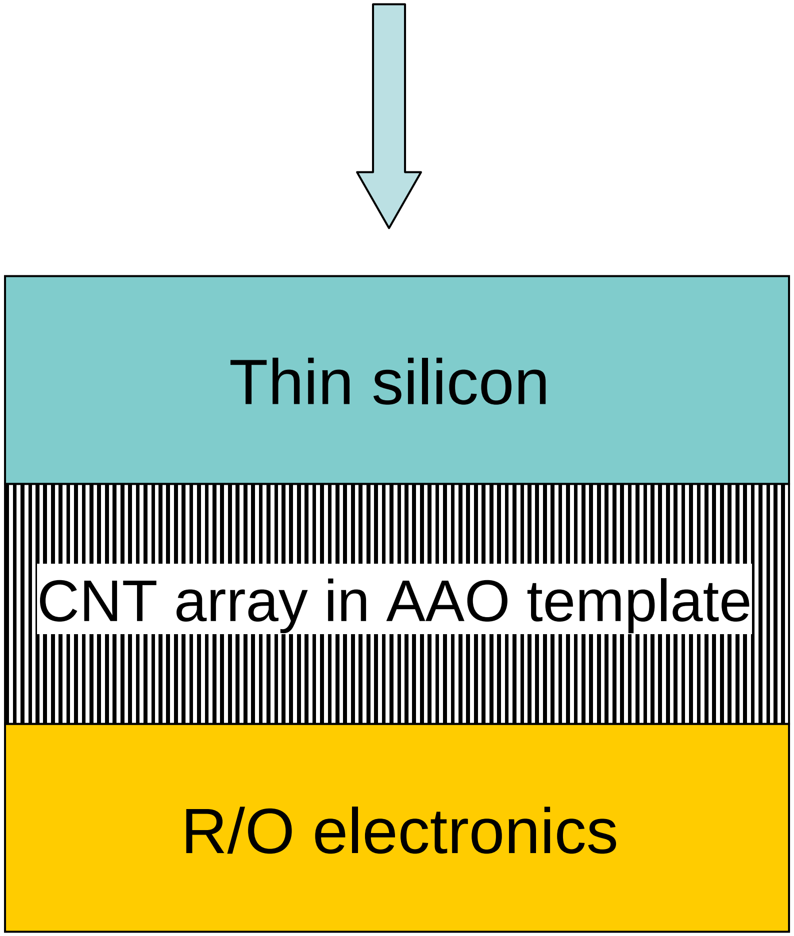
Received 25 March 2005; received in revised form 16 July 2005; accepted 30 July 2005
Available online 21 October 2005


15kU X15,000 1µm 0000 15/APR/04


Deposit DNA on surface of electrode
Add MCH
Measure charge of system
Add Redox Marker
Measure charge of system
Rinse electrode with buffer
Heat electrode and probe DNA solution
Place target DNA on surface of electrode
Allow DNA to hybridize
Add Redox Marker
Measure charge of system

Basic idea for a position particle detector



Thin silicon

CNT array in AAO template

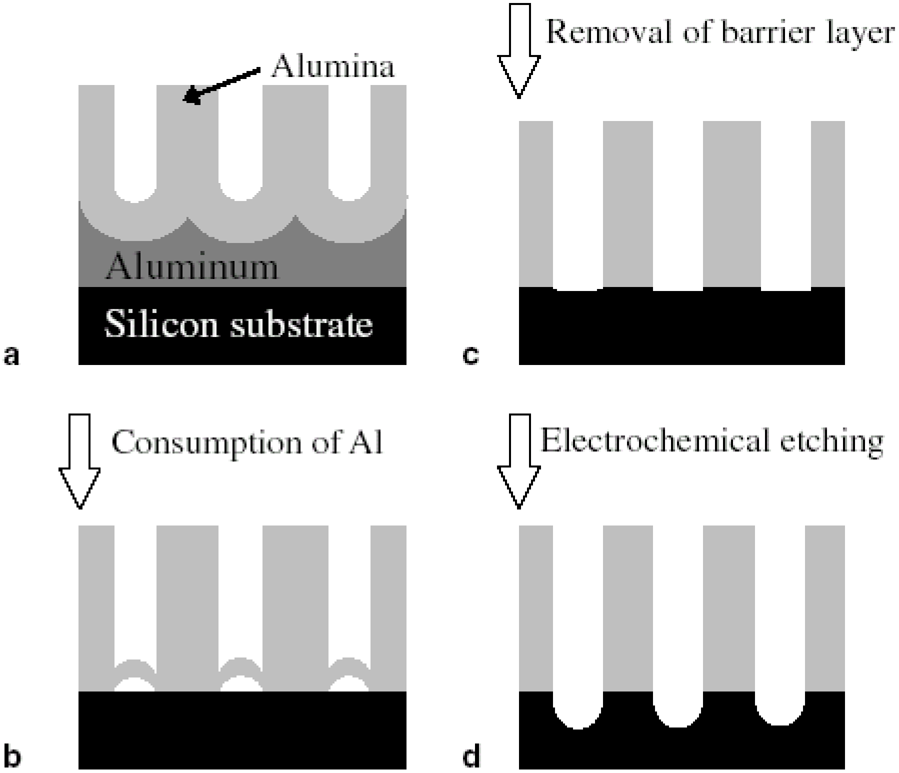
R/O electronics

A regular and uniform matrix of carbon nanotubes, grown inside the alumina template, is sandwiched between an active layer and a readout layer. The active layer is formed formed by a reverse biased silicon diode, in which a charged particle produces electro-hole pairs during its passage. The readout layer is constituted by CMOS electronics embedded in a silicon substrate.

R.Angelucci et al., Application of Nanotechnologies in High Energy Physics, Nuclear Physics B (Proc. Suppl.) 125 (2003) 164-168

Transfer of the nanoporous pattern of AAO into a Si substrate

Anodic oxidation of a Al film sputtered on a p-type Si substrate

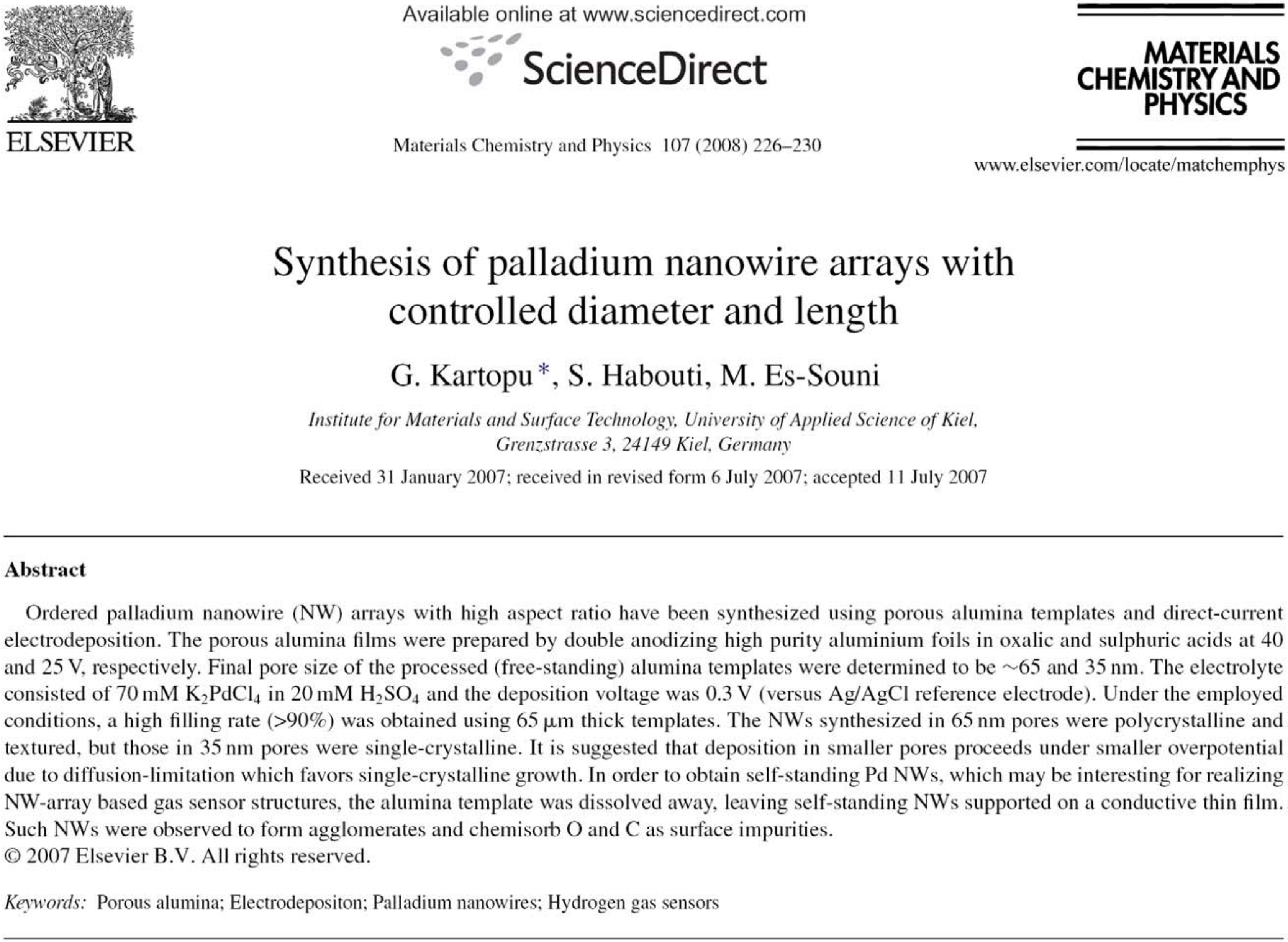


Dissolution of the barrier layer in H_3PO_4 solution

Silicon electrochemical etching in a HF containing solution

H. Asoh, Electrochemical etching of silicon through anodic porous alumina, Electrochemistry Communications 7 (2005) 953–956.

Gas sensors



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Materials Chemistry and Physics 107 (2008) 226–230
MATERIALS CHEMISTRY AND PHYSICS
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Synthesis of palladium nanowire arrays with controlled diameter and length

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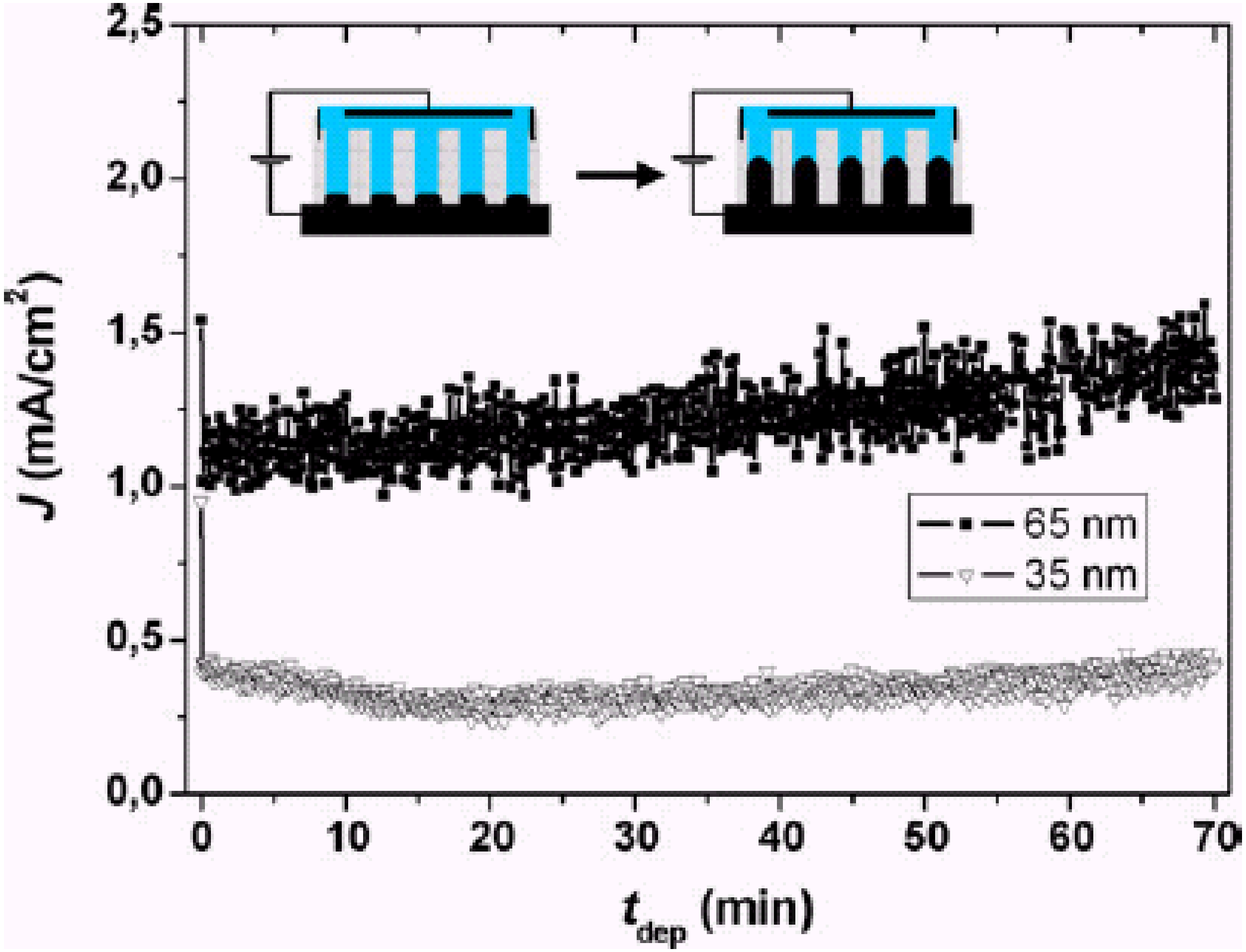
Received 31 January 2007; received in revised form 6 July 2007; accepted 11 July 2007

Abstract

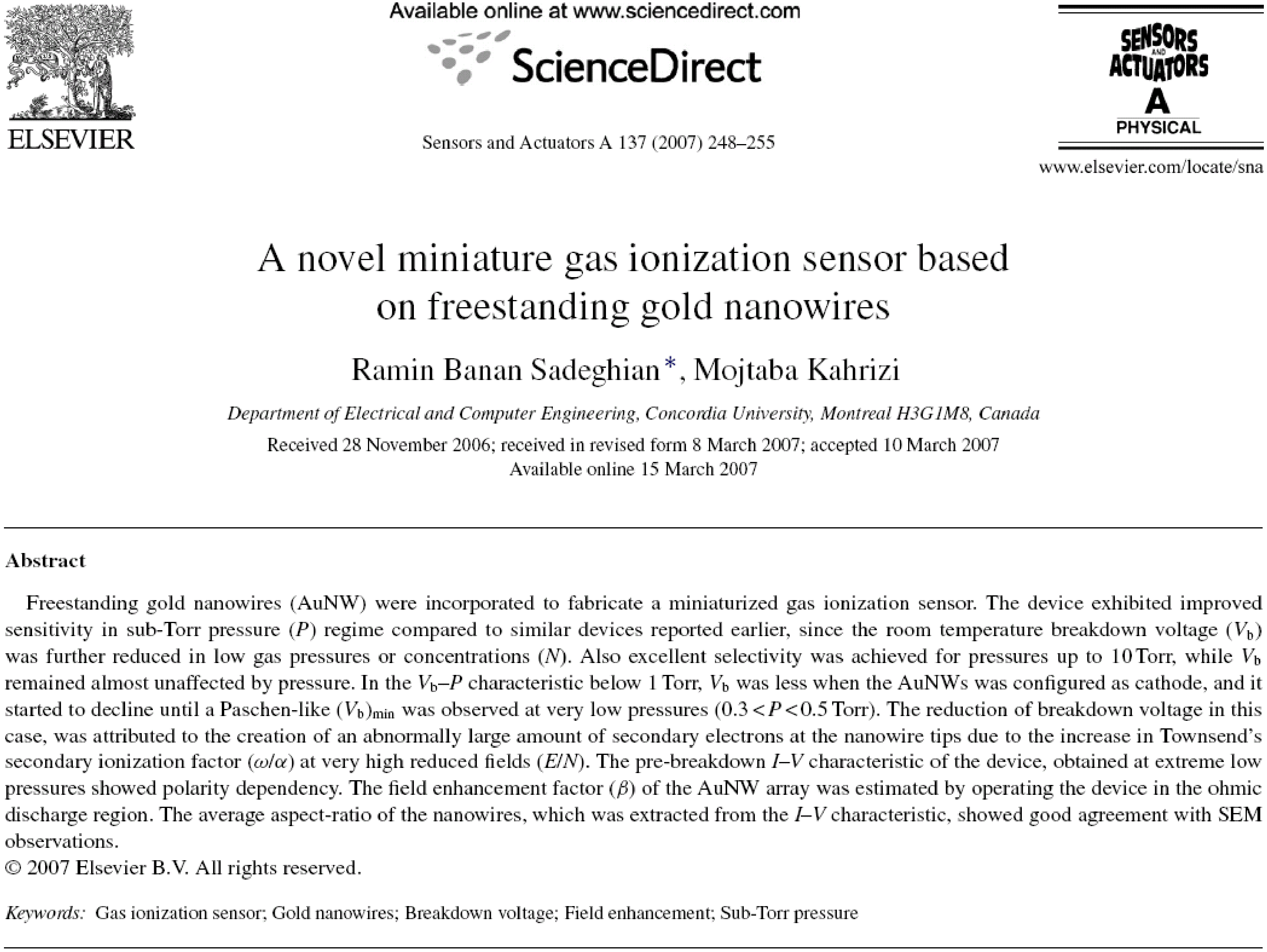
Ordered palladium nanowire (NW) arrays with high aspect ratio have been synthesized using porous alumina templates and direct-current electrodeposition. The porous alumina films were prepared by double anodizing high purity aluminium foils in oxalic and sulphuric acids at 40 and 25 V, respectively. Final pore size of the processed (free-standing) alumina templates were determined to be ~65 and 35 nm. The electrolyte consisted of 70 mM K_2PdCl_4 in 20 mM H_2SO_4 and the deposition voltage was 0.3 V (versus Ag/AgCl reference electrode). Under the employed conditions, a high filling rate (>90%) was obtained using 65 μm thick templates. The NWs synthesized in 65 nm pores were polycrystalline and textured, but those in 35 nm pores were single-crystalline. It is suggested that deposition in smaller pores proceeds under smaller overpotential due to diffusion-limitation which favors single-crystalline growth. In order to obtain self-standing Pd NWs, which may be interesting for realizing NW-array based gas sensor structures, the alumina template was dissolved away, leaving self-standing NWs supported on a conductive thin film. Such NWs were observed to form agglomerates and chemisorb O and C as surface impurities.

Keywords: Porous alumina; Electrodepositon; Palladium nanowires; Hydrogen gas sensors

Palladium nanowires for hydrogen sensors



G. Kartopu, Synthesis of palladium nanowire arrays with controlled diameter and length, Materials Chemistry and Physics 107 (2008) 226–230.



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Sensors and Actuators A 137 (2007) 248–255

SENSORS AND ACTUATORS A PHYSICAL

www.elsevier.com/locate/sna

A novel miniature gas ionization sensor based on freestanding gold nanowires

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Received 28 November 2006; received in revised form 8 March 2007; accepted 10 March 2007
Available online 15 March 2007

Abstract

Freestanding gold nanowires (AuNW) were incorporated to fabricate a miniaturized gas ionization sensor. The device exhibited improved sensitivity in sub-Torr pressure (P) regime compared to similar devices reported earlier, since the room temperature breakdown voltage (V_b) was further reduced in low gas pressures or concentrations (N). Also excellent selectivity was achieved for pressures up to 10 Torr, while V_b remained almost unaffected by pressure. In the V_b–P characteristic below 1 Torr, V_b was less when the AuNWs was configured as cathode, and it started to decline until a Paschen-like $(V_b)_{min}$ was observed at very low pressures ($0.3 < P < 0.5$ Torr). The reduction of breakdown voltage in this case, was attributed to the creation of an abnormally large amount of secondary electrons at the nanowire tips due to the increase in Townsend's secondary ionization factor (ω/α) at very high reduced fields (E/N). The pre-breakdown I–V characteristic of the device, obtained at extreme low pressures showed polarity dependency. The field enhancement factor (β) of the AuNW array was estimated by operating the device in the ohmic discharge region. The average aspect-ratio of the nanowires, which was extracted from the I–V characteristic, showed good agreement with SEM observations.

Keywords: Gas ionization sensor; Gold nanowires; Breakdown voltage; Field enhancement; Sub-Torr pressure

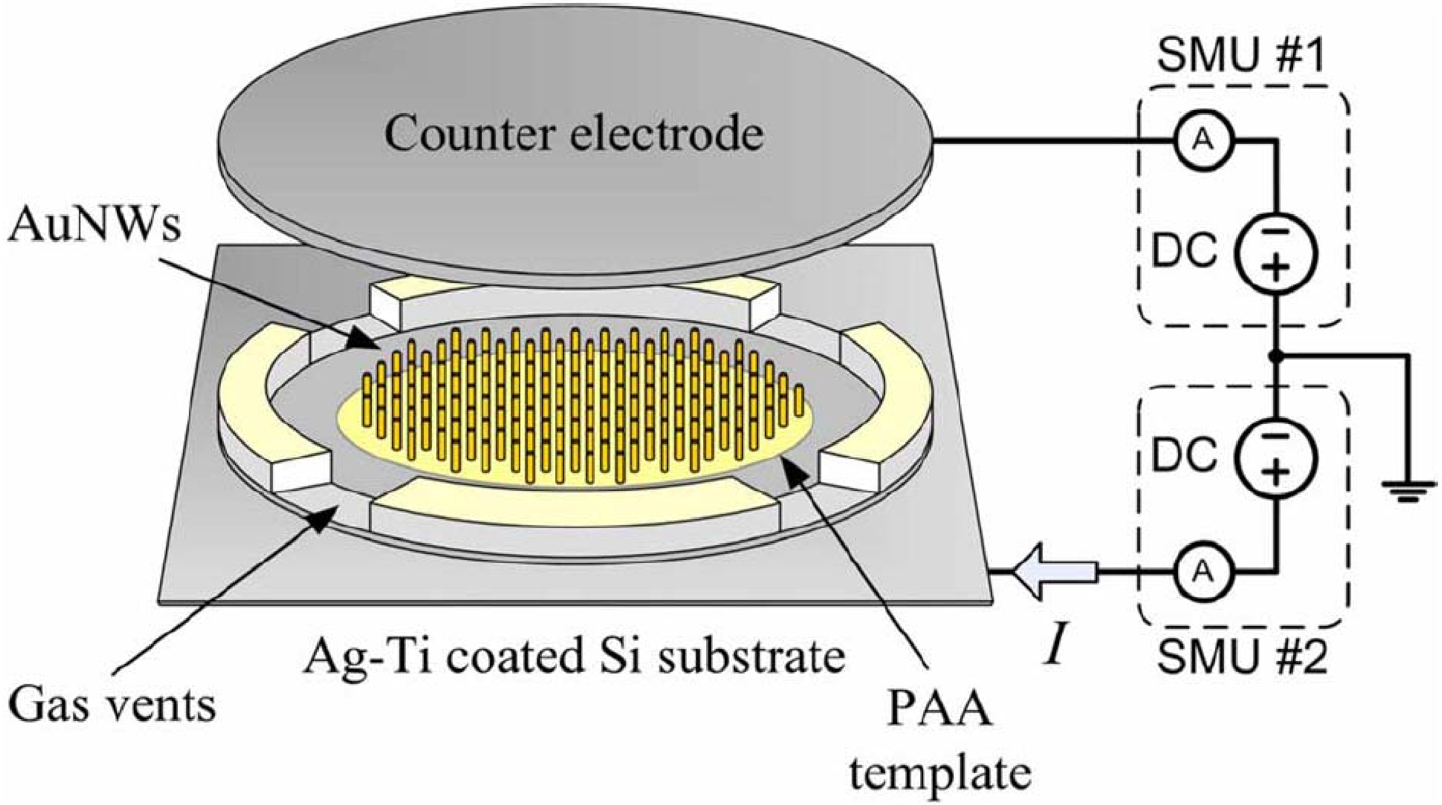
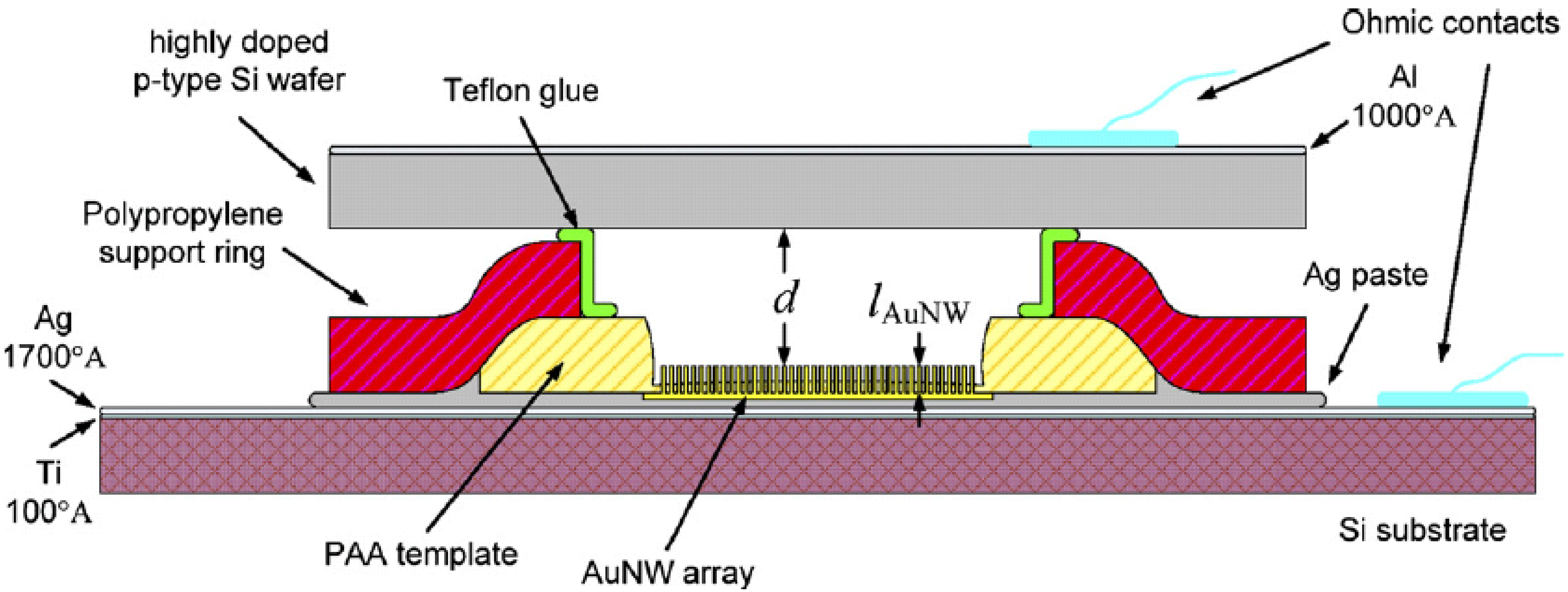


Fig. 6. Schematic illustration of the GFIS cell and the measurement setup. The counter electrode is mounted on the peripheral supporting ring. *I* denotes the field-ion current.


highly doped
p-type Si wafer
Teflon glue
Ohmic contacts
Al
1000°A
Polypropylene
support ring
d
l_{AuNW}
Ag paste
Ag
1700°A
Ti
100°A
PAA template
AuNW array
Si substrate

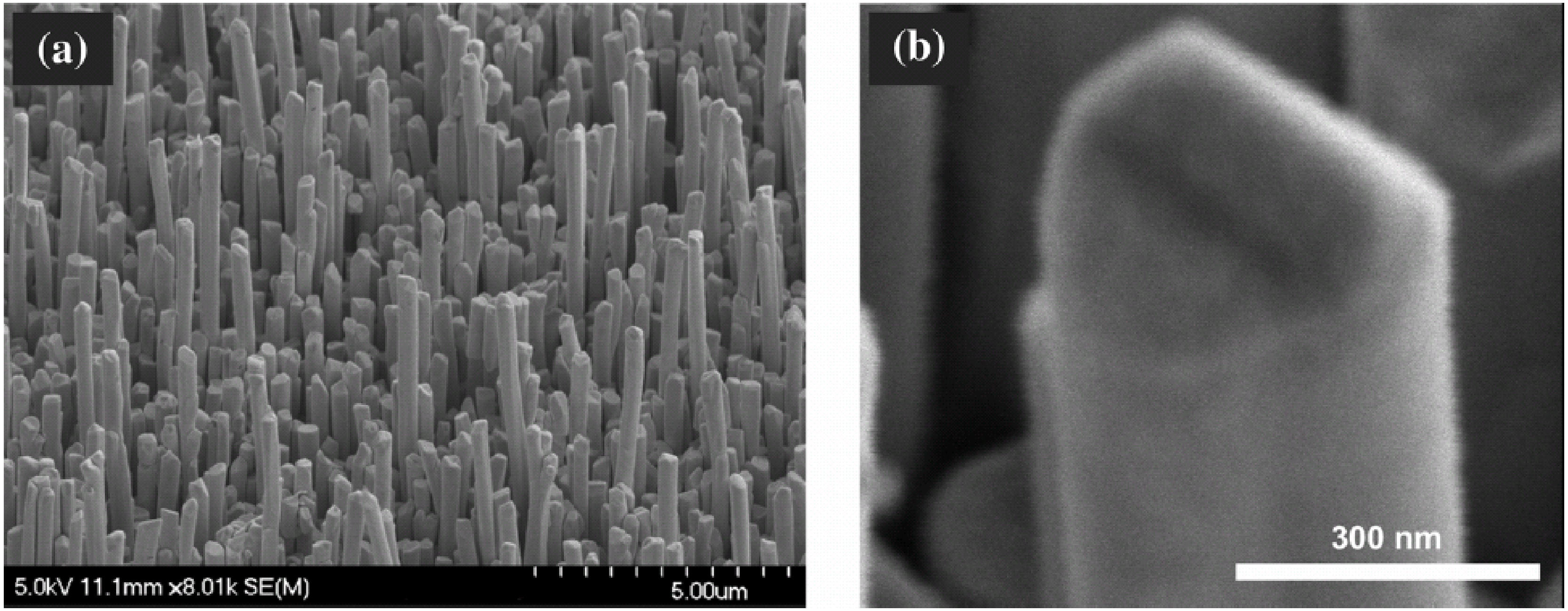
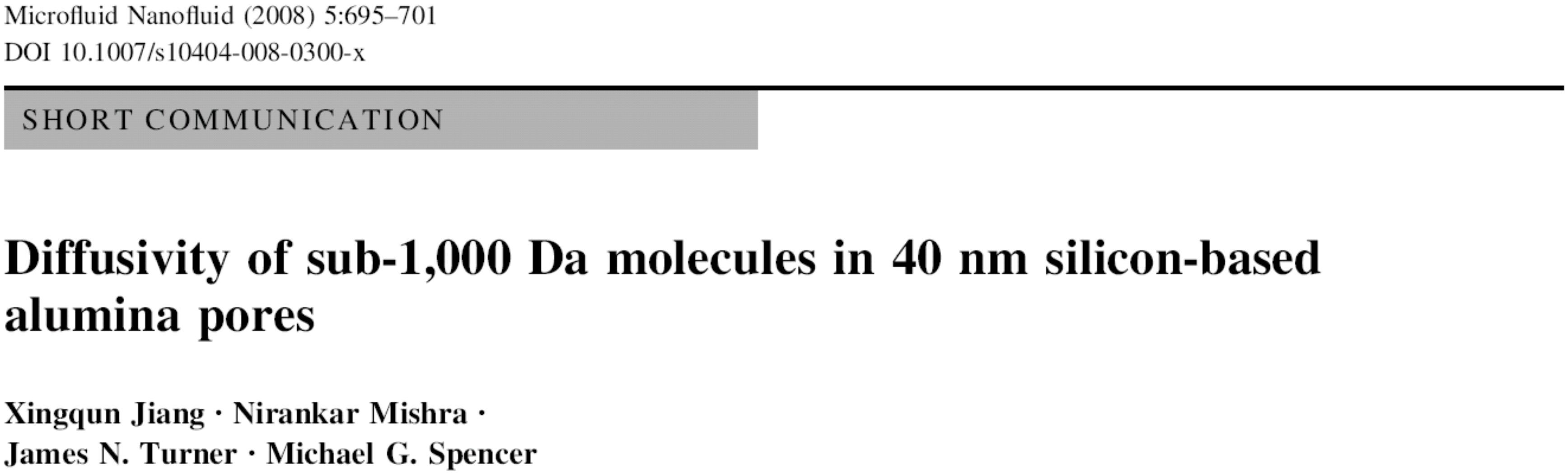


Fig. 4. (a) SEM image of the array of AuNWs grown in PAA #2. (b) A close-up view of a regular AuNW tip.



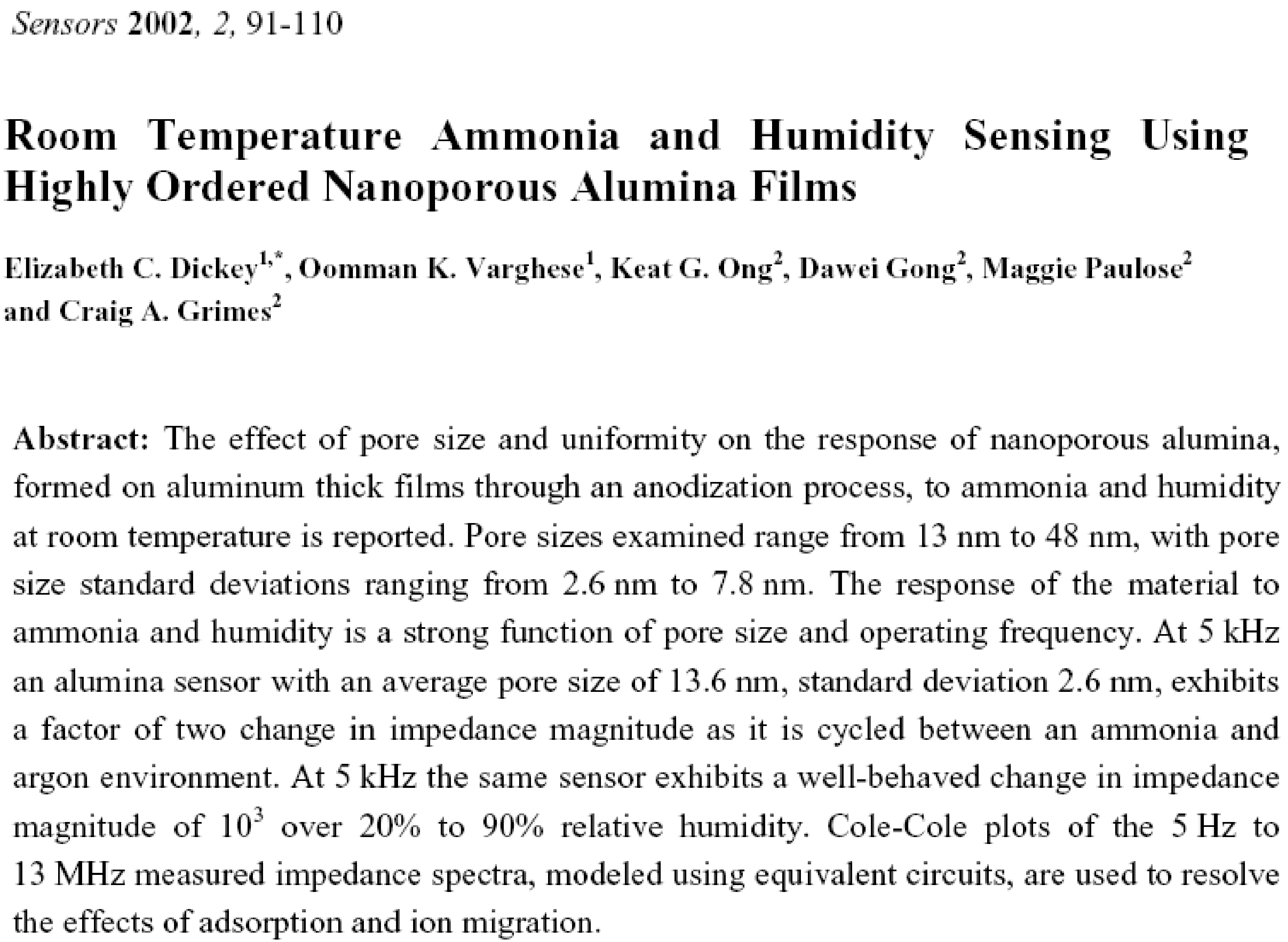
Microfluid Nanofluid (2008) 5:695–701
DOI 10.1007/s10404-008-0300-x

SHORT COMMUNICATION

Diffusivity of sub-1,000 Da molecules in 40 nm silicon-based alumina pores

**Xingqun Jiang · Nirankar Mishra ·
James N. Turner · Michael G. Spencer**

Abstract Porous anodic alumina has been of an increasing interest to applications of on-chip biosensors and bioseparations. However, the characteristics of molecular diffusion in alumina nanopores have not been fully explored. Here, we have investigated an ultra-thin freestanding alumina membrane fabricated on a silicon substrate as a new on-chip diffusion system. Sub-1,000 Da molecules such as caffeine were diffused through alumina pores with a pore diameter of 40 nm and a pore length of 1.2 lm. The diffusion dynamics was characterized by modeling the molecular transport as one-dimensional convective Fickian flow. The diffusion coefficients were calculated to be on the order of 10-8 cm2 s-1. The transport rate of coions was enhanced by increasing the ionic strength of diffusion solution. Relative to thick alumina membranes, the thin-film alumina was able to achieve a significantly higher flux rate, making it more favorable for rapid molecular transport. The characterizations we present here have contributed important experimental data toalumina nanofluidics, and are believed to be valuable for applications such as drug deliveries, molecular separations, and membrane biosensors.



Sensors **2002**, *2*, 91-110

Room Temperature Ammonia and Humidity Sensing Using Highly Ordered Nanoporous Alumina Films

Elizabeth C. Dickey[1,*], Oomman K. Varghese[1], Keat G. Ong[2], Dawei Gong[2], Maggie Paulose[2] and Craig A. Grimes[2]

Abstract: The effect of pore size and uniformity on the response of nanoporous alumina, formed on aluminum thick films through an anodization process, to ammonia and humidity at room temperature is reported. Pore sizes examined range from 13 nm to 48 nm, with pore size standard deviations ranging from 2.6 nm to 7.8 nm. The response of the material to ammonia and humidity is a strong function of pore size and operating frequency. At 5 kHz an alumina sensor with an average pore size of 13.6 nm, standard deviation 2.6 nm, exhibits a factor of two change in impedance magnitude as it is cycled between an ammonia and argon environment. At 5 kHz the same sensor exhibits a well-behaved change in impedance magnitude of 10^3 over 20% to 90% relative humidity. Cole-Cole plots of the 5 Hz to 13 MHz measured impedance spectra, modeled using equivalent circuits, are used to resolve the effects of adsorption and ion migration.

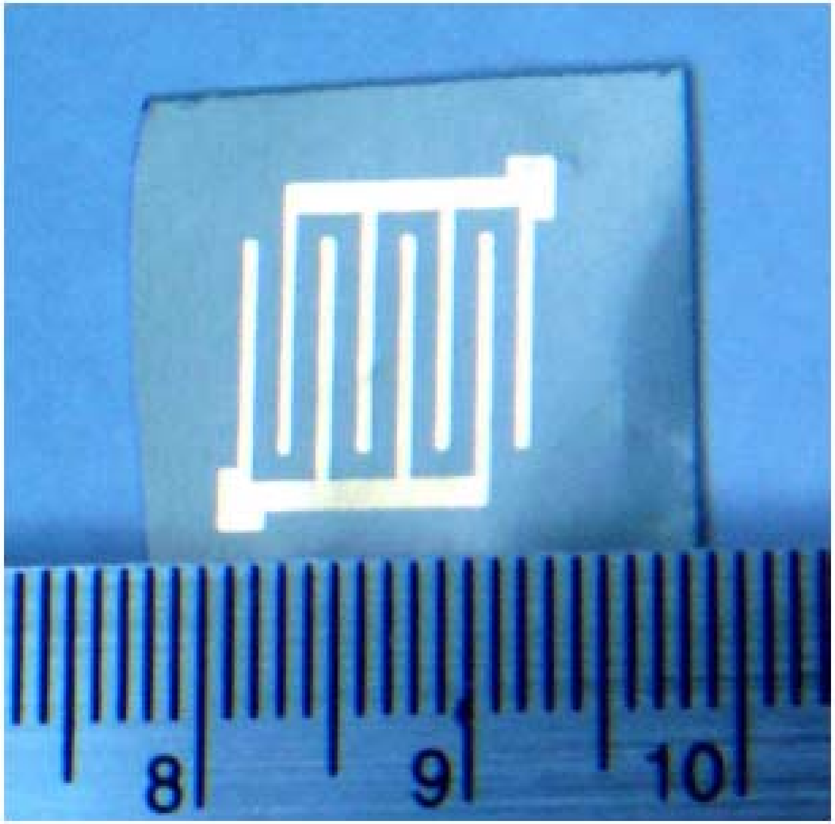
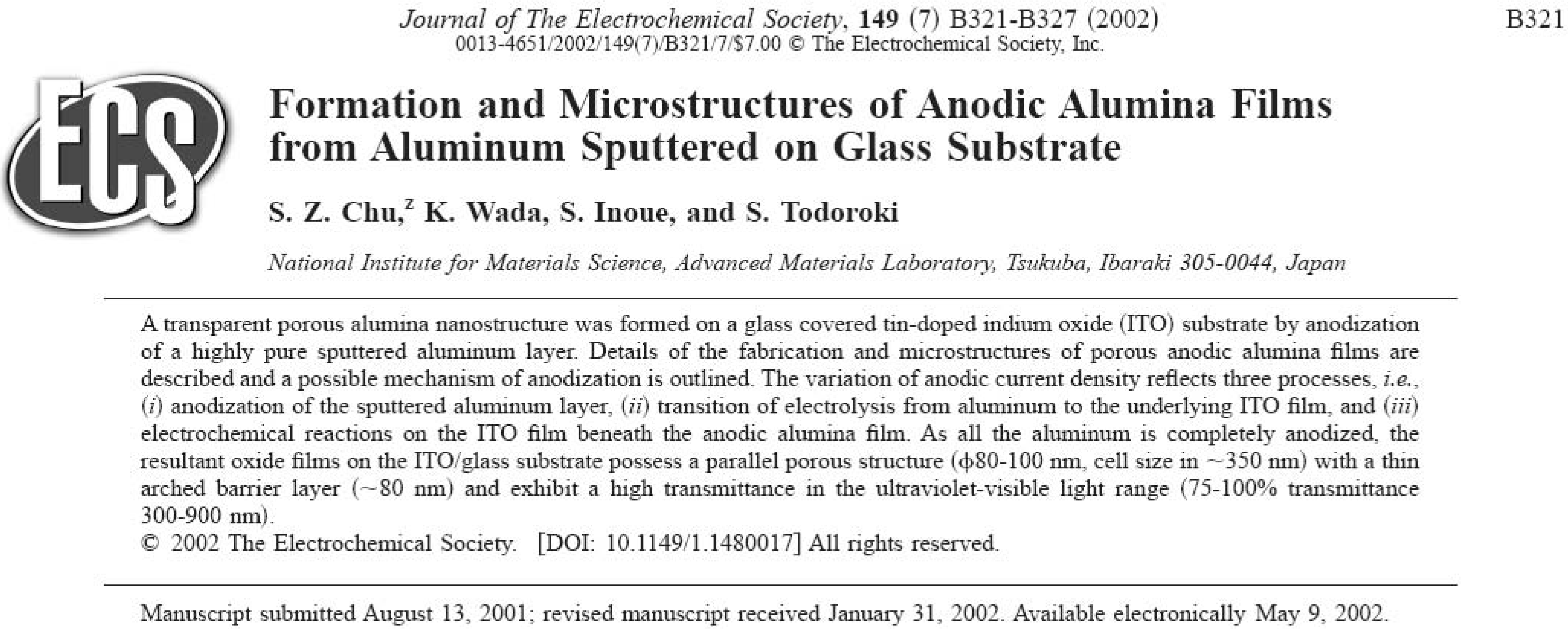


Figure 1. Digital image of a typical nanoporous alumina sensor.



Journal of The Electrochemical Society, **149** (7) B321-B327 (2002) B321
0013-4651/2002/149(7)/B321/7/$7.00 © The Electrochemical Society, Inc.

Formation and Microstructures of Anodic Alumina Films from Aluminum Sputtered on Glass Substrate

S. Z. Chu,[z] K. Wada, S. Inoue, and S. Todoroki

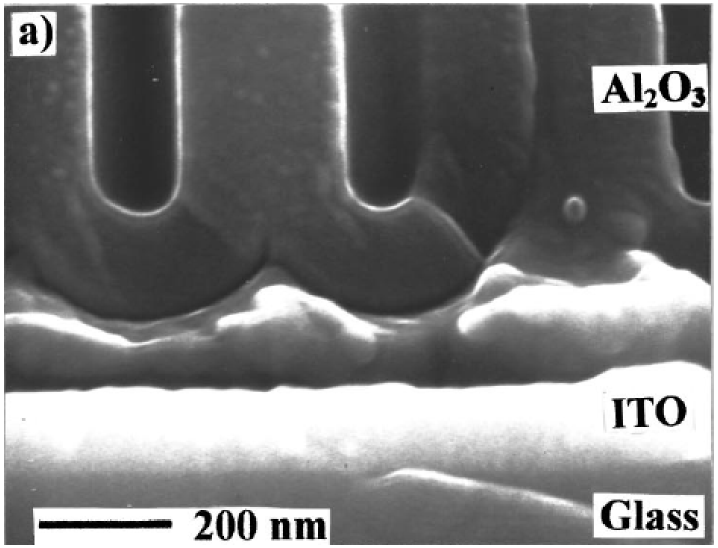
National Institute for Materials Science, Advanced Materials Laboratory, Tsukuba, Ibaraki 305-0044, Japan

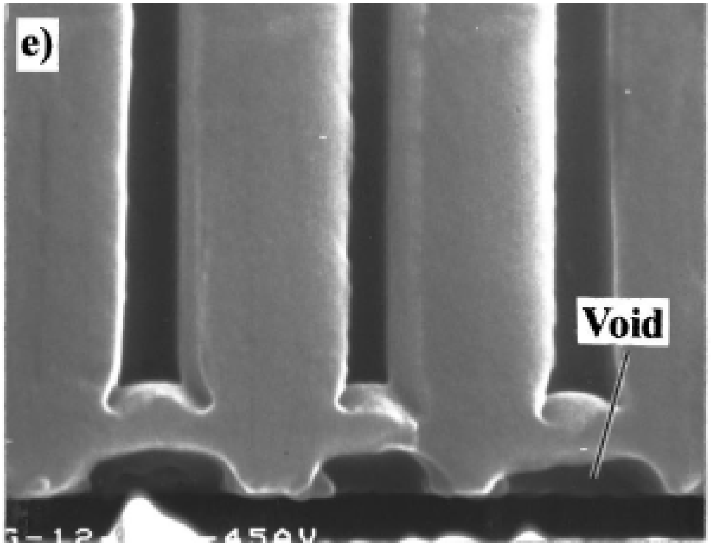
A transparent porous alumina nanostructure was formed on a glass covered tin-doped indium oxide (ITO) substrate by anodization of a highly pure sputtered aluminum layer. Details of the fabrication and microstructures of porous anodic alumina films are described and a possible mechanism of anodization is outlined. The variation of anodic current density reflects three processes, *i.e.*, (*i*) anodization of the sputtered aluminum layer, (*ii*) transition of electrolysis from aluminum to the underlying ITO film, and (*iii*) electrochemical reactions on the ITO film beneath the anodic alumina film. As all the aluminum is completely anodized, the resultant oxide films on the ITO/glass substrate possess a parallel porous structure (ϕ80-100 nm, cell size in ~350 nm) with a thin arched barrier layer (~80 nm) and exhibit a high transmittance in the ultraviolet-visible light range (75-100% transmittance 300-900 nm).

Manuscript submitted August 13, 2001; revised manuscript received January 31, 2002. Available electronically May 9, 2002.

Nanostructures of transparent porous anodic alumina films are formed on a glass substrate with an ITO film through the anodization of sputter-deposited aluminum layer. The anodic alumina films are composed of straight and parallel nanopores with a thin arched barrier layer and transverse holes, and exhibit a high transmittance in the UV-visible light range, due to the complete anodizing of aluminum.

Therefore, a transparent porous electrode material with good conductivity and large surface area can be obtained for various practical purposes.





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Electrochimica Acta 48 (2003) 3147–3153

ELECTROCHIMICA Acta

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Fabrication and characteristics of nanostructures on glass by Al anodization and electrodeposition

S.Z. Chu *, K. Wada, S. Inoue, S. Todoroki

Advanced Materials Laboratory, National Institute for Materials Science, Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japan

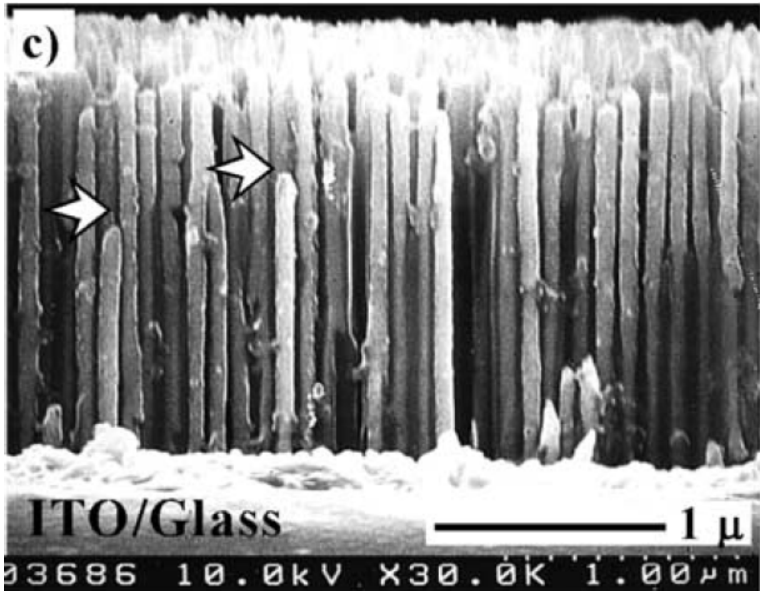
Received 1 October 2002; received in revised form 2 April 2003; accepted 3 April 2003

Abstract

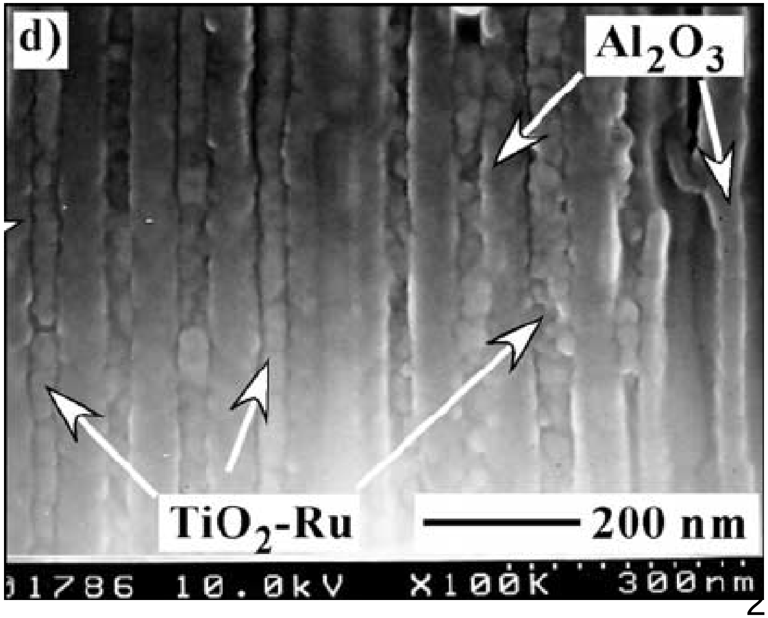
A novel fabrication process of metal and semiconductor nanostructure arrays directly onto glass substrates is described below. An aluminum film was sputter-deposited on a glass substrate coated with a tin-doped indium oxide (ITO) film. The film was then anodically oxidized to obtain a porous alumina template with pore diameters ranging from 5 to 120 nm. Through appropriate chemical dissolution, the barrier layer of the anodic alumina film was removed and the underlying ITO film was exposed to the electrolytes, thus making it possible to deposit metals or semiconductors in the pores of anodic alumina films by a direct current (dc) electrodeposition. In Ni electrodeposition, the porous alumina films not only define the dimensions of the Ni nanowires but also influence their crystalline orientation, showing a textured {220} orientation for ϕ 18 nm nanowires. In addition, through a cathodic electrosynthesis, a peroxocompound of titanium and ruthenium was deposited in the pores of anodic alumina film on ITO/glass substrate. After heating at 873 K for 2 h, a translucent TiO_2–RuO_2/Al_2O_3 composite nanostructure on the ITO/glass substrate was finally fabricated.

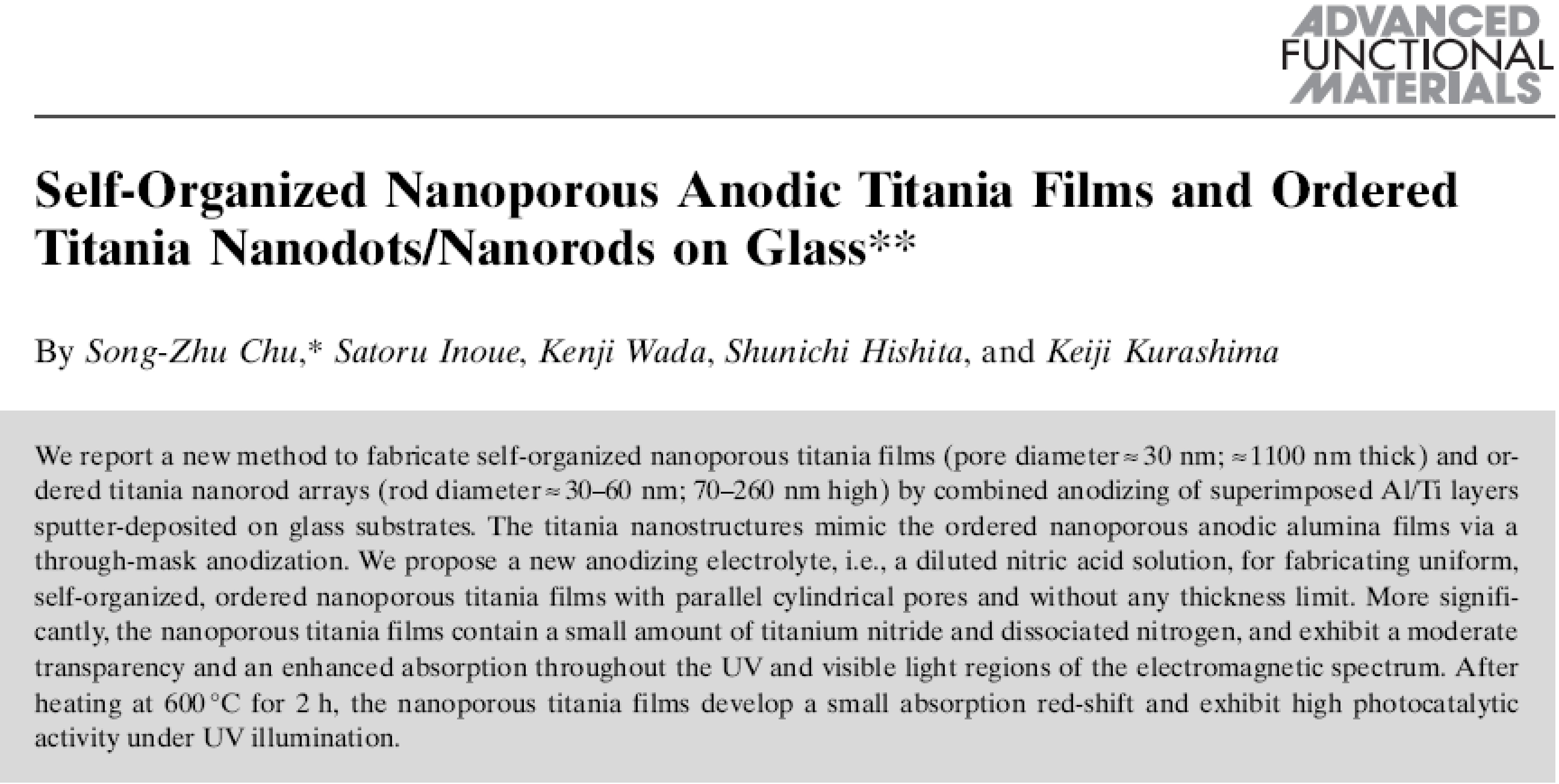
Keywords: Ni nanowire array; TiO_2–RuO_2/Al_2O_3 composite nanostructure; Anodization; Electrodeposition; Glass

Nickel nanowire arrays are fabricated in porous alumina films on the ITO/glass substrate. The Ni (Φ 18-150 nm, A.R. 20-183) nanowires are polycrystalline, and show a textured structure in {220} orientation.



Titania/ruthenium can be deposited in the porous alumina films on ITO/glass by a cathodic electrosynthesis. After heating a transparent $TiO_2/RuO_2/Al_2O_3$ composite nanostructure is fabricated onto the ITO/glass substrate.





ADVANCED FUNCTIONAL MATERIALS

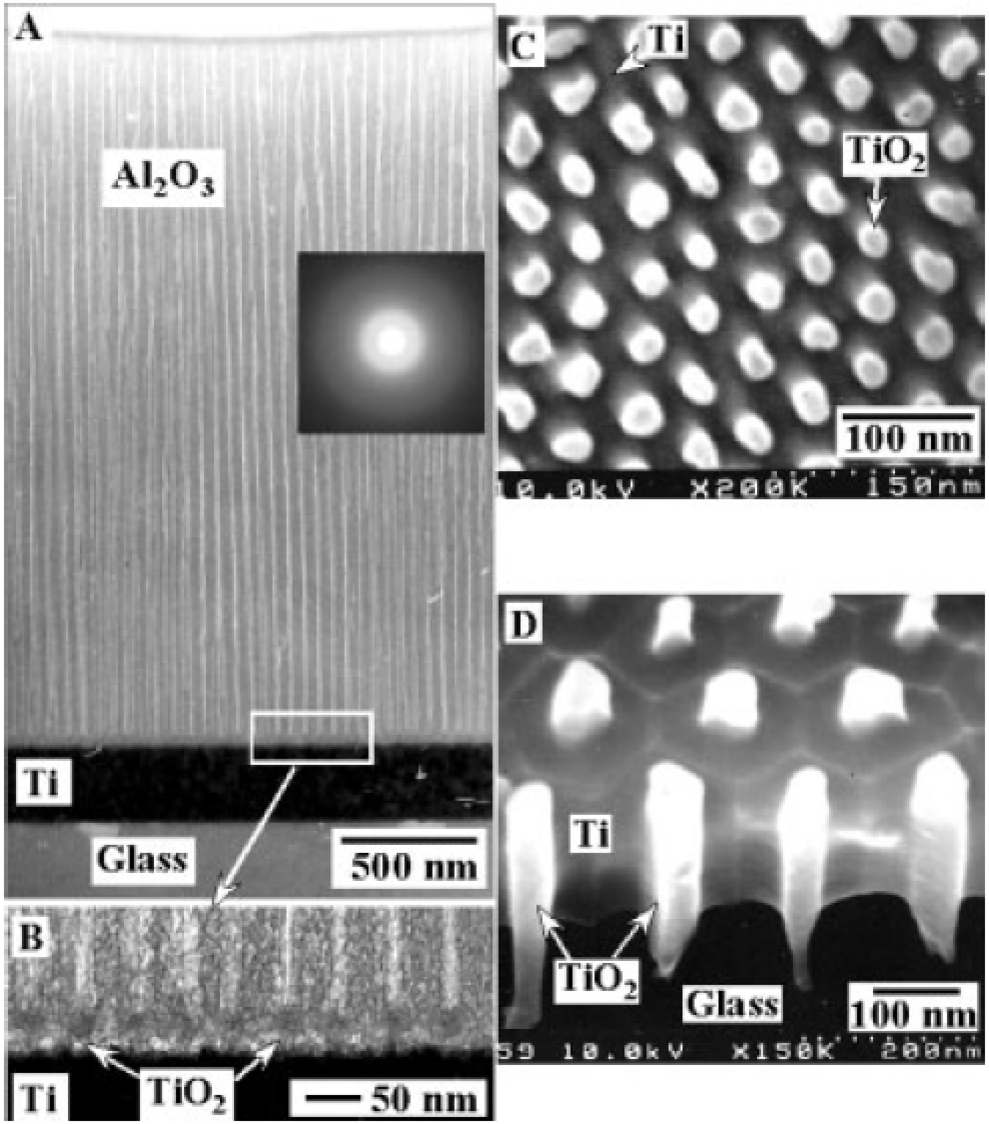
Self-Organized Nanoporous Anodic Titania Films and Ordered Titania Nanodots/Nanorods on Glass**

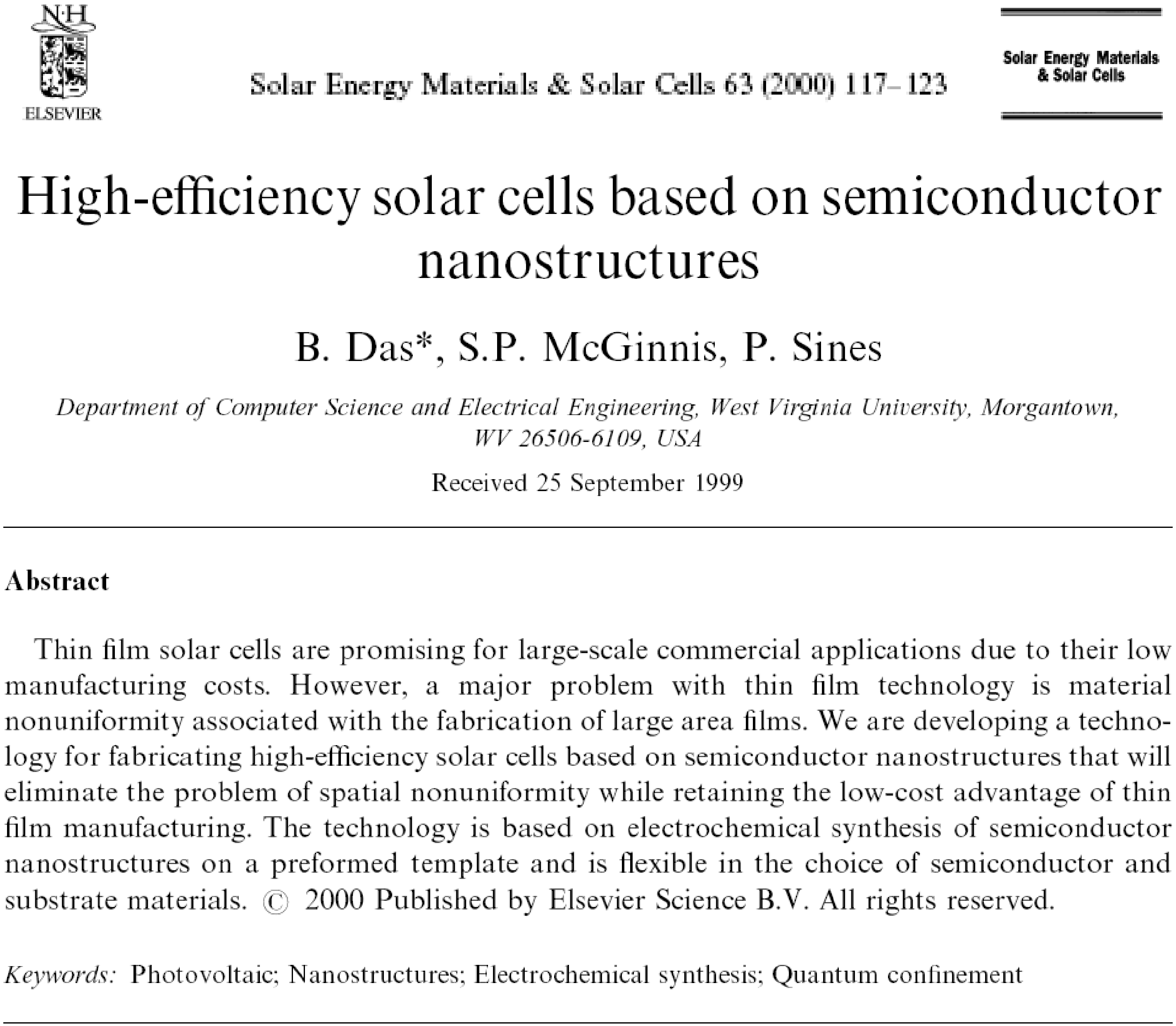
By *Song-Zhu Chu,** *Satoru Inoue*, *Kenji Wada*, *Shunichi Hishita*, and *Keiji Kurashima*

We report a new method to fabricate self-organized nanoporous titania films (pore diameter ≈ 30 nm; ≈ 1100 nm thick) and ordered titania nanorod arrays (rod diameter ≈ 30–60 nm; 70–260 nm high) by combined anodizing of superimposed Al/Ti layers sputter-deposited on glass substrates. The titania nanostructures mimic the ordered nanoporous anodic alumina films via a through-mask anodization. We propose a new anodizing electrolyte, i.e., a diluted nitric acid solution, for fabricating uniform, self-organized, ordered nanoporous titania films with parallel cylindrical pores and without any thickness limit. More significantly, the nanoporous titania films contain a small amount of titanium nitride and dissociated nitrogen, and exhibit a moderate transparency and an enhanced absorption throughout the UV and visible light regions of the electromagnetic spectrum. After heating at 600 °C for 2 h, the nanoporous titania films develop a small absorption red-shift and exhibit high photocatalytic activity under UV illumination.

Adv. Funct. Mater. **2005**, *15*, 1343–1349

Aaaa


A
Al_2O_3
Ti
Glass
500 nm
B
Ti
TiO_2
50 nm
C
Ti
TiO_2
100 nm
10.0kV X200K 150nm
D
Ti
TiO_2
Glass
100 nm
10.0kV X150K 200nm



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Solar Energy Materials & Solar Cells 63 (2000) 117–123

Solar Energy Materials & Solar Cells

High-efficiency solar cells based on semiconductor nanostructures

B. Das*, S.P. McGinnis, P. Sines

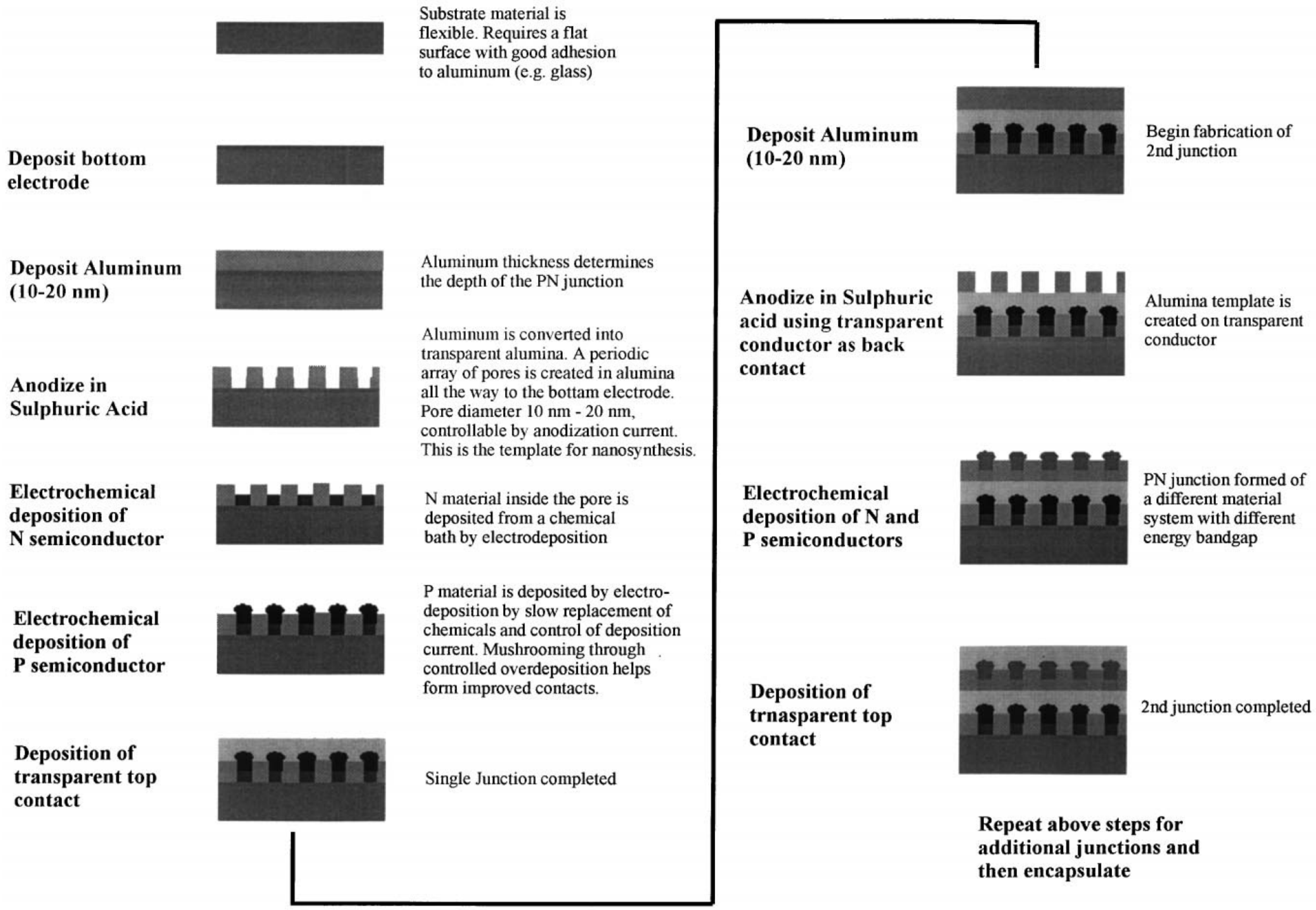
Department of Computer Science and Electrical Engineering, West Virginia University, Morgantown, WV 26506-6109, USA

Received 25 September 1999

Abstract

Thin film solar cells are promising for large-scale commercial applications due to their low manufacturing costs. However, a major problem with thin film technology is material nonuniformity associated with the fabrication of large area films. We are developing a technology for fabricating high-efficiency solar cells based on semiconductor nanostructures that will eliminate the problem of spatial nonuniformity while retaining the low-cost advantage of thin film manufacturing. The technology is based on electrochemical synthesis of semiconductor nanostructures on a preformed template and is flexible in the choice of semiconductor and substrate materials.

Keywords: Photovoltaic; Nanostructures; Electrochemical synthesis; Quantum confinement



Substrate material is flexible. Requires a flat surface with good adhesion to aluminum (e.g. glass)

Deposit bottom electrode

Deposit Aluminum (10-20 nm)

Aluminum thickness determines the depth of the PN junction

Anodize in Sulphuric Acid

Aluminum is converted into transparent alumina. A periodic array of pores is created in alumina all the way to the bottam electrode. Pore diameter 10 nm - 20 nm, controllable by anodization current. This is the template for nanosynthesis.

Electrochemical deposition of N semiconductor

N material inside the pore is deposited from a chemical bath by electrodeposition

Electrochemical deposition of P semiconductor

P material is deposited by electro-deposition by slow replacement of chemicals and control of deposition current. Mushrooming through controlled overdeposition helps form improved contacts.

Deposition of transparent top contact

Single Junction completed

Deposit Aluminum (10-20 nm)

Begin fabrication of 2nd junction

Anodize in Sulphuric acid using transparent conductor as back contact

Alumina template is created on transparent conductor

Electrochemical deposition of N and P semiconductors

PN junction formed of a different material system with different energy bandgap

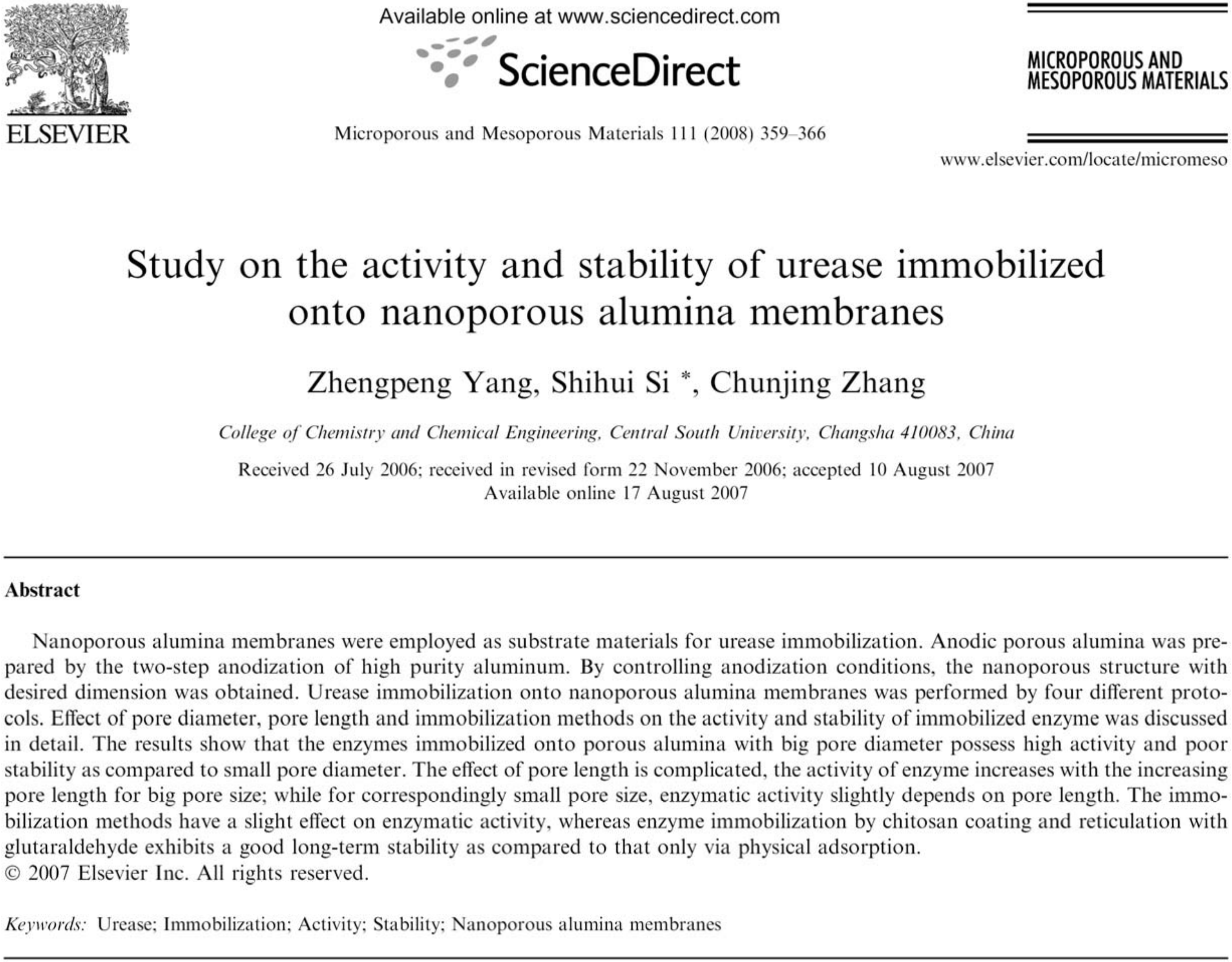
Deposition of trnasparent top contact

2nd junction completed

Repeat above steps for additional junctions and then encapsulate

Fig. 2. Diagram showing the process flow for fabricating semiconductor nanostructure-based multijunction photovoltaic cells.

Biosensors



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Microporous and Mesoporous Materials 111 (2008) 359–366

MICROPOROUS AND MESOPOROUS MATERIALS

www.elsevier.com/locate/micromeso

Study on the activity and stability of urease immobilized onto nanoporous alumina membranes

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Received 26 July 2006; received in revised form 22 November 2006; accepted 10 August 2007
Available online 17 August 2007

Abstract

Nanoporous alumina membranes were employed as substrate materials for urease immobilization. Anodic porous alumina was prepared by the two-step anodization of high purity aluminum. By controlling anodization conditions, the nanoporous structure with desired dimension was obtained. Urease immobilization onto nanoporous alumina membranes was performed by four different protocols. Effect of pore diameter, pore length and immobilization methods on the activity and stability of immobilized enzyme was discussed in detail. The results show that the enzymes immobilized onto porous alumina with big pore diameter possess high activity and poor stability as compared to small pore diameter. The effect of pore length is complicated, the activity of enzyme increases with the increasing pore length for big pore size; while for correspondingly small pore size, enzymatic activity slightly depends on pore length. The immobilization methods have a slight effect on enzymatic activity, whereas enzyme immobilization by chitosan coating and reticulation with glutaraldehyde exhibits a good long-term stability as compared to that only via physical adsorption.

Keywords: Urease; Immobilization; Activity; Stability; Nanoporous alumina membranes

Urease was chosen as a model to study the activity and stability of enzyme immobilized onto porous alumina. Urease was immobilized on nanoporous alumina membranes by four different procedures:

(A) physical adsorption;

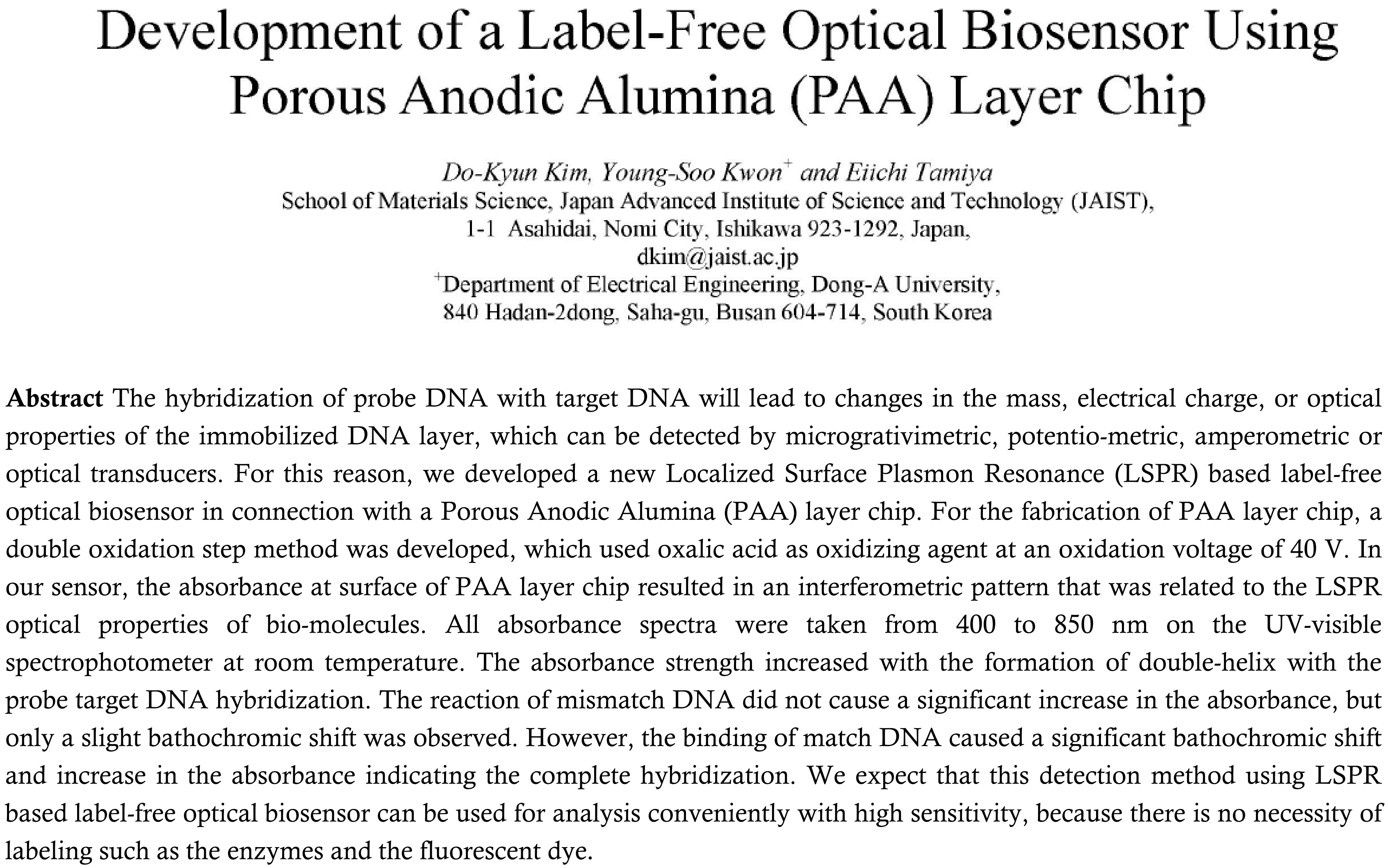
(B) adsorption followed by reticulation with dilute glutaraldehyde solution;

(C) adsorption followed by chitosan coating;

(D) reticulation followed by chitosan coating.

The results indicate that big pore diameter is favorable for increasing enzymatic activity, whereas small pore favors the increase of enzymatic stability. The effect of pore length is complicated, the activity of enzyme increases with the increasing pore length for big pore size; while for small pore size, enzymatic activity slightly depends on pore length. The immobilization procedures, adsorption followed by chitosan coating or reticulation with glutaraldehyde, slightly affect the activity of immobilized urease, whereas greatly increase the stability and lifetime of urease. Such conclusions suggest that nanoporous alumina membranes can be employed to fabricate enzyme biosensors with high activity and stability. Such sensors may be applied to medical and environmental fields in the future.

IEEE SENSORS 2006, EXCO, Daegu, Korea / October 22~25, 2006



Development of a Label-Free Optical Biosensor Using Porous Anodic Alumina (PAA) Layer Chip

Do-Kyun Kim, Young-Soo Kwon[+] and Eiichi Tamiya
School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST),
1-1 Asahidai, Nomi City, Ishikawa 923-1292, Japan,
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Abstract The hybridization of probe DNA with target DNA will lead to changes in the mass, electrical charge, or optical properties of the immobilized DNA layer, which can be detected by micrograviimetric, potentio-metric, amperometric or optical transducers. For this reason, we developed a new Localized Surface Plasmon Resonance (LSPR) based label-free optical biosensor in connection with a Porous Anodic Alumina (PAA) layer chip. For the fabrication of PAA layer chip, a double oxidation step method was developed, which used oxalic acid as oxidizing agent at an oxidation voltage of 40 V. In our sensor, the absorbance at surface of PAA layer chip resulted in an interferometric pattern that was related to the LSPR optical properties of bio-molecules. All absorbance spectra were taken from 400 to 850 nm on the UV-visible spectrophotometer at room temperature. The absorbance strength increased with the formation of double-helix with the probe target DNA hybridization. The reaction of mismatch DNA did not cause a significant increase in the absorbance, but only a slight bathochromic shift was observed. However, the binding of match DNA caused a significant bathochromic shift and increase in the absorbance indicating the complete hybridization. We expect that this detection method using LSPR based label-free optical biosensor can be used for analysis conveniently with high sensitivity, because there is no necessity of labeling such as the enzymes and the fluorescent dye.

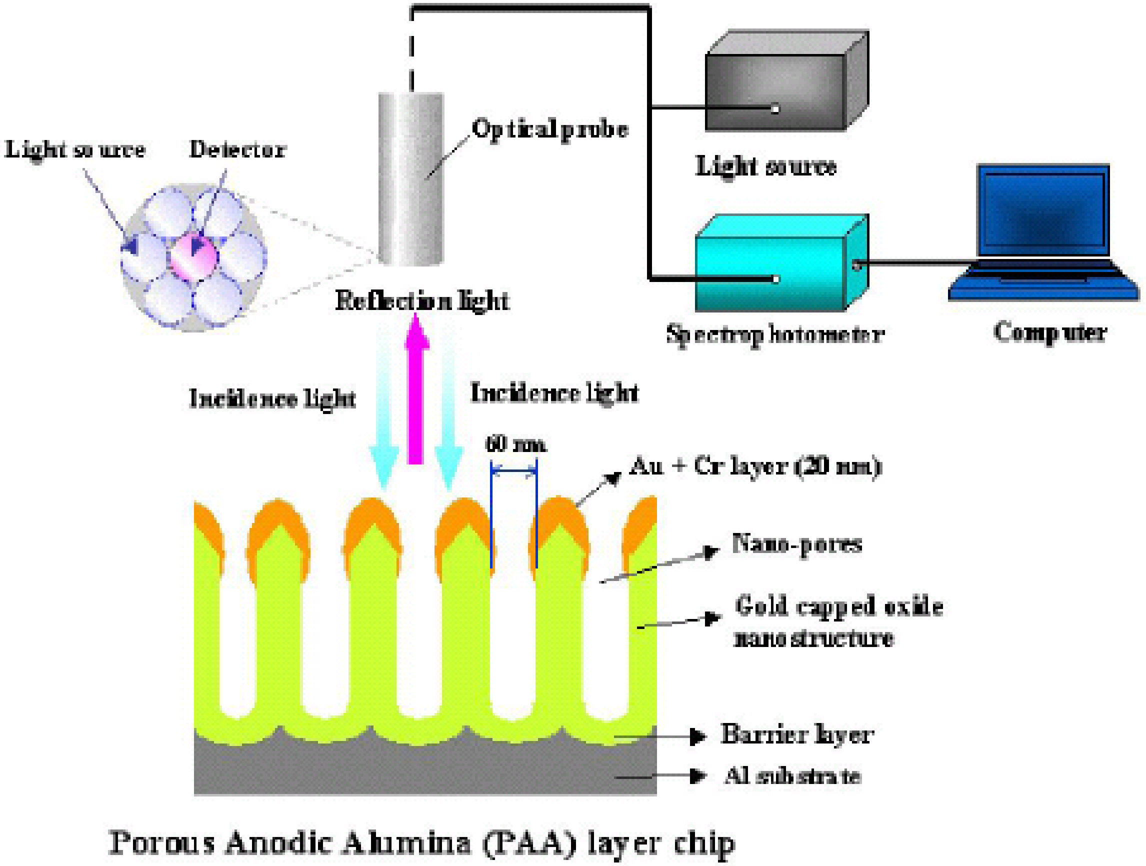


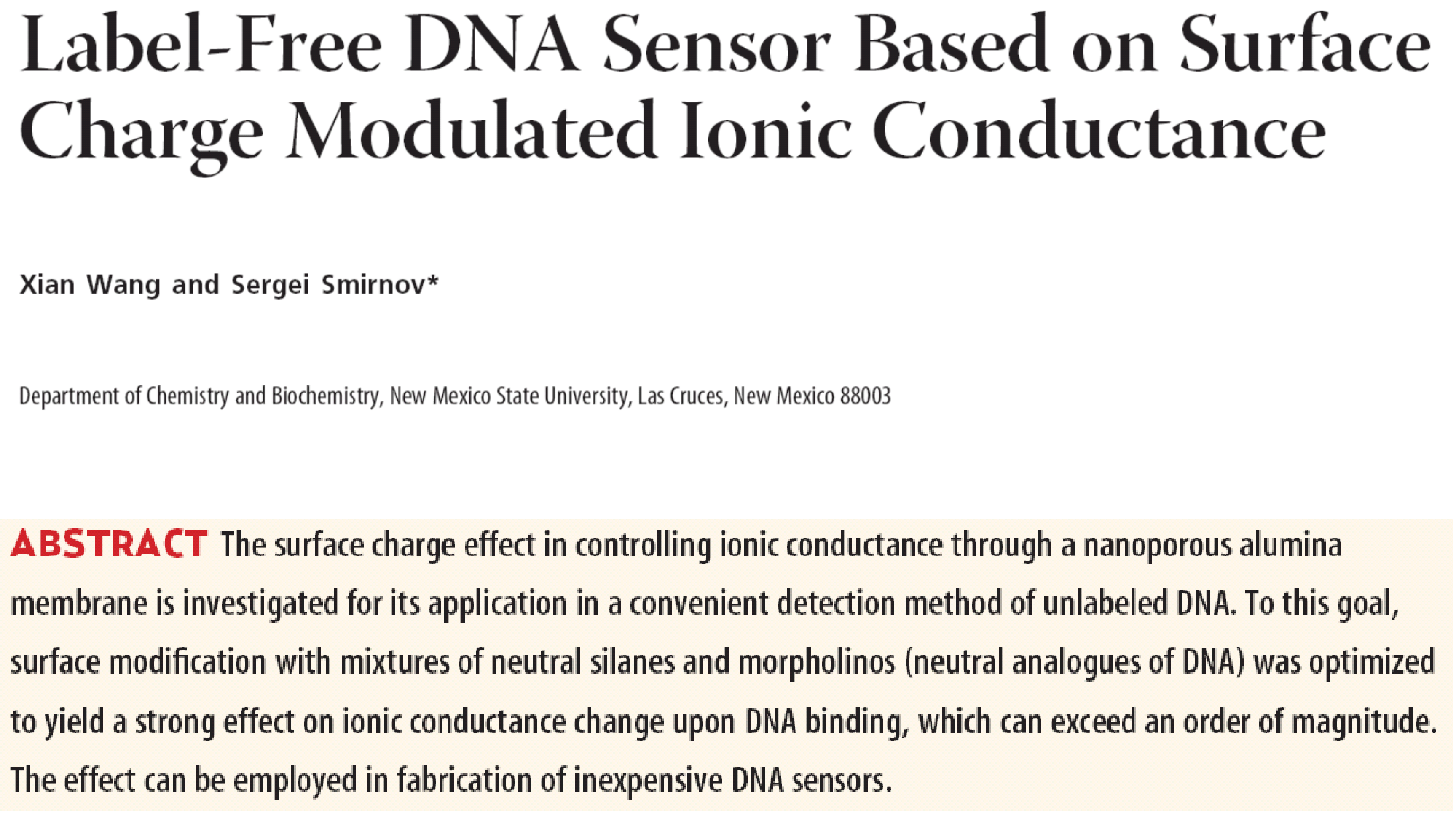
Figure 1. Experimental setup and construction of LSPR and interferometry based label-free optical biosensor with PAA layer chip.

Label-free optical detection of protein antibody-antigen interaction on Au capped porous anodic alumina layer chip

Kim, Do-Kyun; Kerman, Kagan; Yamamura, Shohei; Kwon, Young-Soo; Takamura, Yuzuru; Tamiya, Eiichi

Japanese Journal of Applied Physics 47 (2008) 1351-1354

Abstract: The interaction of protein antibody and antigen will lead to change in the mass, electrical charge, or optical properties of the immobilized protein layer, which can be detected by microgratiivimetric, potentiometric, amperometric or optical transducers. For this reason, we developed a new localized surface plasmon resonance (LSPR) coupled with interferometry based label-free optical **biosensor** in connection with a Au capped **porous anodic alumina** (PAA) layer chip. We could observe the formations of the self-assembled monolayer (SAM)/protein A/C-reactive protein (CRP) antibody/CRP antigen on the Au capped PAA layer chip surface by means of LSPR and interferometric characteristics. In the presence of CRP antigen, the change of the relative reflected intensity (RRI) in the interferometric pattern and a significant bathochromic shift were observed. The fabrication of uniformed Au capped oxide nanostructure is the primary advantage of our chip. It is known that biomolecular interaction which contributed to the change in the refractive index depends on the absorbance intensity change and wavelength shift. Using our Au capped PAA layer chip, one can measure both the information in one single event using a single optical fiber, which is the great additional advantage over SPR. © 2008 The Japan Society of Applied Physics. (14 refs.)



Label-Free DNA Sensor Based on Surface Charge Modulated Ionic Conductance

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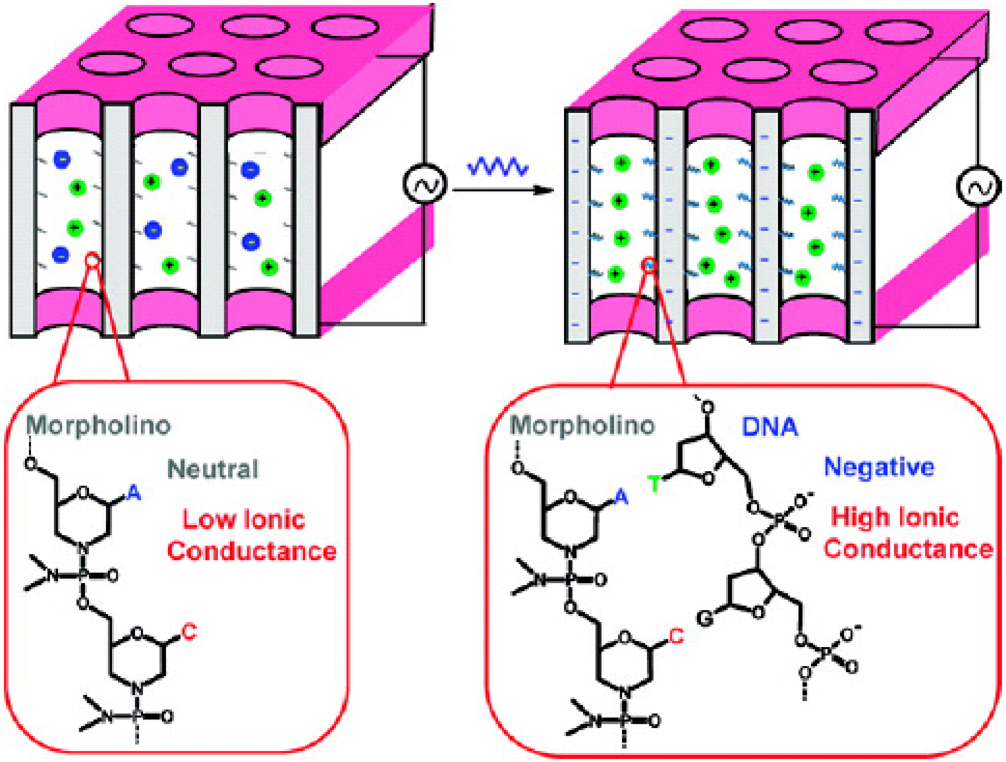
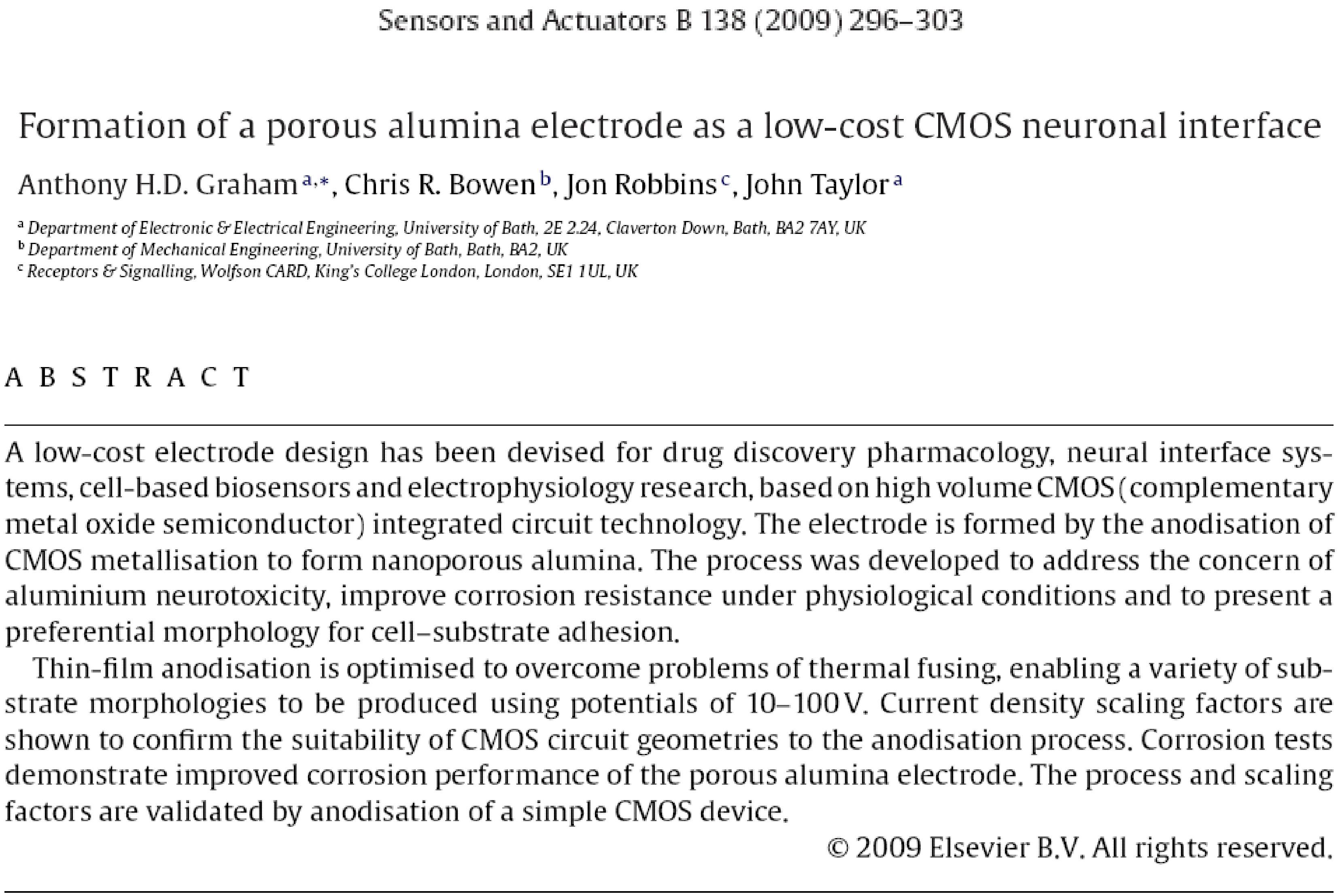
ABSTRACT The surface charge effect in controlling ionic conductance through a nanoporous alumina membrane is investigated for its application in a convenient detection method of unlabeled DNA. To this goal, surface modification with mixtures of neutral silanes and morpholinos (neutral analogues of DNA) was optimized to yield a strong effect on ionic conductance change upon DNA binding, which can exceed an order of magnitude. The effect can be employed in fabrication of inexpensive DNA sensors.

ACS Nano, **2009**, 3 (4), 1004-1010



The surface charge effect in controlling the ionic conductance through a nanoporous alumina membrane can be applied as a convenient detection method for unlabeled DNA. The method was realized on the membranes with gold electrodes deposited directly on its opposite sides and the surface of nanopores modified by an optimized mixture of neutral ester silanes and morpholinos (neutral analogue of DNA). Even though there is room for further optimization, it is obvious that the surface charge effect can be employed in fabrication of inexpensive electrical DNA sensors. Such a sensor would not require an electrochemical potentiostat and can be eventually employed with standard interfaces available on every computer.



Sensors and Actuators B 138 (2009) 296–303

Formation of a porous alumina electrode as a low-cost CMOS neuronal interface

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ABSTRACT

A low-cost electrode design has been devised for drug discovery pharmacology, neural interface systems, cell-based biosensors and electrophysiology research, based on high volume CMOS (complementary metal oxide semiconductor) integrated circuit technology. The electrode is formed by the anodisation of CMOS metallisation to form nanoporous alumina. The process was developed to address the concern of aluminium neurotoxicity, improve corrosion resistance under physiological conditions and to present a preferential morphology for cell–substrate adhesion.

Thin-film anodisation is optimised to overcome problems of thermal fusing, enabling a variety of substrate morphologies to be produced using potentials of 10–100 V. Current density scaling factors are shown to confirm the suitability of CMOS circuit geometries to the anodisation process. Corrosion tests demonstrate improved corrosion performance of the porous alumina electrode. The process and scaling factors are validated by anodisation of a simple CMOS device.

Langmuir **2004,** *20,* 7711−7719

Multinuclear NMR Studies of Single Lipid Bilayers Supported in Cylindrical Aluminum Oxide Nanopores

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Received March 16, 2004. In Final Form: June 2, 2004

Lipid bilayers were deposited inside the 0.2 μm pores of anodic aluminum oxide (AAO) filters by extrusion of multilamellar liposomes and their properties studied by ^{2}H, ^{31}P, and ^{1}H solid-state NMR. Only the first bilayer adhered strongly to the inner surface of the pores. Additional layers were washed out easily by a flow of water as demonstrated by ^{1}H magic angle spinning NMR experiments with addition of Pr^{3+} ions to shift accessible lipid headgroup resonances. A 13 mm diameter Anopore filter of 60 μm thickness oriented approximately 2.5×10^{-7} mol of lipid as a single bilayer, corresponding to a total membrane area of about 500 cm^2. The ^{2}H NMR spectra of chain deuterated POPC are consistent with adsorption of wavy, tubular bilayers to the inner pore surface. By NMR diffusion experiments, we determined the average length of those lipid tubules to be approximately 0.4 μm. There is evidence for a thick water layer between lipid tubules and the pore surface. The ends of tubules are well sealed against the pore such that Pr^{3+} ions cannot penetrate into the water underneath the bilayers. We successfully trapped poly(ethylene glycol) (PEG) with a molecular weight of 8000 in this water layer. From the quantity of trapped PEG, we calculated an average water layer thickness of 3 nm. Lipid order parameters and motional properties are unperturbed by the solid support, in agreement with existence of a water layer. Such unperturbed, solid supported membranes are ideal for incorporation of membrane-spanning proteins with large intra- and extracellular domains. The experiments suggest the promise of such porous filters as membrane support in biosensors.

Nanopillar arrays with superior mechanical strength and optimal spacing for high sensitivity biosensors

Anandan, Venkataramani[1]; Rao, Yeswanth L.[1]; Zhang, Guigen[1, 2, 3]

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ISBN-10: 0976798522
Conference: 2005 NSTI Nanotechnology Conference and Trade Show - NSTI Nanotech 2005, May 08,2005 - May 12,2005
Sponsor: Motorola; Nanotech Japan; Texas Instruments; General Electric Company; Sigma-Aldrich; et al
Publisher: Nano Science and Technology Institute

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Abstract: The fabrication of metallic nanopillar structures and their application as electrodes in electrochemical processes are discussed in this report. Structures of arrays of vertically standing nanopillars were fabricated by electrodeposition technique with the use of porous anodic alumina as masking templates. To explore the possibility of using these nanostructures for biosensing applications, they were evaluated mechanically and electrochemically. Mechanically, these standing nanopillars should have sufficient strength to sustain the capillary forces caused by the nanopillar-liquid interactions. Electrochemically, these standing nanopillars should provide increased sensitivity in an electrochemical process. Our results showed that the nanopillars were mechanically stable during the electrochemical process and the electrodes with nanopillars exhibited increased electrochemical response as compared with flat electrodes. (8 refs.)

Catalytic reactor

Catalytic nanoliths

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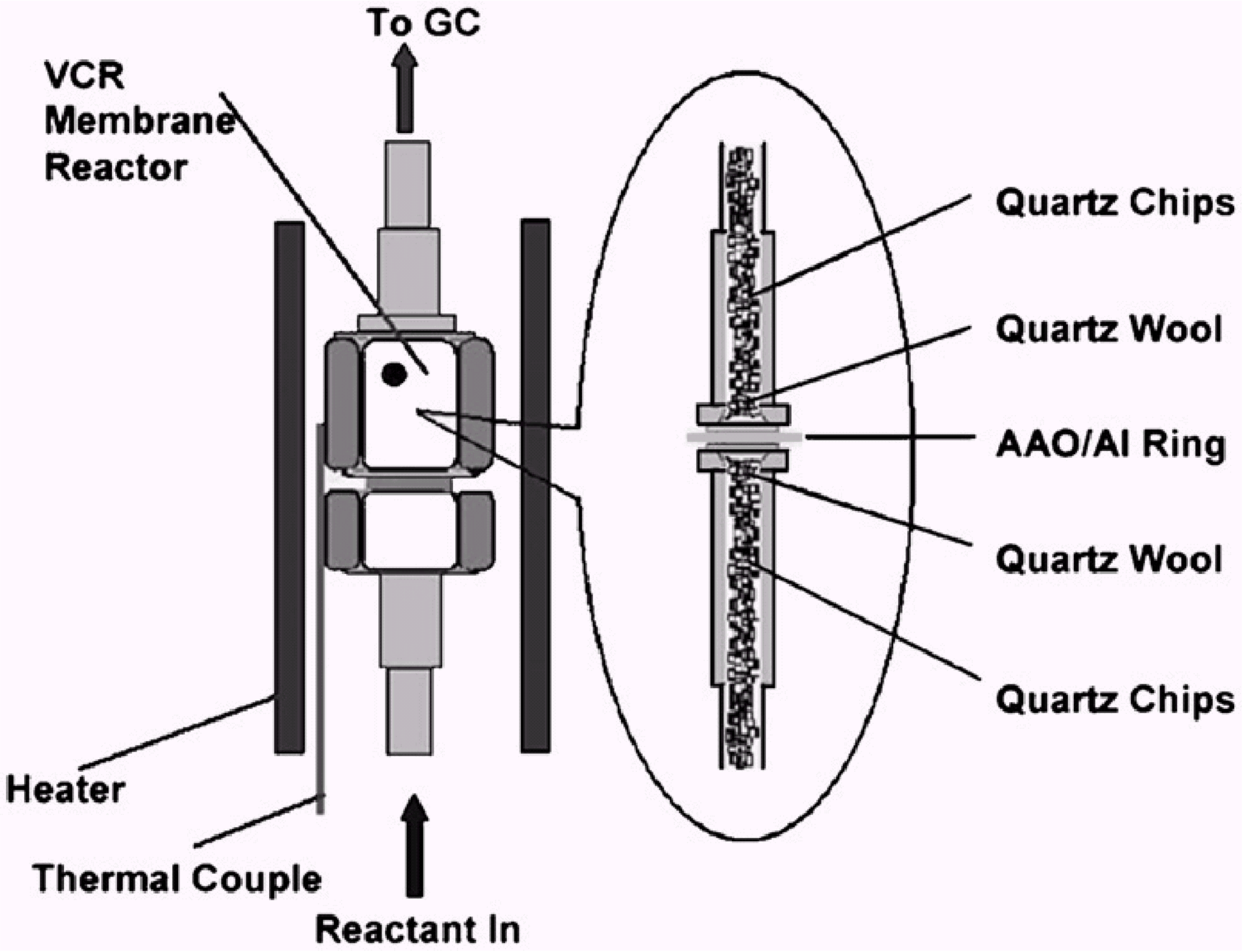
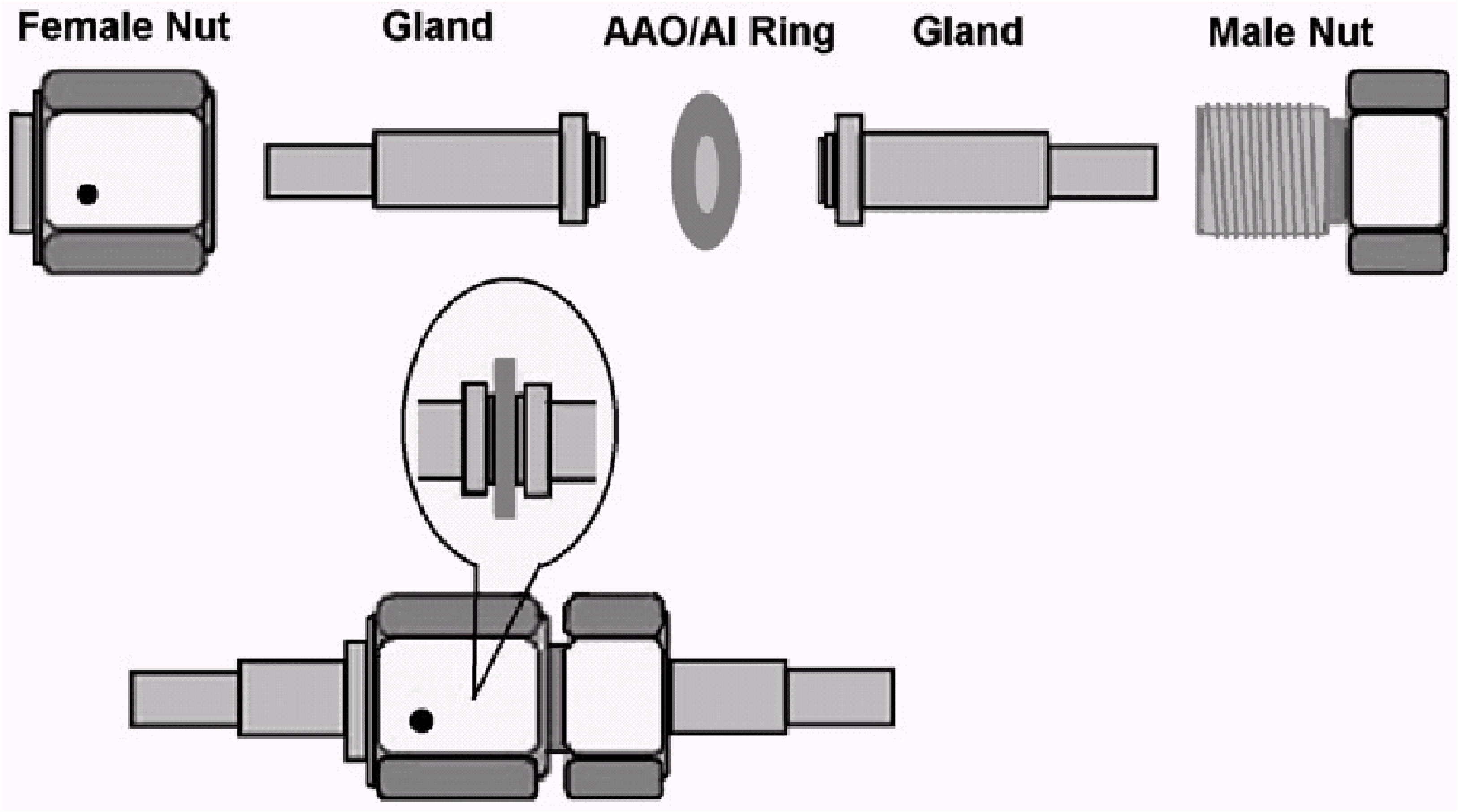
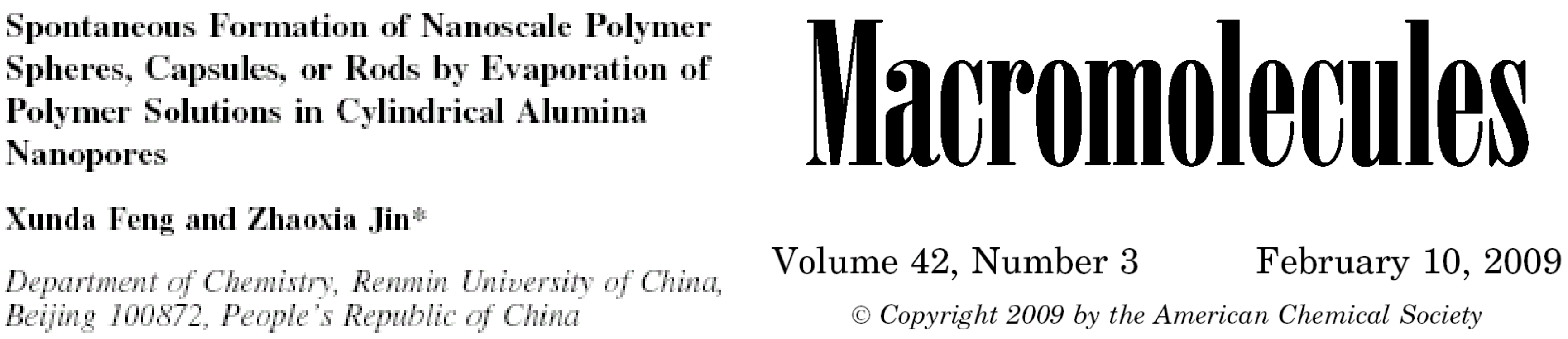
ABSTRACT: The nanoporous anodic aluminum oxide (AAO) structure is shown to be a useful platform for heterogeneous catalysis. By appropriately masking the perimeter during anodization and etching, the AAO can be formed at the center of an aluminum disc. The remaining aluminum ring connects seamlessly to the AAO and provides mechanical support for convenient handling. The supported AAO can be sealed in a standard fitting so that the nanopores in the structure function as an array of tubular reactors, i.e. a nanolith. Coating the walls with catalytically active materials turns the nanolith into a novel catalytic system. For the oxidative dehydrogenation (ODH) of cyclohexane, the nanolith catalytic system is superior to a conventional powdered catalyst in terms of both efficiency and in reducing over oxidation. A simple analysis of the flow through the nanolith combined with experimental data indicates that mass transfer through the nanopores follows a mixed flow model.

Chemical Engineering Science 64 (2009) 560 – 567


To GC
VCR Membrane Reactor
Quartz Chips
Quartz Wool
AAO/Al Ring
Quartz Wool
Quartz Chips
Heater
Thermal Couple
Reactant In


Female Nut
Gland
AAO/Al Ring
Gland
Male Nut



Spontaneous Formation of Nanoscale Polymer Spheres, Capsules, or Rods by Evaporation of Polymer Solutions in Cylindrical Alumina Nanopores

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Macromolecules

Volume 42, Number 3 February 10, 2009

ABSTRACT: In this study, we report for the first time the fabrication of polymer nanospheres, nanocapsules, and hemispherically capped nanorods simply through the wetting of anodic aluminum oxide (AAO) membranes with polymer solutions. For the wetting with polystyrene solutions, we have demonstrated that the formation of nanorods is dependent upon the solvents used (e.g., tetrahydrofuran and methyl ethyl ketone) which have strongly adsorbent nature toward alumina surfaces, displaying no correlation to molecular weight. More importantly, we have shown that there is a coarsening process from spheres to capsules to rods in AAO cylindrical nanopores during solvent evaporation. The coarsening process could serve as the formation mechanism for nanorods which have the similar diameter as the AAO nanopores. Our observation also provides a facile approach for fabricating polymer nanospheres and nanocapsules that can be directed by cylindrical nanopores into ordered arrays.

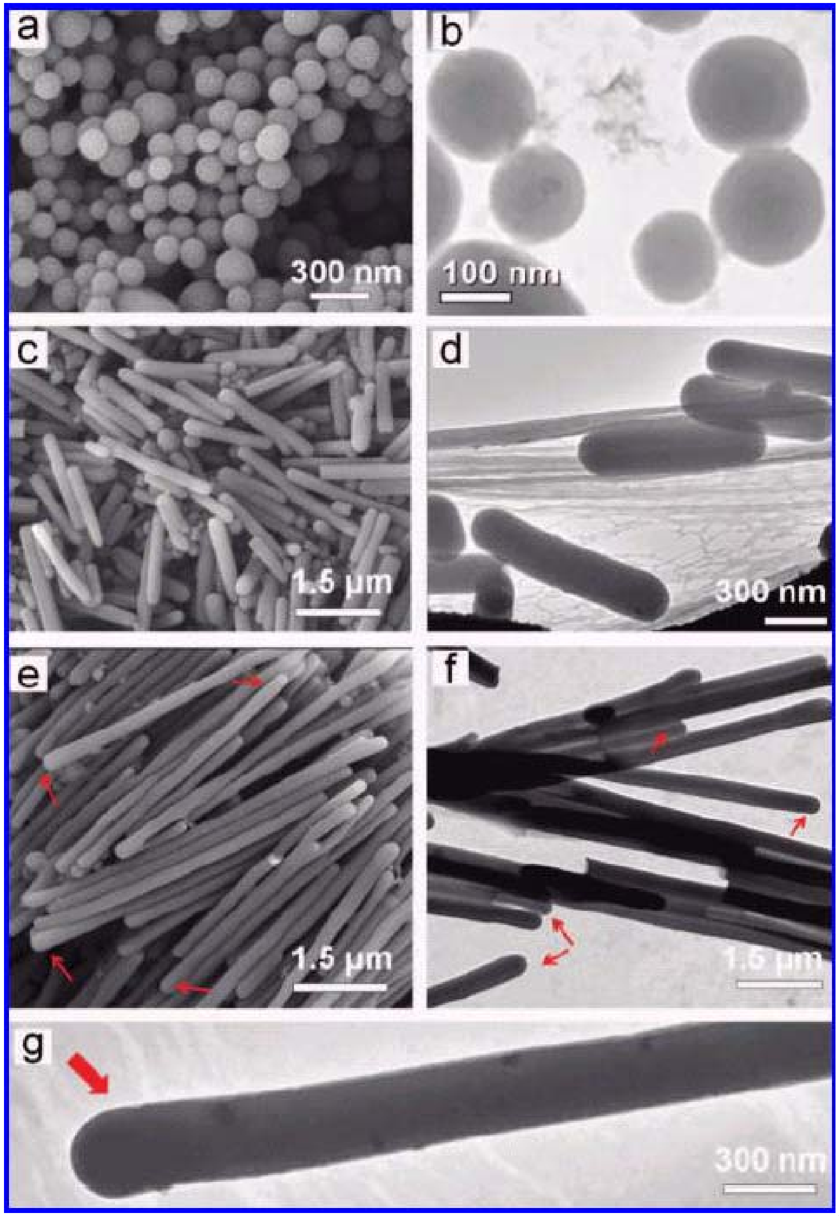
Figure 1. Micrographs of PS nanostructures resulting from PS/THF solutions with different initial concentrations:

(a and b) for **20 mg/mL**;

(c and d) for **40 mg/mL**;

(e and g) for **150 mg/mL**.

The red arrows in parts e-g highlight the hemispherical caps at the ends of the nanorods.



J. Phys. Chem. C **2009,** *113,* 6037–6041

Development of Highly Selective Enzymatic Devices Based on Deposition of Permselective Membranes on Aligned Nanowires

Frank N. Crespilho,*,† Marcos C. Esteves,‡ Paulo T. A. Sumodjo,‡ Elizabeth J. Podlaha,§ and Valtencir Zucolotto||

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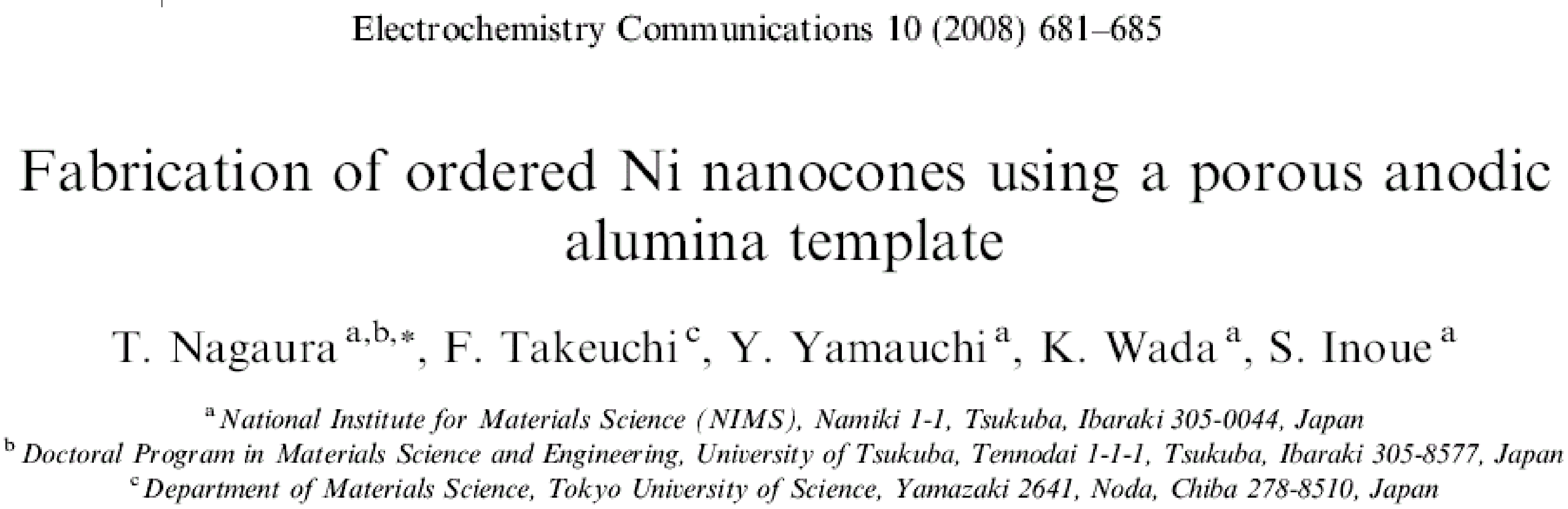
ABSTRACT: We describe a simple and efficient strategy to fabricate enzymatic devices based on the deposition of glucose oxidase on aligned and highly oriented CoNiMo metallic nanowires. CoNiMo nanowires with an average diameter of 200 nm and length of 50 μm were electrodeposited on Au-covered alumina substrates via electrodeposition, using alumina membranes as templates. Enzyme-modified electrodes were fabricated via enzyme immobilization using a cross-linker. To minimize nonspecific reactions in the presence of interfering agents, a permselective membrane composed of poly(vinylsulfonic acid) and polyamidoamine dendrimer was deposited via electrostatic interaction. The formation of hydrogen peroxide as a product of the enzymatic reaction was monitored at low overpotential, 0.0 V (vs Ag/AgCl). The detection limit was estimated at 22 μM under an applied potential of 0.0 V. The apparent Michaelis-Menten constant determined from the Lineweaver-Burke plot was 2 mM.



Electrochemistry Communications 10 (2008) 681–685

Fabrication of ordered Ni nanocones using a porous anodic alumina template

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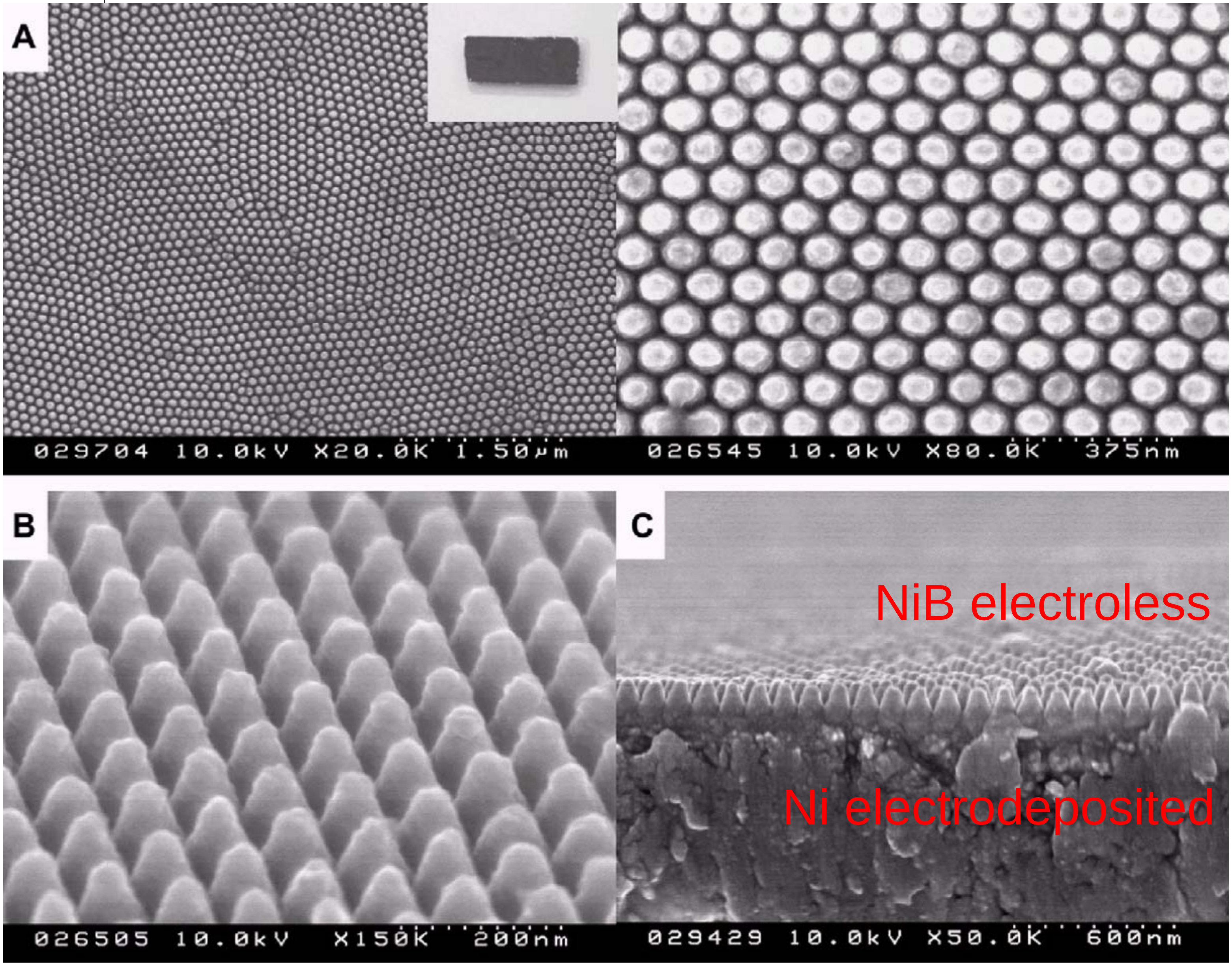
[b] *Doctoral Program in Materials Science and Engineering, University of Tsukuba, Tennodai 1-1-1, Tsukuba, Ibaraki 305-8577, Japan*
[c] *Department of Materials Science, Tokyo University of Science, Yamazaki 2641, Noda, Chiba 278-8510, Japan*

ABSTRACT: Hexagonally ordered Ni nanocones have been produced using an electroless Ni deposition technique on a porous anodic alumina (PAA) template, where the pores are of a cone shape. The conical PAA film was found to exhibit hexagonal order with a period of 100 nm. The aspect ratio (cone height vs. the diameter of the base of the cone) of the conical pores on the PAA film was found to be one. The Ni nanocones and the surface morphology of the nano-conical film exhibit the same periodic structure of the template. A significant advantage of the fabrication process employed in this work is that it utilizes existing techniques.


A
029704 10.0kV X20.0K 1.50µm
026545 10.0kV X80.0K 375nm
B
026505 10.0kV X150K 200nm
C
NiB electroless
Ni electrodeposited
029429 10.0kV X50.0K 600nm

Biomed Microdevices (2009) 11:135–142

Capture and alignment of *phi29* viral particles in sub-40 nanometer porous alumina membranes

**Jeong-Mi Moon · Demir Akin · Yi Xuan · Peide D. Ye ·
Peixuan Guo · Rashid Bashir**

ABSTRACT: Bacteriophage phi29 virus nanoparticles and its associated DNA packaging nanomotor can provide for novel possibilities towards the development of hybrid bionano structures. Towards the goal of interfacing the phi29 viruses and nanomotors with artificial micro and nanostructures, we fabricated nanoporous Anodic Aluminum Oxide (AAO) membranes with pore size of 70 nm and shrunk the pores to sub 40 nm diameter using atomic layer deposition (ALD) of Aluminum Oxide. We were able to capture and align particles in the anodized nanopores using two methods. Firstly, a functionalization and polishing process to chemically attach the particles in the inner surface of the pores was developed. Secondly, centrifugation of the particles was utilized to align them in the pores of the nanoporous membranes. In addition, when a mixture of empty capsids and packaged particles was centrifuged at specific speeds, it was found that the empty capsids deform and pass through 40 nm diameter pores whereas the particles packaged with DNA were mainly retained at the top surface of the nanoporous membranes. Fluorescence microscopy was used to verify the selective filtration of empty capsids through the nanoporous membranes.

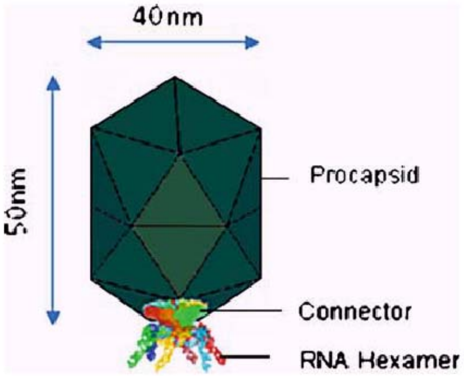
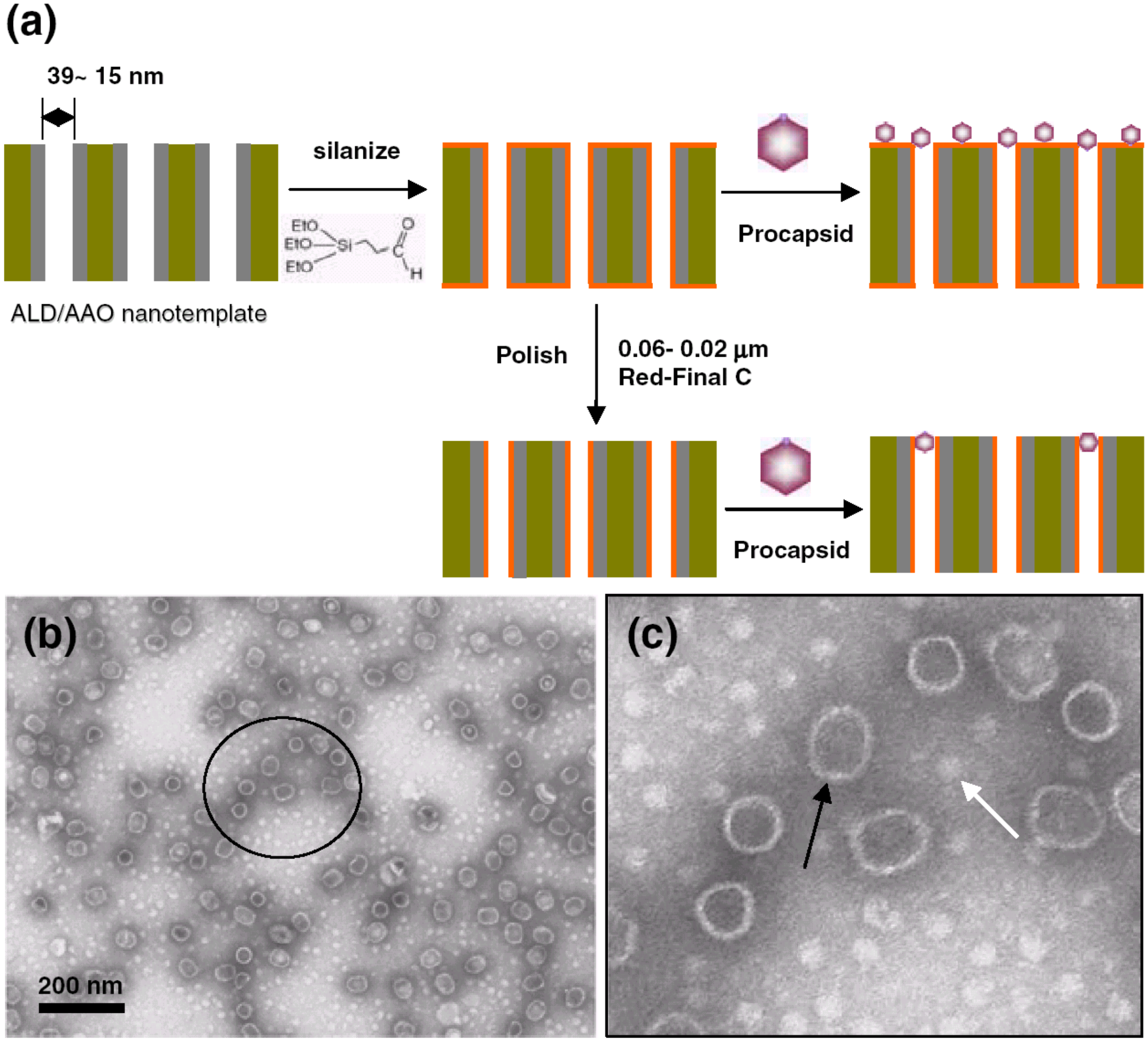


Fig. 1 Schematic of a *phi29* viral particle. The particle size is about 40×50 nm and contains a DNA packaging nanomotor at one end



Phys. Status Solidi A **206**, No. 3, 435–441 (2009)

A micron-sized nanoporous multifunction sensing device

L. Moreno i Codinachs[*, 1], C. Birkenstock[1], T. Garma[1], R. Zierold[2], J. Bachmann[2], K. Nielsch[2],
M. J. Schöning[3, 4], and A. Fontcuberta i Morral[1]

[1] Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany
[2] Institute of Applied Physics, University of Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany
[3] Aachen University of Applied Sciences, Jülich Campus, Institute of Nano- and Biotechnologies (INB), Ginsterweg 1, 52428 Jülich, Germany
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ABSTRACT: In this work, a capacitive sensor based on Anodic Aluminium Oxide (AAO) porous structures has been developed. In some cases, the pores have been also conformally coated with a high chemical pure SiO_2 by means of Atomic Layer Deposition (ALD). **Temperature measurements** have been done in DI water obtaining a response of 5 nF/° C. **pH measurements** have been performed and the responses obtained are between 0.2 and 1 nF/pH. The reproducibility of the sensors has been found to be high and a larger hysteresis effect has been observed in the samples with alumina pores rather than in the SiO_2 ones. The hysteresis seems to be related to the charging of the oxide upon application of a voltage.

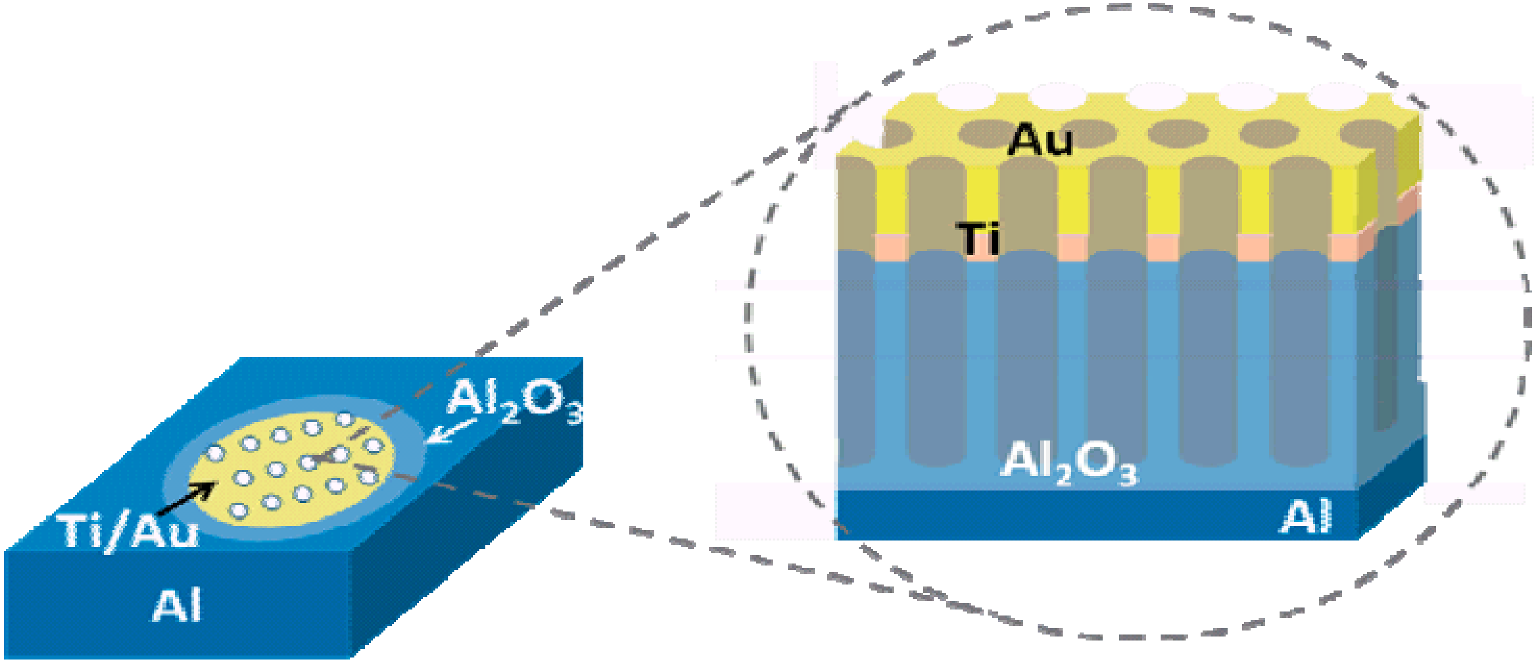

Figure 2 (online colour at: www.pss-a.com) Scheme of the fabricated samples (left top view, right cross section).

Talanta 78 (2009) 647–652

A novel electrochemical biosensor based on dynamic polymerase-extending hybridization for *E. coli* O157:H7 DNA detection

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[b] *Biosensor National Special Laboratory, Key Laboratory of Biomedical Engineering of Education Ministry, Department of Biomedical Engineering, Zhejiang University, Hangzhou 310027, PR China*
[c] *Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong*

ABSTRACT: A novel biosensor based on single-stranded DNA (ssDNA) probe functionalized aluminum anodized oxide (AAO) nanopore membranes was demonstrated for *Escherichia coli* O157:H7 DNA detection. An original and dynamic polymerase-extending (PE) DNA hybridization procedure is proposed, where hybridization happens in the existence of Taq DNA polymerase and dNTPs under controlled reaction temperature. The probe strand would be extended as long as the target DNA strand, then the capability to block the ionic flow in the pores has been prominently enhanced by the double strand complex. We have investigated the variation of ionic conductivity during the fabrication of the film and the hybridization using cyclic voltammetry and impedance spectroscopy. The present approach provides low detection limit for DNA (a few hundreds of pmol), rapid label-free and easy-to-use bacteria detection, which holds the potential for future use in various ss-DNA analyses by integrated into a self-contained biochip.

Fig. 1. The sketch map of the electrochemical DNA biosensor system and the mechanism of the novel polymerase-extending hybridization method (WE: working electrode; RE: reference electrode; CE: counter electrode).