Codice	Esperimento	Gruppo
	NANOCHANT	5
Rapp. naz.: F. Odorici		

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Rappresentante nazionale: F. Odorici
Struttura di appartenenza: BO
Posizione nell'I.N.F.N.:

INFORMAZIONI GENERALI

Linea di ricerca	Studio di matrici di nanotubi di carbonio per l'utilizzo in rivelatori di particelle
Laboratorio ove si raccolgono i dati	IMM − Istituto per la Microelettronica e i Microsistemi , ex LAMEL (CNR sez. di Bologna) ed INFN sezione di Bologna.
Sigla dello esperimento assegnata dal laboratorio	NANOCHANT
Acceleratore usato	
Fascio (sigla e caratteristiche)	
Processo fisico studiato	Produzione di nanotubi di carbonio tramite CVD su template di alumina e test di accoppiamento elettrico con il Silicio.
Apparato strumentale utilizzato	Celle elettochimiche, criogenia, Sputtering, forni, CVD, microscopi SEM e TEM, fotolitografia, impiantazione ionica, sorgenti alpha.
Sezioni partecipanti all'esperimento	BOLOGNA
Istituzioni esterne all'Ente partecipanti	CNR − IMM Sezione di Bologna
Durata esperimento	2 anni

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Struttura
BO

Codice	Esperimento	Gruppo
	NANOCHANT	5
Resp. loc.: F. Odorici		

PREVENTIVO LOCALE DI SPESA PER L'ANNO 2004

In KEuro

VOCI DI SPESA		***DESCRIZIONE DELLA SPESA***	***IMPORTI*** ***Parziali***	***SJ***	***Totale Compet.***	***SJ***	A cura della Comm.ne Scientifica Nazionale
Viaggi e missioni	Interno	Missioni a Catania (ST Catania) per eseguire processi di bonding (con macchine specifiche) tra matrice di nanotubi e wafer di silicio (tre settimane uomo). Riunioni Gr.V e con i referee (due settimane uomo). Partecipazione a conferenze nazionali (2 persone/1 conf. oppure 2 persone/2 conf).	2.5 1.5 1.5		***5.5***	***0.0***	
	Estero	Missione a Monaco (Germania) e/o Ramat−Gan (Israele) per stage su tecniche di bonding nanotubi−silicio (una settimana uomo). Due presentazioni a Conferenze internazionali.	2.5 3.0	2.5	***8.0***	***2.5***	
Materiale Consumo		Produzione matrici di nanotubi (allumina porosa, metalli catalizzatori, accrescimento nanotubi). Bonding silicio / matrice−di−nanotubi (costi di processi e materiali). Elettronica dei circuiti di amplificazione e readout per test del rivelatore con particelle alfa. Manutenzione e consumi di camera pulita (filtri aria/acqua, indumenti, dispositivi di protezione individuale, ecc.).	10.0 12.0 2.0 7.0		***31.0***	***0.0***	
Trasp. e facch.					***0.0***	***0.0***	
Spese Calcolo		Consorzio / Ore CPU / Spazio Disco / Cassette / Altro			***0.0***	***0.0***	
Affitti e manutenz. apparecchiat.					***0.0***	***0.0***	
Materiale inventariabile		Pompa rotativa e camera da vuoto per test con particelle alfa.	1.5		***1.5***	***0.0***	
Costruzione Apparati					***0.0***	***0.0***	
			Totale		***46.0***	***2.5***	

Sono previsti interventi e/o impiantistica che ricadono sotto la disciplina della legge Merloni ? ☐

Breve descrizione dell'intervento:

Mod EC./EN. 2 (a cura del responsabile locale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Codice	Esperimento	Gruppo
	NANOCHANT	5
Resp. loc.: F. Odorici		

Struttura
BO

ALLEGATO MODELLO EC2

(a cura del responsabile locale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno **2004**

Struttura
BO

Codice	Esperimento	Gruppo
	NANOCHANT	5

Resp. loc.: F. Odorici

ALLEGATO MODELLO EC2

(a cura del responsabile locale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Preventivo per l'anno ***2004***

Codice	Esperimento	Gruppo
	NANOCHANT	5
Rapp. naz.: F. Odorici		

PREVENTIVO GLOBALE DI SPESA PER L'ANNO 2004

In KEuro

Struttura	***A CARICO DELL' I.N.F.N.***																		A carico di altri Enti
	Miss. interno		Miss. estero.		Materiale di cons.		Trasp. e Facch.		Spese Calc.		Affitti e Manut. Appar.		Mater. inventar.		Costr. appar.		TOTALE Compet.		
		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***		di cui ***SJ***	
BO	5,5		8,0	2,5	31,0								1,5				46,0	2,5	
TOTALI	***5,5***		***8,0***	***2,5***	***31,0***								***1,5***				***46,0***	***2,5***	

NB. La colonna A carico di altri enti deve essere compilata obbligatoriamente

Note:

Mod EC./EN. 4 (a cura del responsabile nazionale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Codice	Esperimento	Gruppo
	NANOCHANT	5
Rapp. naz.: F. Odorici		

A) ATTIVITA' SVOLTA FINO A GIUGNO 2003

1) Sono stati messi a punto i processi di costruzione del template di allumina, utilizzando la nuova cella di anodizzazione, la quale si e' rivelata fondamentale per ottenere una buona riproducibilita' dei campioni. Sono stati inoltre perfezionati: la produzione di allumina di diverso spessore, i processi di apertura dei nanocanali sul fondo del campione anodizzato e la rimozione dell'alluminio residuo.
2) E' stato messo a punto un sistema di deposizione dei metalli catalizzatori nel fondo dei nanocanali, tramite processo elettrolitico in regime alternato di corrente.
3) E' stato progettato ed allestito un reattore per l'accrescimento dei nanotubi di carbonio, costituito da un gas−sistem a controllo automatico e una camera per CVD a pressione atmosferica ed in vuoto. L'allestimento del sistema ha subito un ritardo di circa 10 mesi rispetto a quanto desiderato, in quanto subordinato ai tempi del finanziamento, disponibile solo ad ottobre 2002. Attualmente si stanno mettendo a punto le fasi preliminari di utilizzo del reattore e a breve si sperimenteranno i processi di accrescimento dei nanotubi. Si prevedono i primi risultati di accrescimento entro l'autunno 2003.
4) Sono stati avviati contatti preliminari con industrie che possiedono il know−how necessario a realizzare il bonding tra silicio e matrice di nanotubi di carbonio.
5) E' stato studiato un set−up per irraggiamento con particelle alfa che sara' realizzato entro fine 2003, utilizzando rivelatori al silicio della Hamamatsu.

B) ATTIVITA' PREVISTA PER L'ANNO 2004

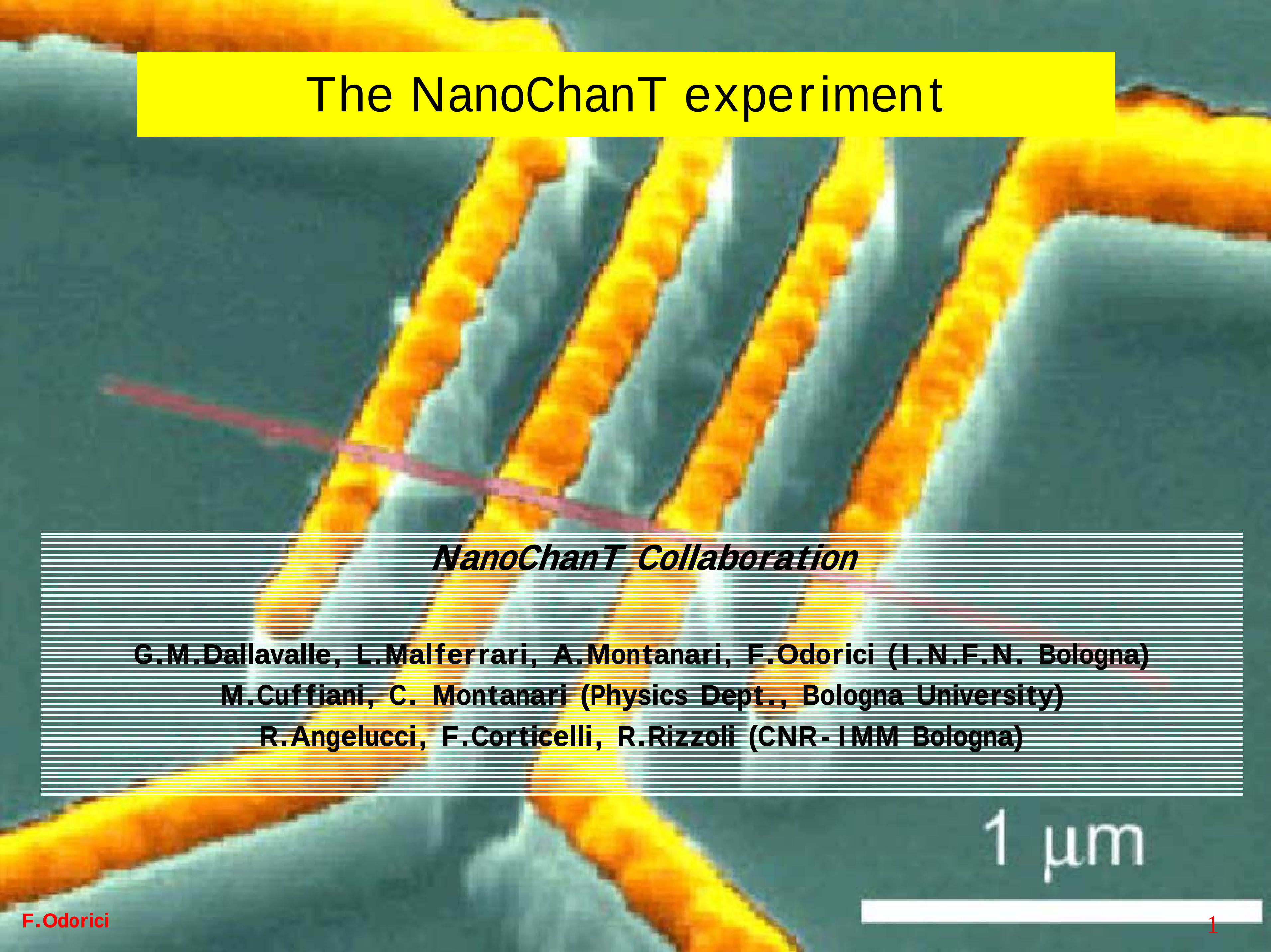
1) Messa a punto dell'accrescimento dei nanotubi di carbonio confinati in allumina porosa.
2) Bonding tra matrice di nanotubi di carbonio e wafer di silicio(diodo).
Questa fase permettera' di ottenere un rivelatore di posizione con geometria semplificata (e bassa risoluzione spaziale), che pero' conserva il principio di funzionamento che si vuole dimostrare.
3)Verifica di funzionamento del rivelatore semplificato, tramite irraggiamento con particelle alfa, al fine di verificare la produzione di carica nel silicio e misurare l'efficienza di raccolta del segnale tramite nanotubi.

C) FINANZIAMENTI GLOBALI AVUTI NEGLI ANNI PRECEDENTI ***In kEuro***

Anno finanziario	Missioni interno	Missioni estero	Materiale di consumo	Trasp. e Facch.	Spese Calcolo	Affitti e Manut. Apparec.	Materiale inventar.	Costruz. apparati	***TOTALE***
2002	1.0	3.0	8.0	0.0	0.0	0.0	5.0	0.0	17.0
2003	2.5	3.0	19.0	0.0	0.0	0.0	1.0	0.0	25.5
TOTALE	**3.5**	**6**	**27**	**0**	**0**	**0**	**6**	**0**	**42.5**

Mod EC. 5 (a cura del rappresentante nazionale)

The NanoChanT experiment



NanoChanT Collaboration

G.M.Dallavalle, L.Malferrari, A.Montanari, F.Odorici (I.N.F.N. Bologna)
M.Cuffiani, C. Montanari (Physics Dept., Bologna University)
R.Angelucci, F.Corticelli, R.Rizzoli (CNR-IMM Bologna)

Examples of nanotechnologies

Technologies for processing materials on a nanometric scale: 1-100 nm

Big interest in many fields of research: biology, chemistry, science of materials, nano-electronics, etc.

Some nano-objects are very actractive if we think to a possible application to a new generation of position particle detectors:

Nanoholes, nanochannels → Masks, dies

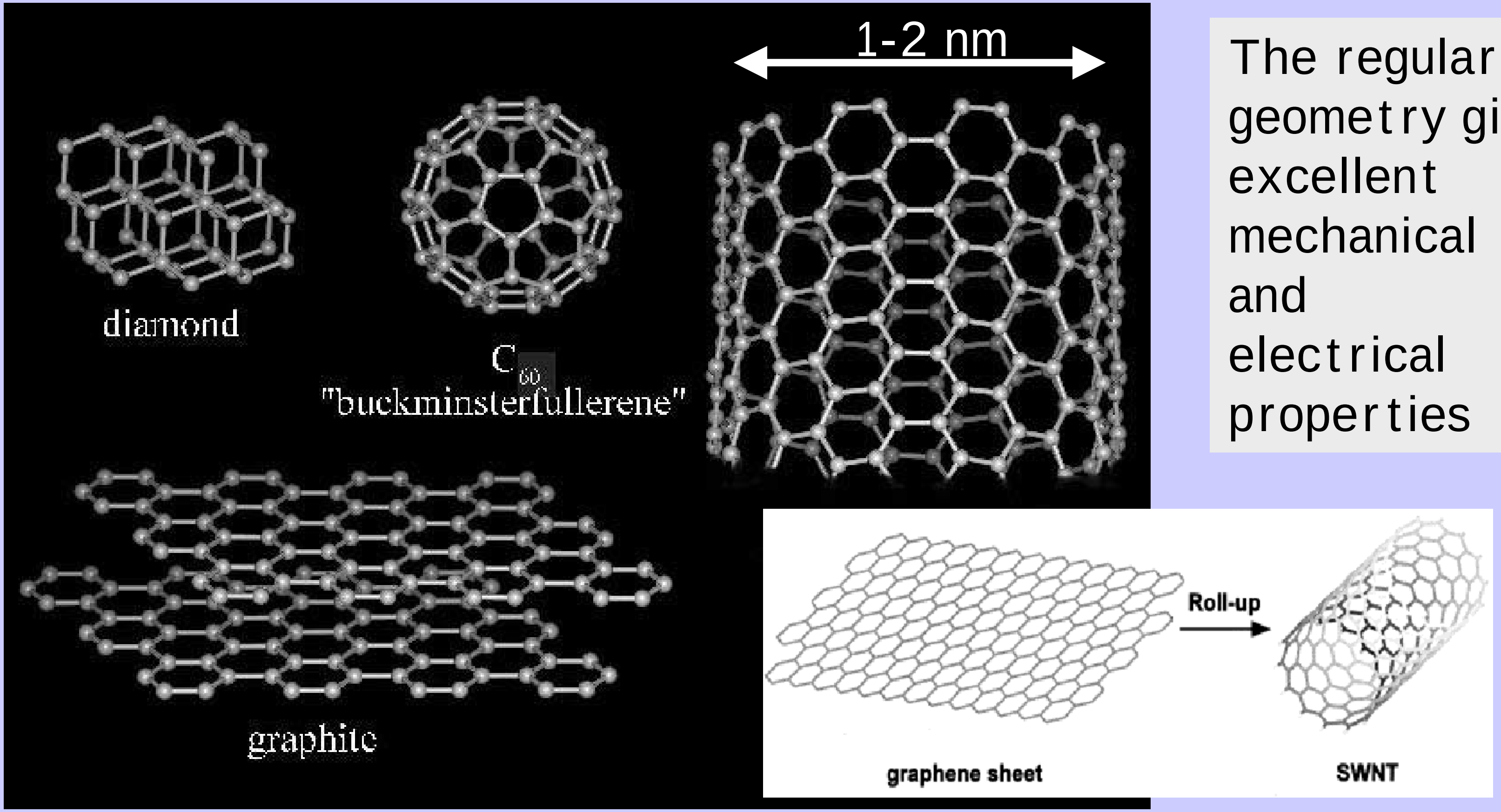
Nanowires, nanotubes → Contacts, probes ...

Carbon Nanotubes (CN)

Among the nano-objects great interest is addressed to Carbon Nanotubes (CN):

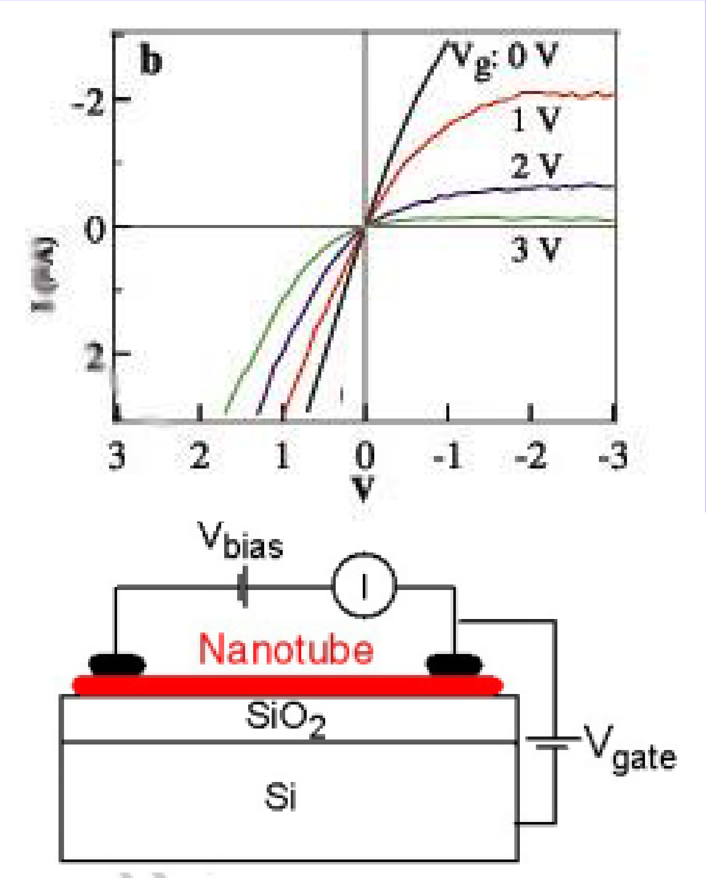
tubes made by a single sheet of graphene (SingleWallNanoTube)

or more sheets (MultiWallNanoTube)



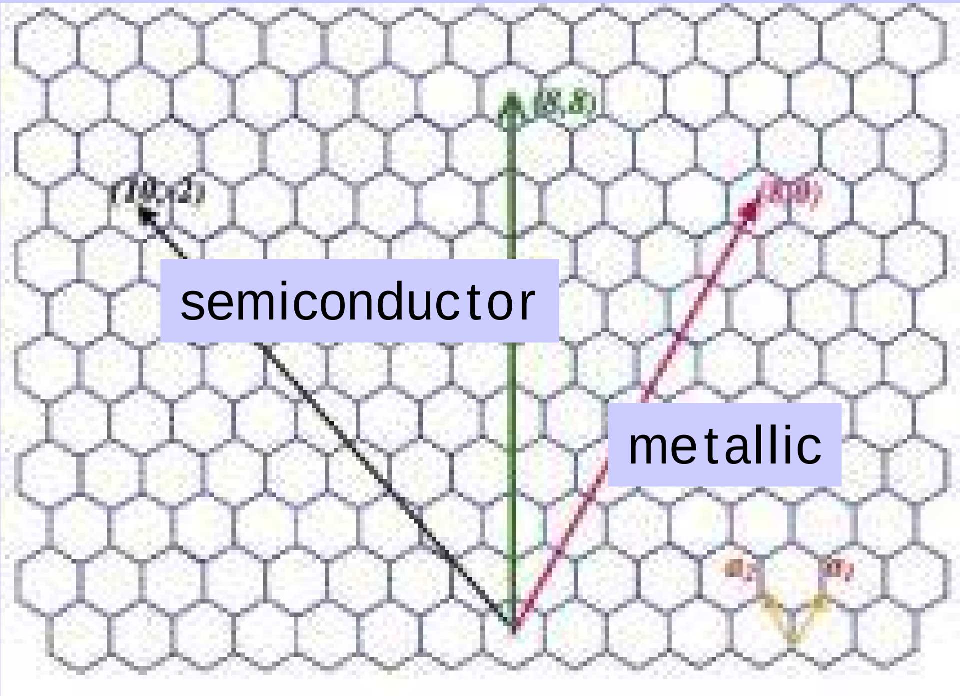
The regular geometry gives excellent mechanical and electrical properties

Electrical properties of CN



H.Dai, Surf. Sci., 500 (2002)

Mainly depend on the curvature axis of the graphene sheet:



semiconductor

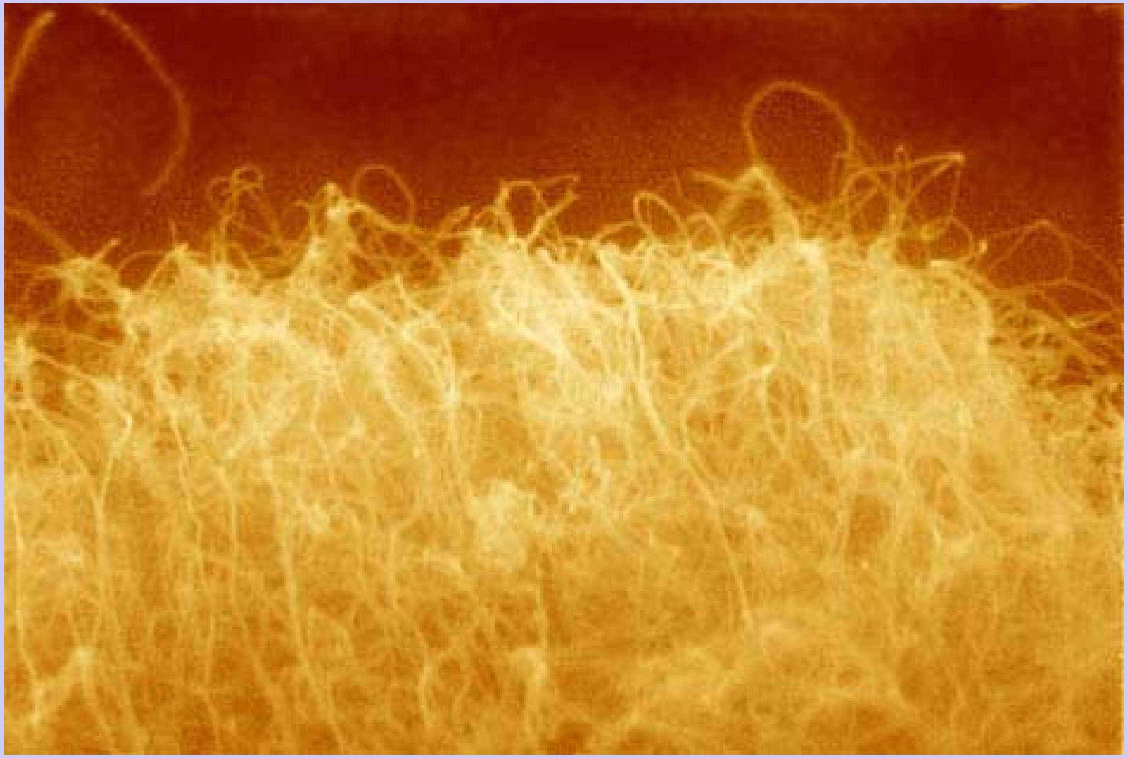
metallic

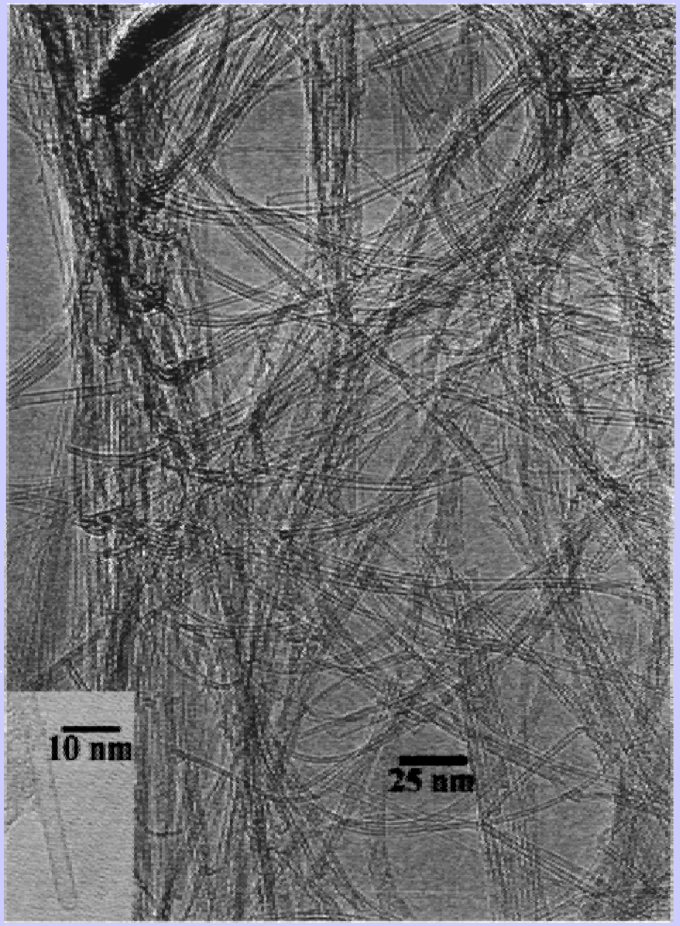
Stables with temperatures in the range of about 0-300 ºK

Growing CNs

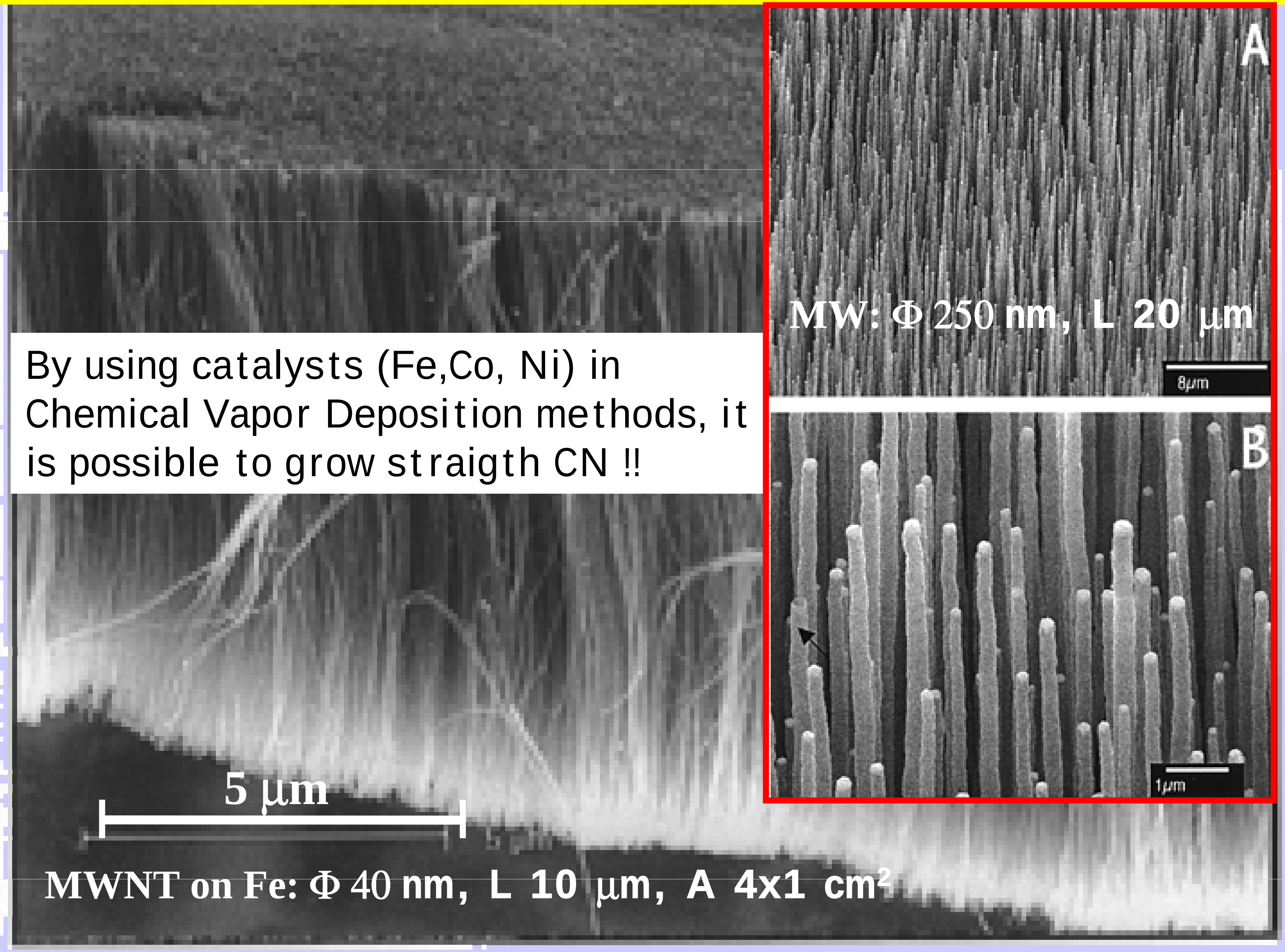
Non catalytic methods (e.g. arc discharge) allow to produce bundles of CN:

BUT for position detector applications we need a regular, uniform and reproducible structure...





Straight CN

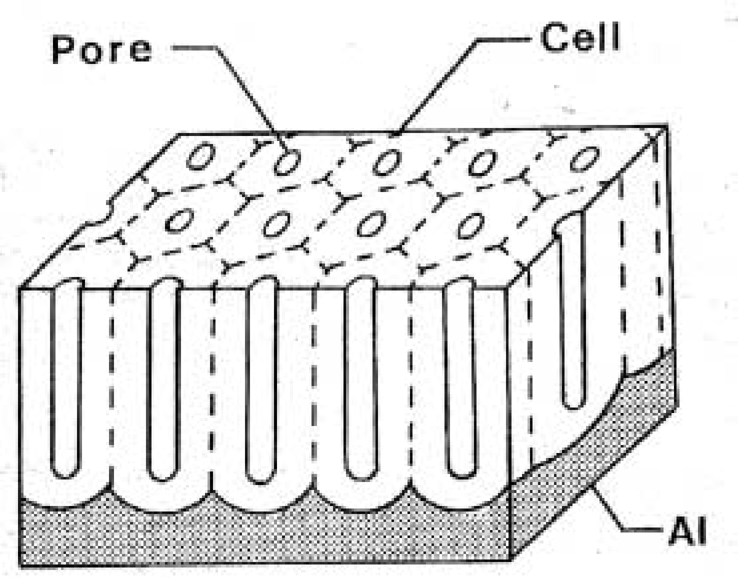


By using catalysts (Fe,Co, Ni) in Chemical Vapor Deposition methods, it is possible to grow straigth CN !!

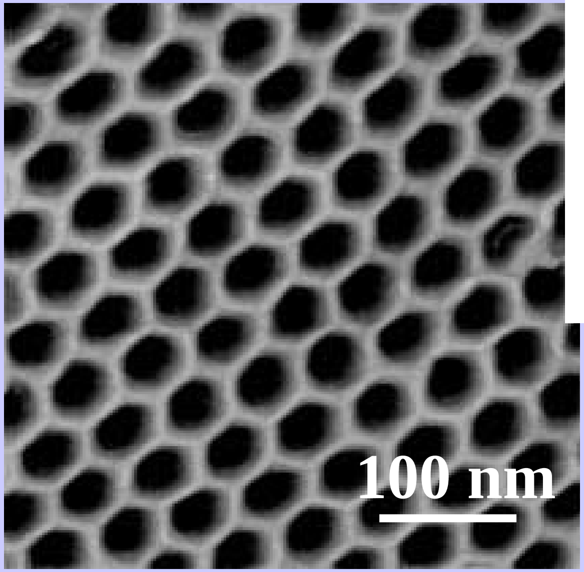
MW: Φ 250 nm, L 20 µm

MWNT on Fe: Φ 40 nm, L 10 µm, A 4x1 cm^2

Nanochannels: Alumina template



Anodization of iperpure Aluminum sheets (100-300 μm thick) under controlled conditions produces an oxide (Al_2O_3, Alumina) with self-organized regular honeycomb structure



The size and pitch of nanochannels depend on the parameters of the process (voltage, acid type, acid concentration, temperature):

- pitch: 40 -> 400 nm

Among Alumina properties:

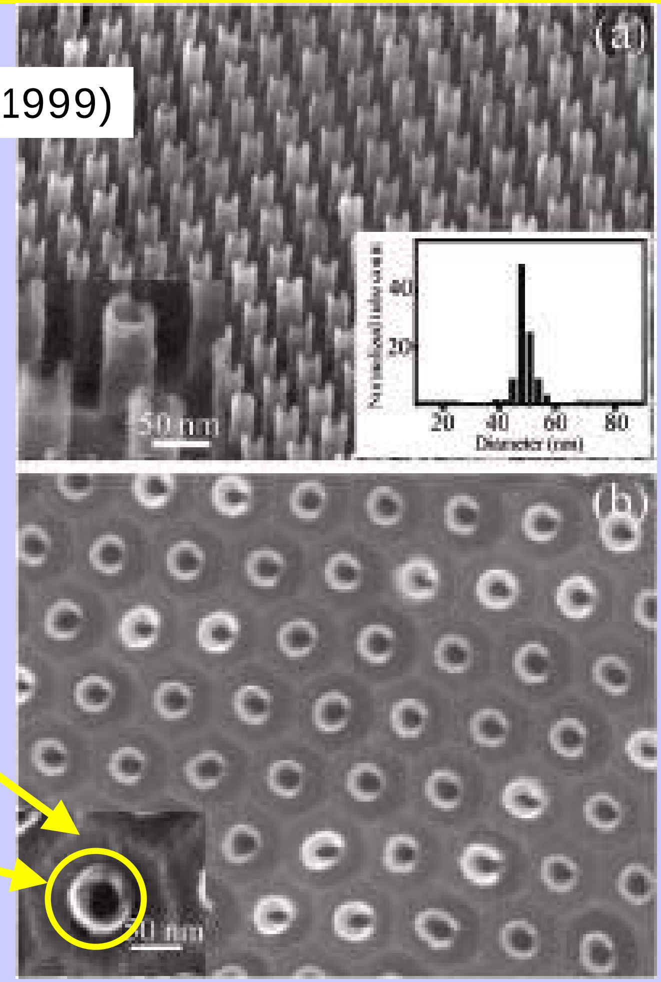
- mechanical strenght
- good insulator

F.Odorici

Growing CN inside Alumina

J.Li et al. PRL 75 (1999)

Alumina nanochannels can be used to grow CNs, after the deposition of the cathalist (Ni,Fe,Co) at the bottom of each single pore

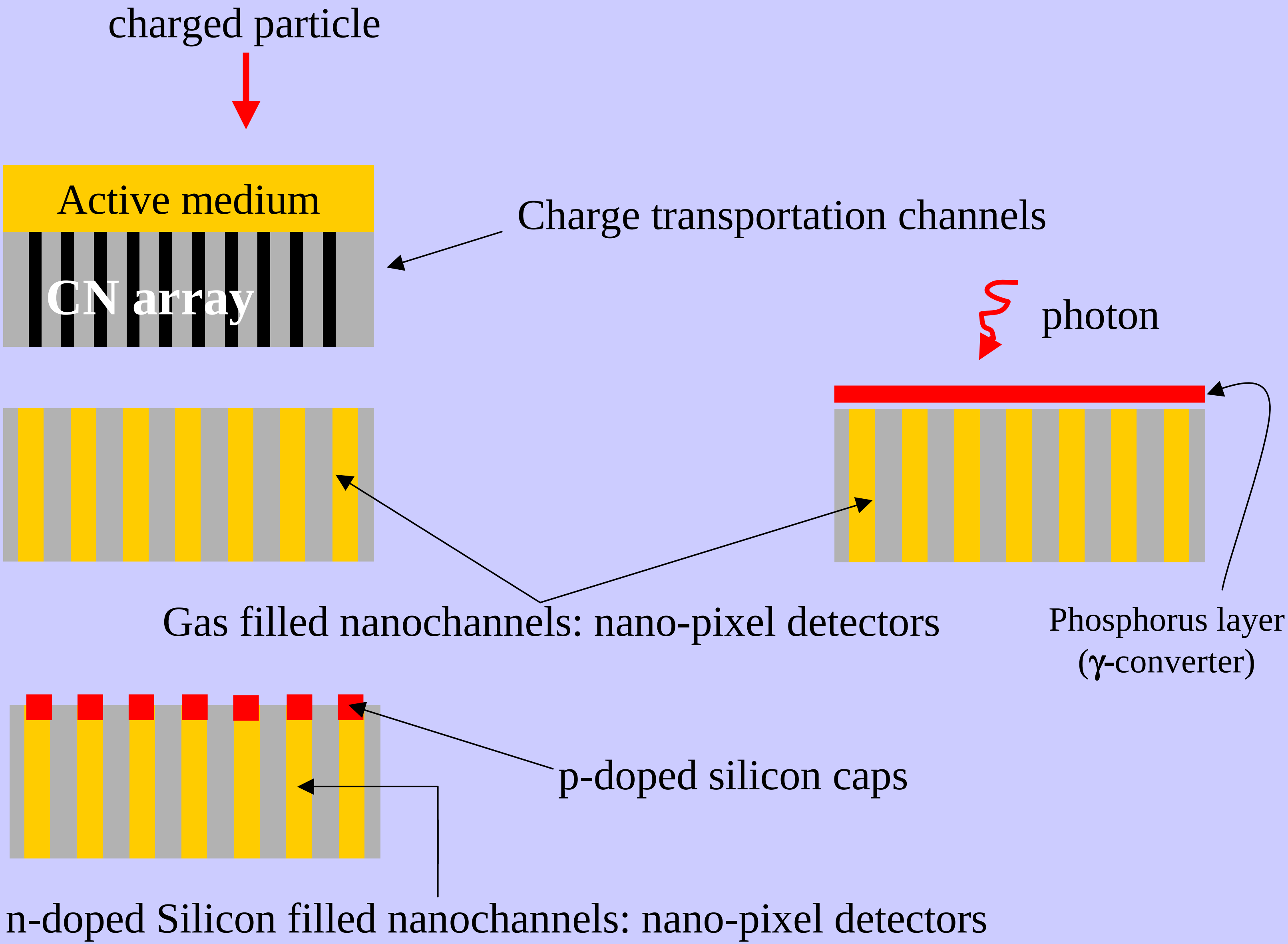


Al_2O_3
Insulator

Carbon Nanotube
Metal or semiconductor

Growth of CN by Chemical Vapor Deposition of an hydrocarbur at 600-800 ºC: temperature, gas concentration and duration of the process determine the CN structure (SWNT or MWNT, metallic or semiconductor)

Ideas for detector applications



charged particle

Active medium

CN array

Charge transportation channels

photon

Gas filled nanochannels: nano-pixel detectors

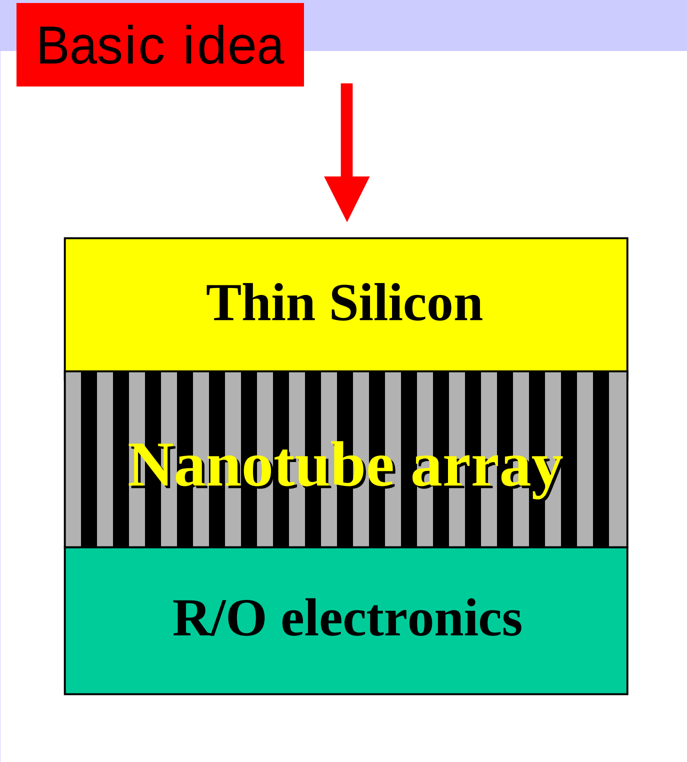
Phosphorus layer
(γ-converter)

p-doped silicon caps

n-doped Silicon filled nanochannels: nano-pixel detectors

NanoChanT project

Nano Channel Template: fabrication of a position particle detector which allows to gain at least one order of magnitude in spatial resolution



Basic idea

Thin Silicon

Nanotube array

R/O electronics

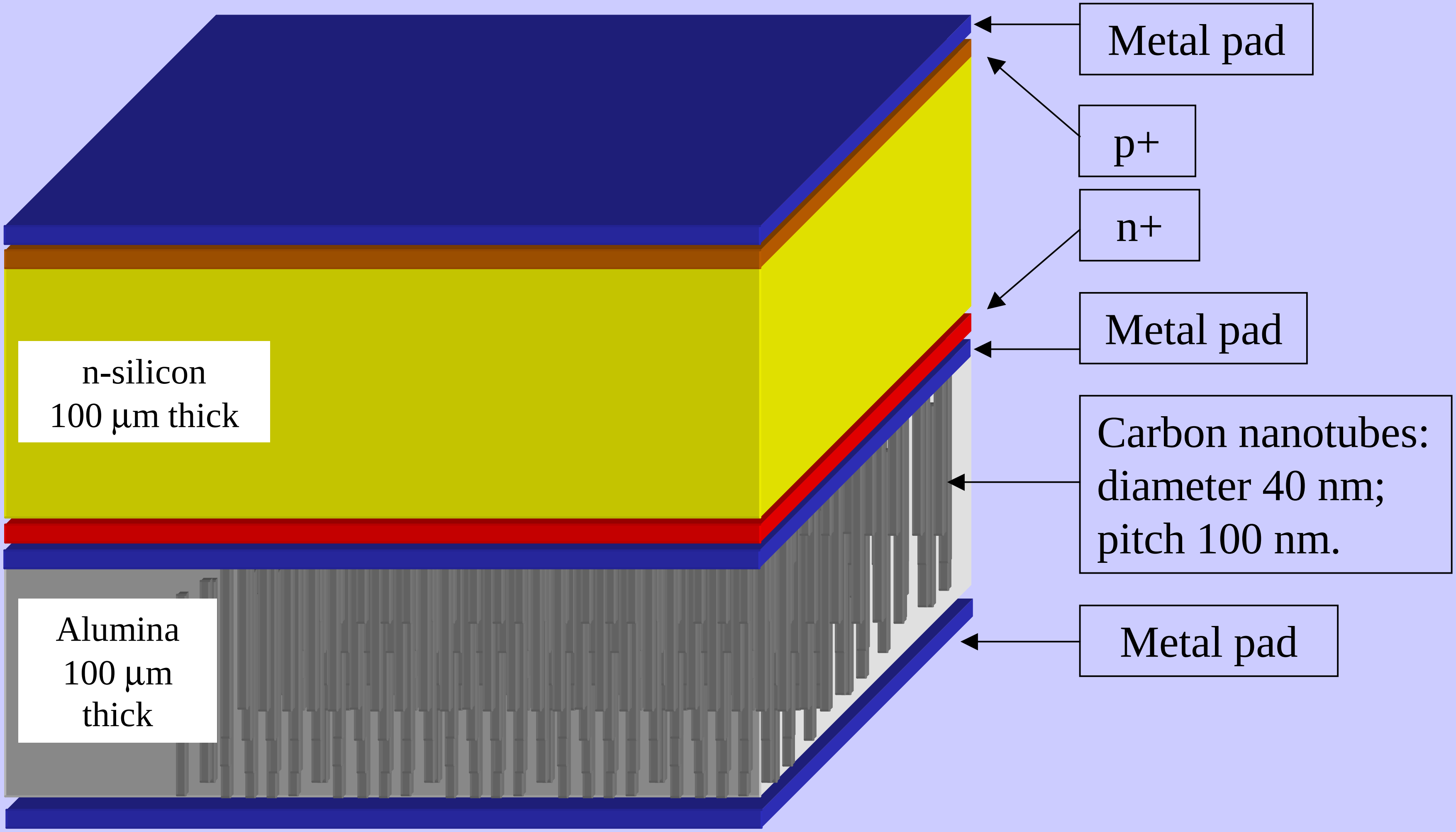
TWO nanotechnologies involved:

1. *Nanochannels* built in the Alumina template with regular and uniform pattern (overall area:1 cm^2)
2. *Carbon nanotubes* grown inside Alumina template

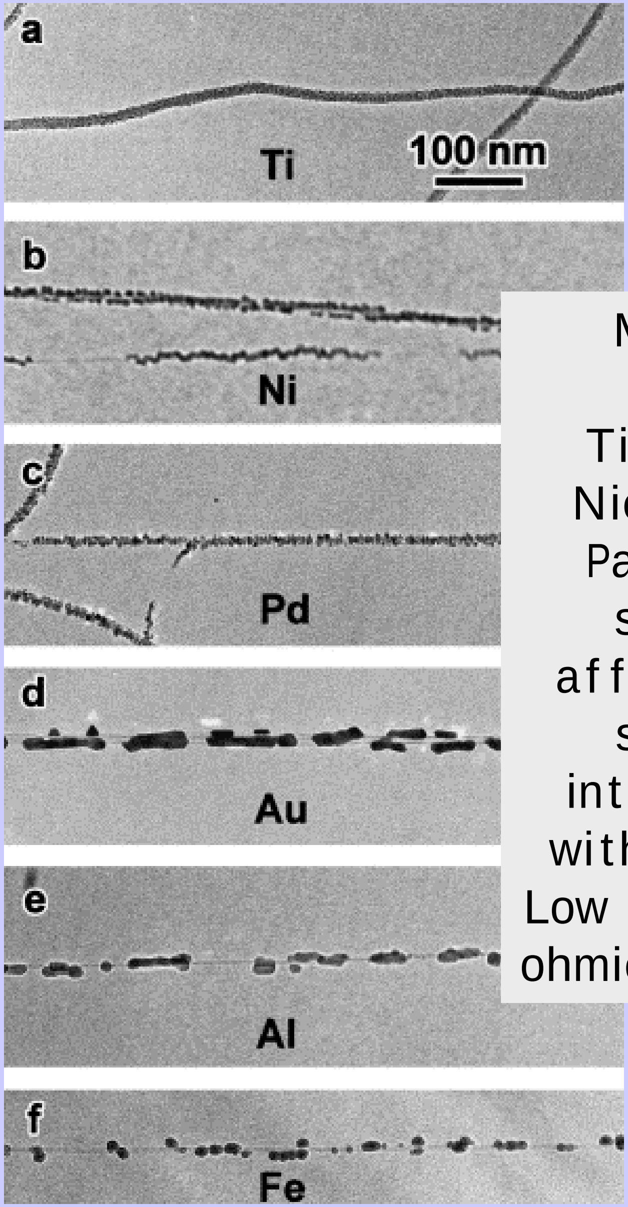
Optimize CN properties in order to use them as charge collectors between an active medium and the readout electronics and study the coupling

Nano Channel Active Layer Detector (simplified)

- ❑ Coupling of a silicon diode & CNT's array:
  ➡ verification of charge production and collection efficiency

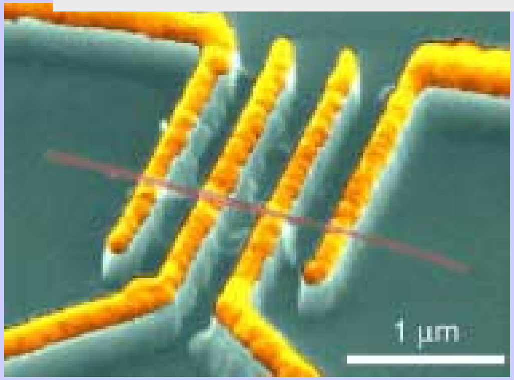


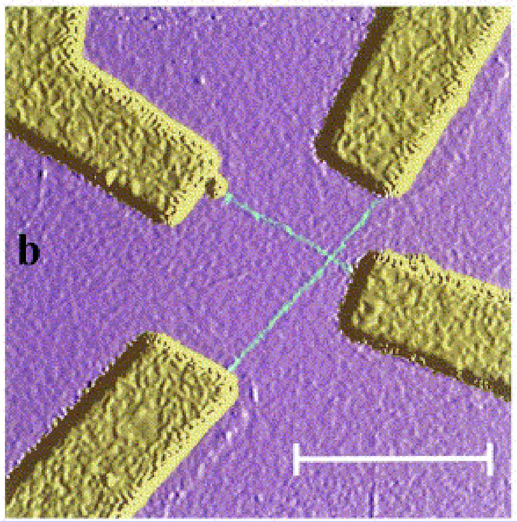
Coupling of CN with metals



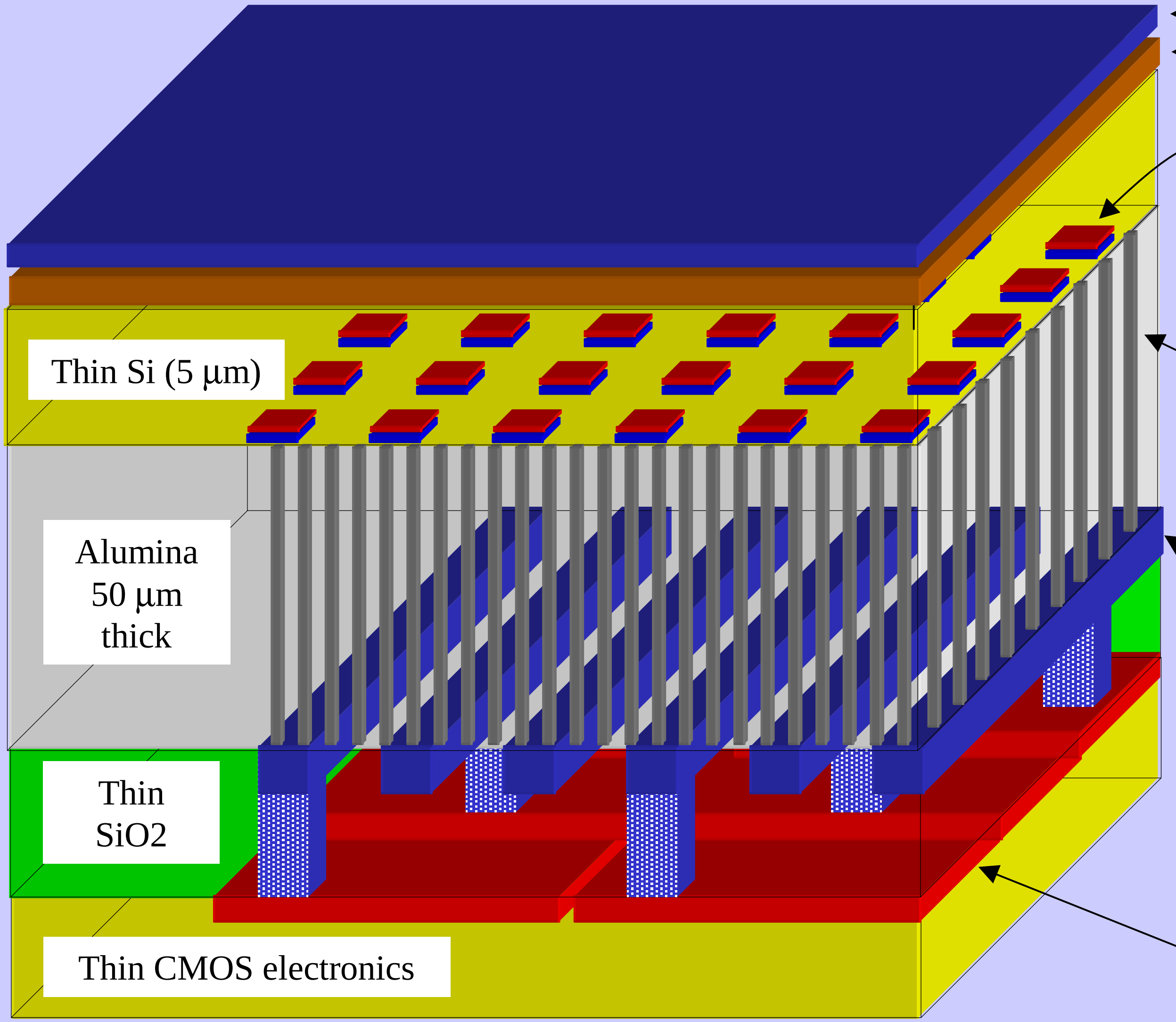
Metals like Titanium, Nichel and Palladium shows affinity and strong interaction with SWNT. Low resistivity ohmic contacts

Titanium contact for electrical measurements





Nano Channel Active Layer Detector



Thin Si (5 µm)

Alumina
50 µm
thick

Thin
SiO2

Thin CMOS electronics

metal pad

p+

n+ & metal pixels
pitch 500 nm

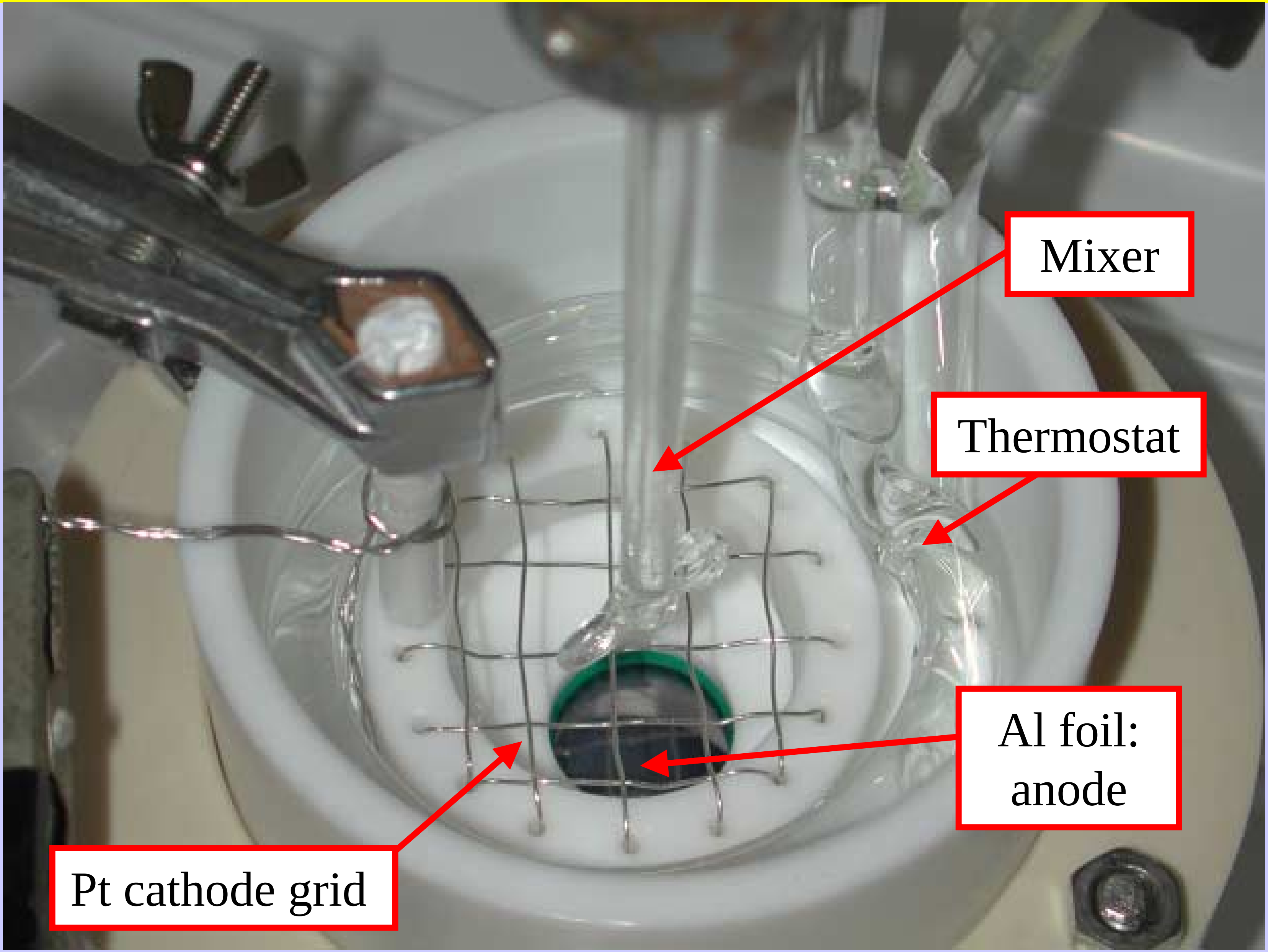
Carbon nanotubes:
diameter 40 nm;
pitch 100 nm.

Metallic strips:
pitch 500 nm;
length 10 mm;
area $5 \cdot 10^3$ µm^2

Same area

R/O electronics:
50 x 100 µm^2;
area $5 \cdot 10^3$ µm^2

First anodization cell



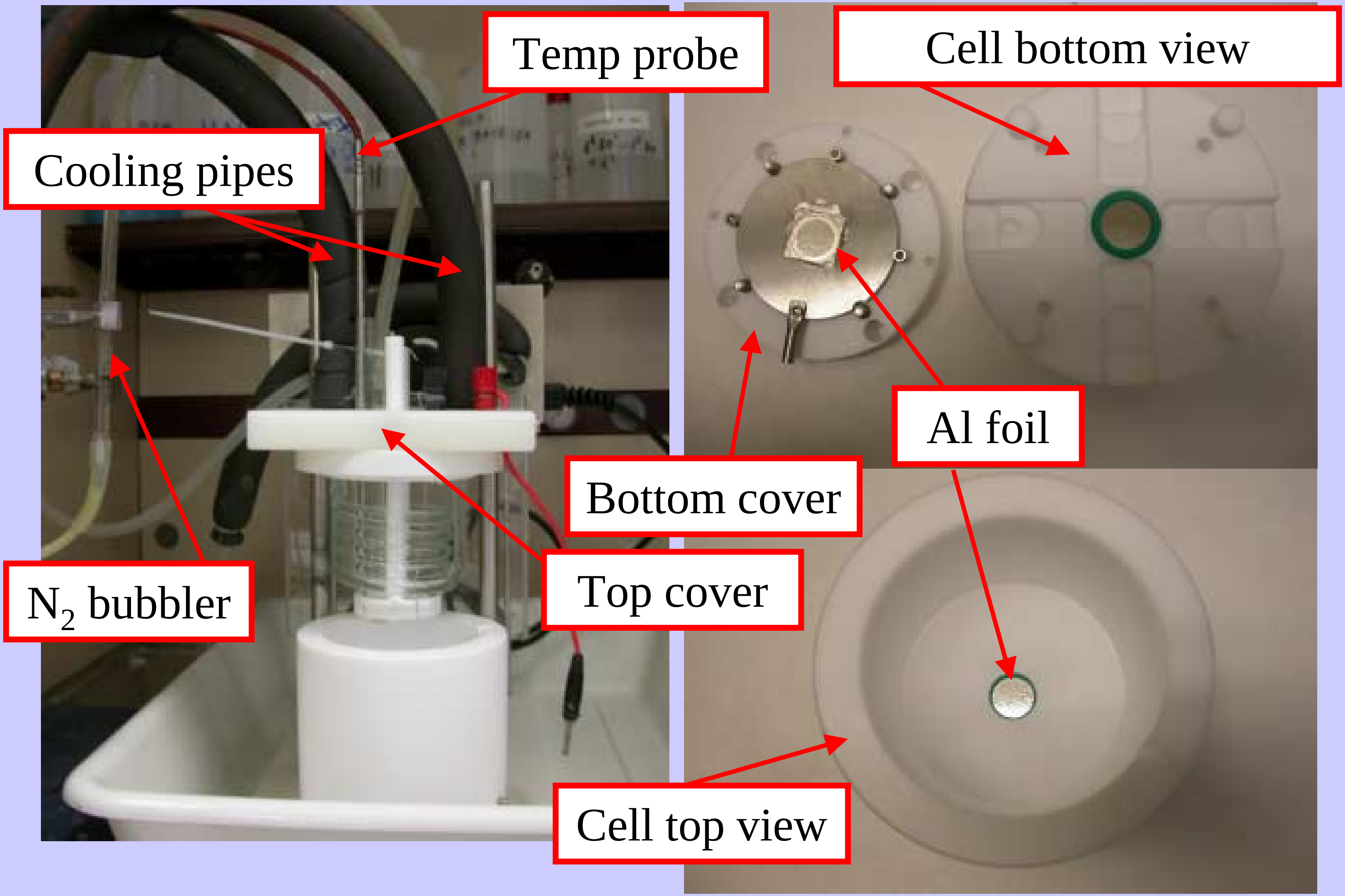
Mixer

Thermostat

Al foil: anode

Pt cathode grid

New anodization cell



Temp probe

Cell bottom view

Cooling pipes

Al foil

Bottom cover

N_2 bubbler

Top cover

Cell top view

Alumina processes

Substrate	high purity Al foils 100 µm thick
Pre-anodization	degreasing, annealing, surface cleaning and electropolishing
Anodization	Pt cathode grid electrolytes: - oxalic acid (0.3 M $(COOH)_2$) or - phosphoric acid (0.3 M H_3PO_4) temperature: 0 - 5 °C voltage: 40 – 195 V
Post-anodization	5% phosphoric acid etching, 30 °C

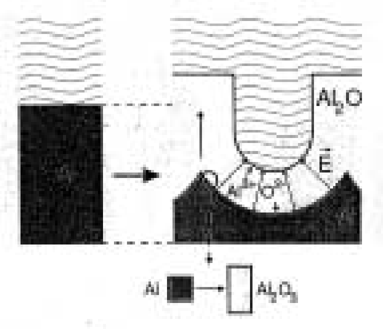
Two step Alumina growth

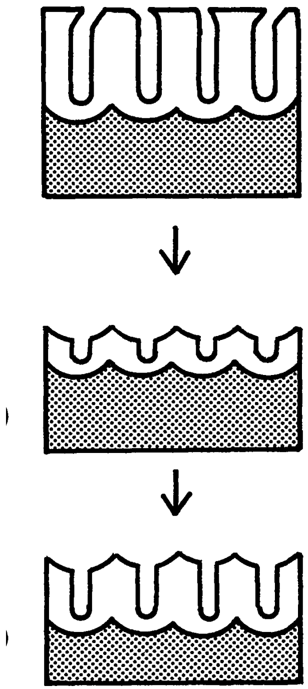
Two steps anodization:

- 1st step:
  - a) formation of a sacrificial alumina layer (>10µm);
  - b) partial removal of the sacrificial alumina layer, up to the target pore size
- 2nd step:
  - c) formation of the target alumina thickness;

Processes Tuning:

- direct measurements of growth and etching rates of the alumina layer.



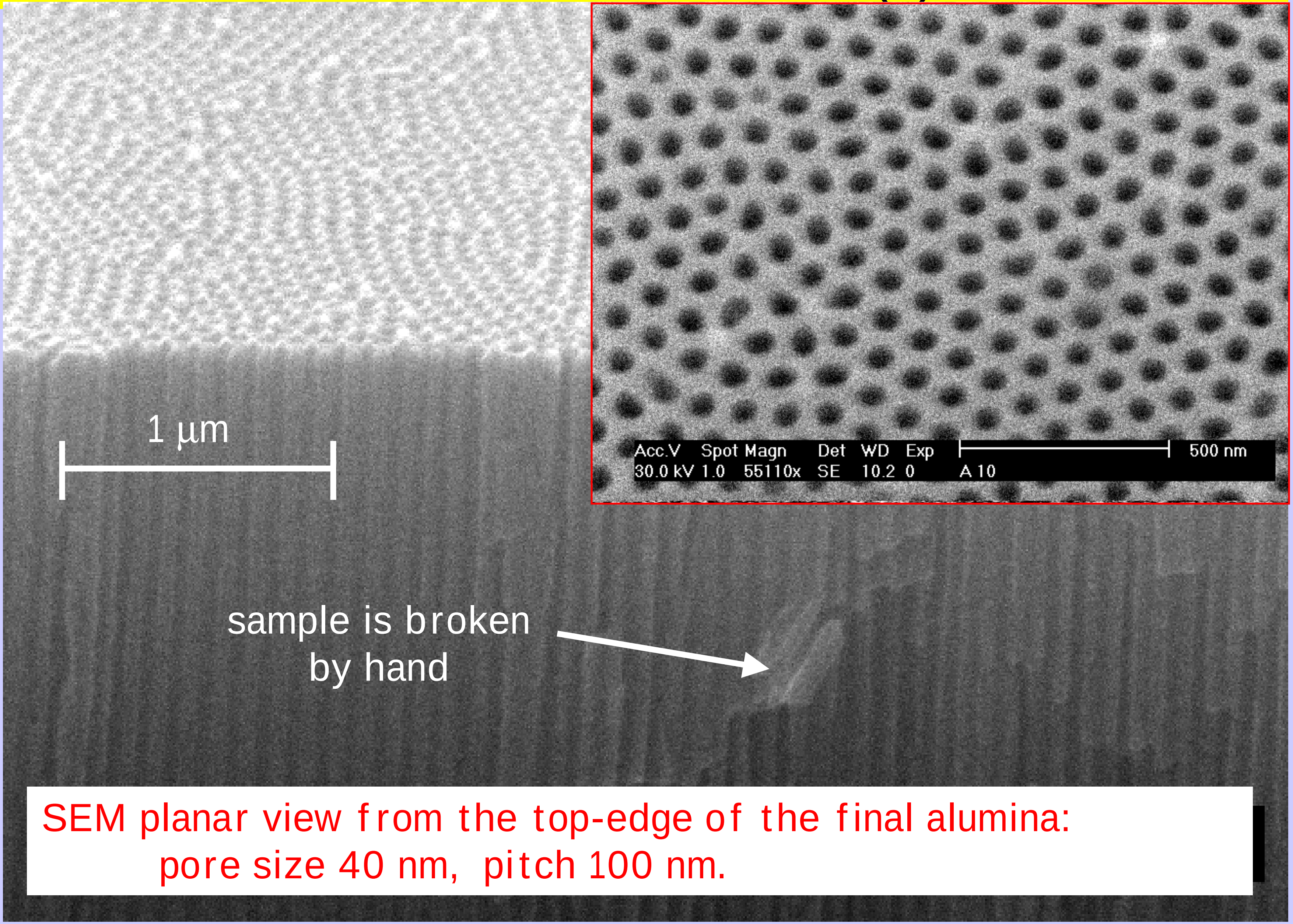


Sacrificial layer

Partial removing

Target thickness

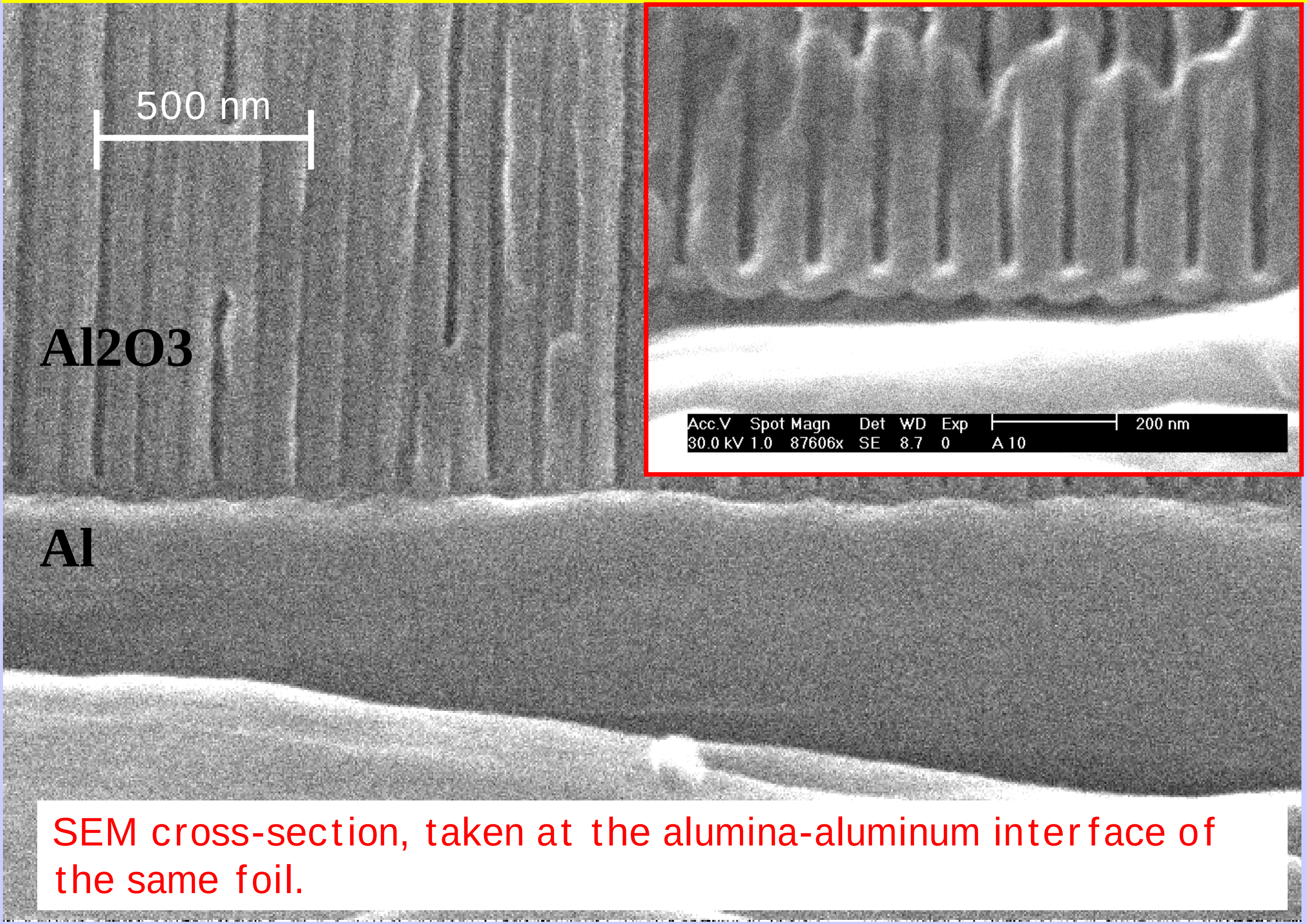
Al anodisation tests (1)



sample is broken by hand

SEM planar view from the top-edge of the final alumina: pore size 40 nm, pitch 100 nm.

Al anodisation tests (2)

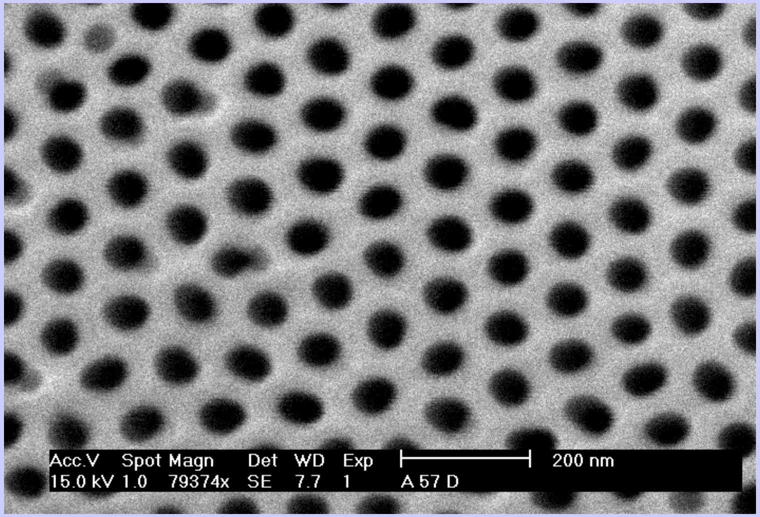


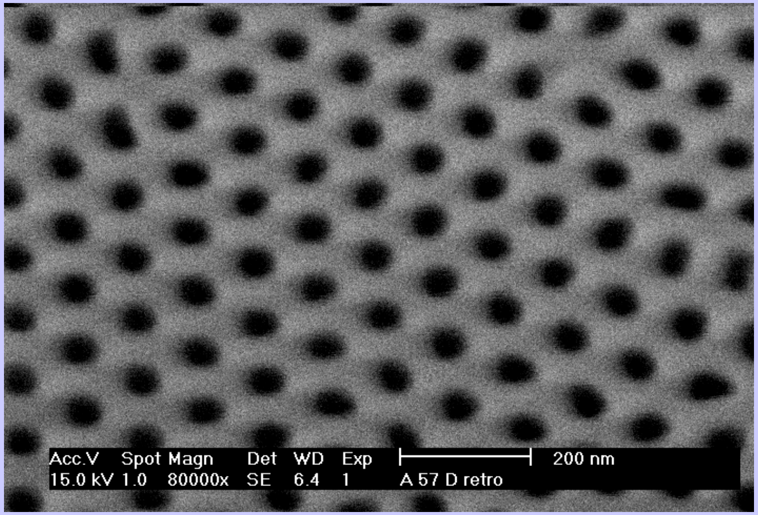
SEM cross-section, taken at the alumina-aluminum interface of the same foil.

Final nano-channel matrix

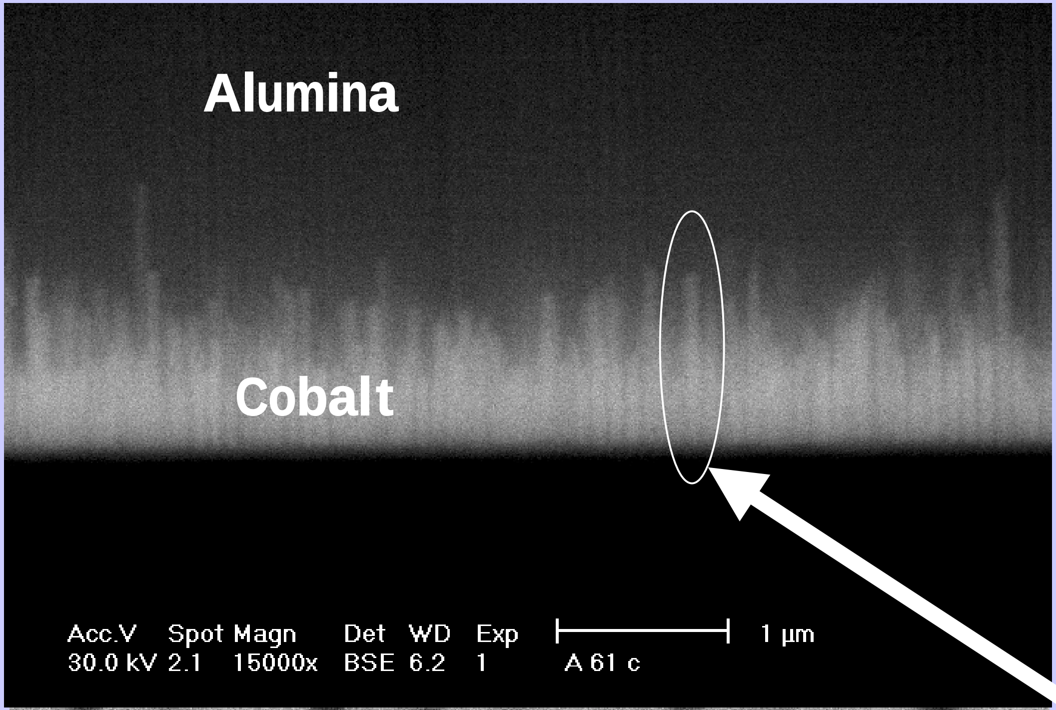
- Post-anodisation processes:
  - Detachment of Alumina-disk from original Al-foil
  - Removing Residual Aluminum from the back-face of the disk
  - Opening of the pores-bottom
- Final nano-channel matrix: no difference between faces!

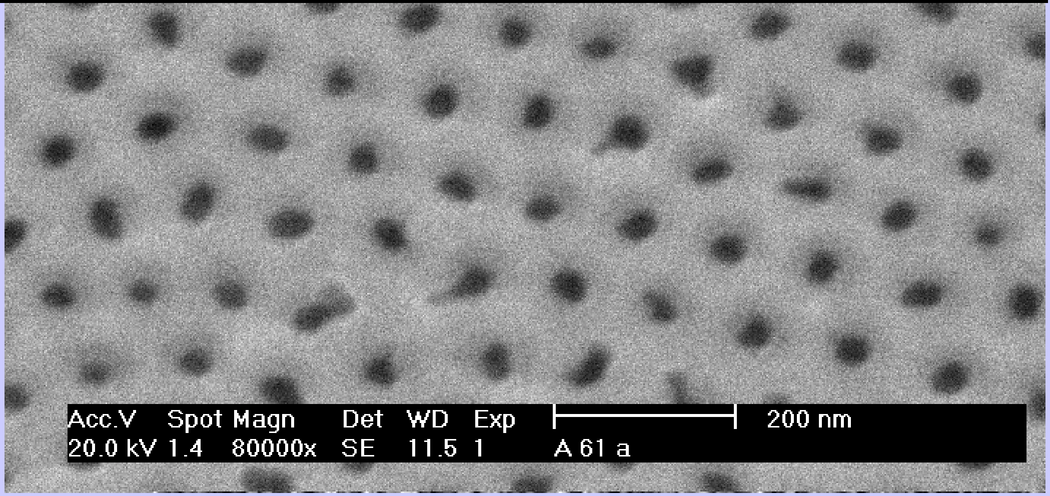
top-face & bottom-face





Cobalt electrodeposition





Method:

- Co wire anode
- Co (II) based electrolyte
- AC regime: 200Hz, 16 Vrms

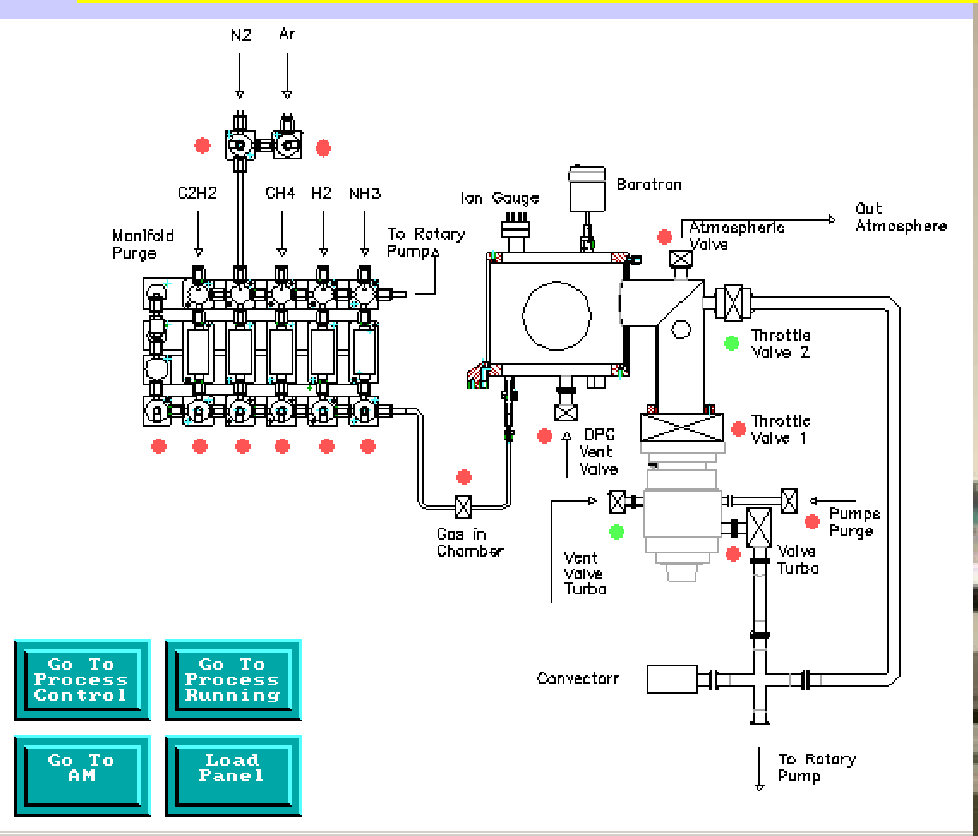
SEM cross-section (with back-scattered electrons): 18.5 µm thick alumina layer. Pores: size ~30 nm, pitch 100nm.

Co wires (length ~ 1 µm)

SEM image of alumina surface after Co deposition:

no Cobalt contamination.

Reactor for CNs synthesis



APCVD, LPCVD; arranged for PECVD.

Gas: Ar, N_2 H_2, CH_4, C_2H_2, NH_3

Temperature: 600-900 C

Vacuum: rotary + turbo (< 10^{-7} mbar)

Experiment status & milestones

Nov 2001: experiment proposal submission

Feb 2002: experiment approved and partially financed
Jul 2002: high quality alumina template obtained

Oct 2002: experiment fully financed
Nov 2002: CVD reactor commissioning
Jan 2003: catalyst deposition process tuned
Jun 2003: CVD reactor ready

Oct 2003: carbon nanotube synthesis
Jun 2004: simplified detector prototype assembling
Sep 2004: charge production/collection test (with alpha)

Application of Nanotechnologies in High Energy Physics

R. Angelucci[a], F. Corticelli[a], M. Cuffiani[b], G.M. Dallavalle[c], L. Malferrari[c], A. Montanari[c],
C. Montanari[b], F. Odorici[c], R. Rizzoli[a], C. Summonte[a]

[a]Consiglio Nazionale delle Ricerche-IMM, Sezione di Bologna, V. Gobetti 101, 40129 Bologna, ITALY

[b]Dipartimento di Fisica dell'Universita di Bologna, V.le B. Pichat 6/2, 40127 Bologna, ITALY

[c]Istituto Nazionale di Fisica Nucleare, Sezione di Bologna, V.le B. Pichat 6/2, 40127 Bologna, ITALY

In the past, the progressive reduction of electronics integration scale has allowed high energy physics experiments to build particle detectors with a high number of sensitive channels and high spatial granularity, down to the micron scale. Nowadays, the increasing effort towards nanoelectronics and progresses in various fields of nanotechnologies, suggests that the time for nanodetectors is not far to come. As an example of possible application of nanotechnologies in HEP, we present results on fabrication of nanochannel matrices in anodic porous alumina as a template for preparing an array of carbon nanotubes, which we believe can be a promising building block in developing particle detectors with high spatial resolution.

(To be published in Nuclear Physics B (Proceedings Supplement) as Proceedings of "8th Topical Seminar on Innovative Particle and Radiation Detectors", 21 - 24 October 2002 Siena)

1. INTRODUCTION

In 1991 quasi one-dimensional structures of bonded carbon atoms, named carbon nanotubes (CN), were discovered [1]. Since then, CN have attracted the attention of many researchers and several application opportunities have been suggested [2]. CN are thin graphene foils, rolled as tubes with 1-100 nm diameters and lengths well above one micron. As a function of their diameter and rolling chirality CN behave as good conductors or semiconductors and thus they are studied with extreme interest within nanoelectronics [3]. CN are already applied as nanowires, even superconductors, and are candidate to the fabrication of nanodiodes and nanotransistors [4,5]. In fact, when a CN is bent at an angle of some tenth of degrees it behaves like a diode, while Y-shaped nanotubes behave like transistors. A suggested applications of CN in High Energy Physics consists in the beam transport in particle accelerators [6].

In 1999 a technique for fabrication of uniform matrices of parallel CN at controlled pitch has been demonstrated [7]. In this work, CN are grown inside a mould constituted by anodic porous alumina (Al_2O_3), commonly referred to as "alumina template". The diameter, pitch and length of nanopores can be controlled by adjusting the parameters of the aluminum anodization process. Pore diameters in the range of 10-100 nm can be obtained, with a pitch between 20-200 nm. CN are then grown inside the nanochannels by means of a chemical vapor deposition process, with decomposition of carbon gasses. CN matrices with area 1 cm^2 and thickness 100 μm, corresponding to the nanochannels length, are feasible. The possibility to build a regular and uniform matrix of CN, make these nanotechnologies very attractive for applications to new position particle detectors.

2. THE NANOCHANT PROJECT

The aim of the NanoChanT ("Nano Channel Template") project is to adapt some available nanotechnologies, in particular nanochannels and CN, to build a position particle detector which can improve resolution by at least one order of magnitude with respect to present detectors.

The basic starting point is illustrated in Figure 1: a regular and uniform matrix of CN, grown inside the alumina template, is sandwiched between an active layer and a readout layer. The active layer is formed by a reverse biased silicon diode, in which a charged particle produces electron-hole pairs during its passage. The readout layer is constituted by CMOS electronics embedded in a silicon substrate. The alumina layer gives the mechanical stiffness to the system. In this way the upper sensitive silicon layer can be kept small in order to reduce the effects of charge spreading in the active layer, which presently limits the resolution of silicon detectors. The CN are isolated each other by the aluminum oxide and act as conductors of the charge collected in the diode to the readout electronics. In principle each CN is independent from the others and the resolution can scale as the pitch of the matrix. Resolution is limited by the amount of the charge spread in the thin silicon layer and by the granularity of the readout logic. At the moment the scale of integration of CMOS electronics limits the readout granularity to values much larger then CN pitch. But, for the future, improvements in the readout electronics could fully benefit of the CN geometry.

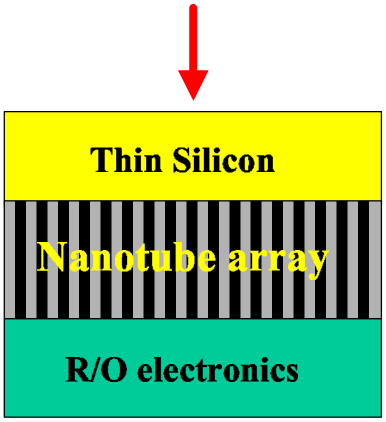


Figure 1. Basic idea for a position particle detector.

2.1. Aluminum anodization tests

The basic component for the growth of the array of CN is the alumina template. By using a technique similar to the one illustrated in [8,9], several samples of alumina templates were produced at CNR-IMM laboratory in Bologna. The starting point is an high purity aluminum foil, 100 μm thick, which is anodized in an electrolytic cell. Under controlled condition, the current spontaneously creates holes in the aluminum oxide, with self organization in a regular honeycomb-like structure. The type of acid, temperature, voltage bias and duration of the process are critical parameters through which it is possible to control the size and the pitch of such holes. Typically, by using a 0.3 molar solution of oxalic acid with a voltage bias of about 40 V, it is possible to produce nanochannels with a pitch of about 100 nm. By using phosphoric acid with a bias of 190 V, larger pitch of about 200 nm can be obtained. The size of the holes diameter scales with the pitch. It ranges from about 40 nm, for oxalic acid, to 100 nm, for phosphoric acid.
For the success of the process, the preparation of the aluminum foil is a delicate phase. The foil is degreased and annealed at high temperature in order to remove impurities. Then the surface is treated with an electropolishing process in order to remove defects and improve the planarity.

In Figure 2 a picture from a Scanning Electron Microscope of an alumina sample, obtained by using oxalic acid, is shown. It represents the top surface of the alumina template. The holes have a diameter of about 40 nm and a pitch of 100 nm. The regularity of the pattern of the holes is limited by the grain boundaries of the original aluminum foil.
A side view of the same sample is shown in Figure 3: the sample is broken in two halves, in order to show the depth of the straight nanochannels. At a process temperature of about 5^o C, the excavation rate was about 3 μm/h, and a full depth of about 100 μm was obtained after 30 hours of anodization in the electrolytic cell.

The bottom edge of the alumina template is visible in Figure 4 with the interface between the oxidized aluminum, with the channels dig by the current, and the original aluminum.

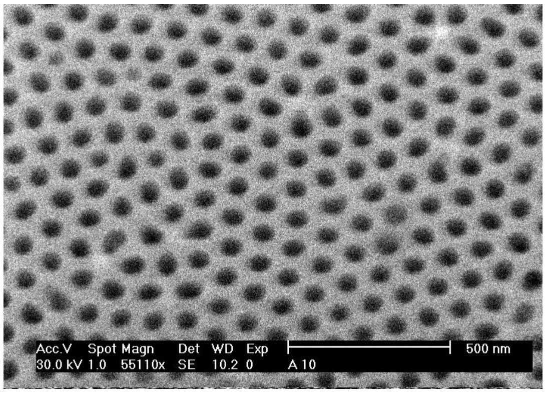


Figure 2. SEM image of the top surface of an alumina sample.

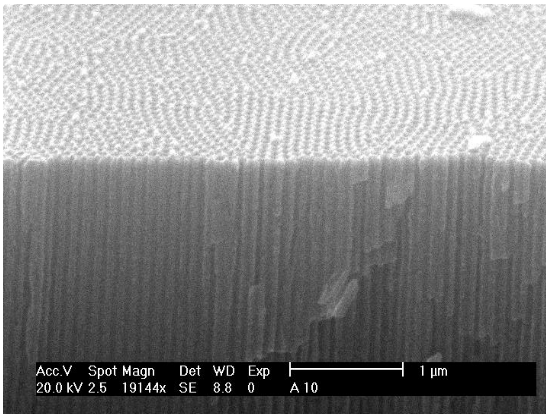


Figure 3. SEM side image of an alumina sample.

Other samples were obtained by using phosphoric acid, with nanochannels of 100 μm diameter and 200 μm pitch.

2.2. Synthesis of CN

The synthesis of CN will be done by using a dedicated reactor for chemical vapor deposition, following a technique similar to the one described in [10]. The first step of the process is the electrodeposition of a metallic catalyst, like Nickel or Cobalt, at the bottom of the pores of the nanochannel template.

The sample is then inserted in the reactor, where an hydrocarbon (ethylene, acetylene or methane) is decomposed at atmospheric pressure, at a temperature of 700-800 Celsius degrees. The metallic particle catalyzes the deposition and crystallization of carbon atoms in the form of nanotubes which cover the nanochannels walls. The type of hydrocarbon and temperature determine the electrical (conductor or semiconductor) and morphological properties of the nanotubes. A dedicated reactor for this purpose, designed in order to use different gas species and working modes, is in the commissioning phase.

2.3. Coupling between carbon nanotubes and silicon

A critical aspect of the device is the efficiency of charge collection through CN to the readout electronics. CN properties must be optimized for such purpose, as well as the coupling of CN to the active layer and the readout electronics. In order to study the efficiency of charge collection, a basic step for the NanoChanT project will be the building of a simplified detector, which is schematically shown in Figure 5.

A layer of n-doped silicon is p^+-implanted in the upper surface and n^+-implanted in the lower one: the total thickness is about 100 μm. A reverse bias is applied to the silicon layer through metal pads, in order to completely deplete the silicon diode. The alumina template, containing the regular structure of carbon nanotubes, is bonded to the metallic pad of the lower surface of the diode via intermediate layers of transition metals [11]. A metallic pad is attached to the lower surface of the alumina layer, and can be used to extract the total charge produced by the passage of a charged particle in the active layer and collected through the CN. The idea is to expose such a device to a known flux of alpha particles in order to quantify the efficiency for charge collection via CN.

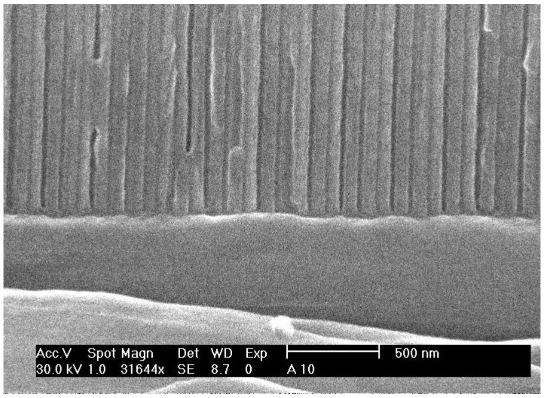


Figure 4. Bottom part of an alumina sample.

2.4. Nanochannel Active Layer detector

Once the CN array, with the optimized characteristics for our purpose, will be produced and its coupling to the silicon layer will be tuned, a complete position detector will be assembled , according the guidelines depicted in Figure 6.

In this case, the thickness of the silicon diode is only 5 μm, while the thickness of the alumina template is about 50 μm. CN have a diameter of 40 nm and a pitch of 100 nm. The n^+ implantation on the lower surface of the active silicon layer is segmented in form of pixels, in order to collect the charge into a localized region of the detector. This geometry also reduces the detector capacitance. CMOS readout electronics is integrated in a silicon substrate which is interfaced to CN matrix through a thin layer of silicon oxide. The charge carried by groups of CN is collected onto metallic strips, obtained in the silicon oxide and having the same pitch of the pixels. The charge is finally collected from each strip to the corresponding electronics channel via metallic contacts. In this geometry the particle position is reconstructed in one dimension and the pitch of the strips determines the ultimate resolution of the detector. At the moment, a possible pitch of 500 nm would correspond to 20000 channels per square centimeter.

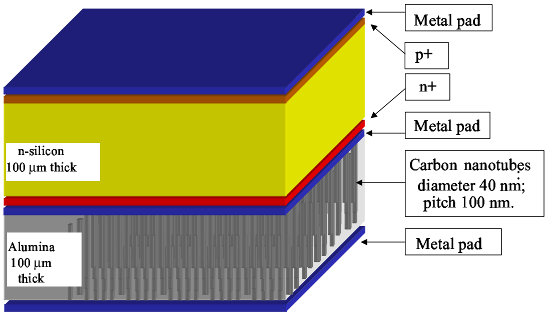


Figure 5. Simplified detector for the study of the coupling between CN and silicon.

3. PERSPECTIVES AND CONCLUSIONS

Nanotechnologies have found in recent years many applications in different research areas. In this work, carbon nanotubes grown in a regular matrix of nanochannels inside alumina, are considered as a possible application for a position particle detector. CN are used as collectors for the charge produced in a silicon active layer. The stiffness of alumina allows to reduce the thickness of the silicon layer, in order to limit the effects of charge diffusion. The geometry of the detector keeps low its capacitance. At the moment the readout is foreseen through one dimensional strips, with submicron resolution.

Samples of alumina with the desired geometry have already been successfully produced. The next step will be the growth of CN inside the alumina template and the study of the coupling to the silicon active layer and the readout electronics.

Still all the potentiality of CN are not used in this scheme, but many possibilities are opened for the future. For example, an interesting scenario could be to insert the active medium in the CN themselves [12] and to use CN as charge amplifiers[13].

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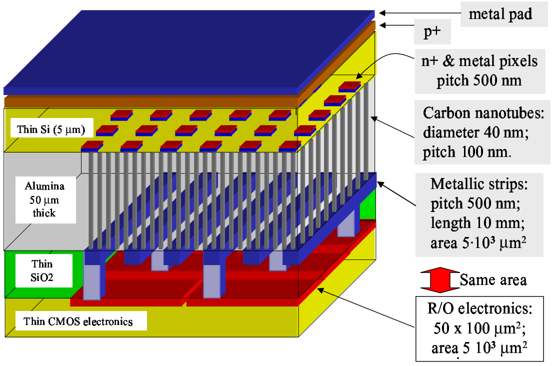

Figure 6. Geometry for a Nanochannel Active Layer detector.

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ISTITUTO NAZIONALE DI FISICA NUCLEARE
Preventivo per l'anno ***2004***

Codice	Esperimento	Gruppo
	NANOCHANT	5
Rapp. naz.: F. Odorici		

PREVISIONE DI SPESA

Piano finanziario globale di spesa

In KEuro

ANNI FINANZIARI	Miss. interno	Miss. estero.	Materiale di cons.	Trasp. e Facch.	Spese Calc.	Affitti e Manut. Appar.	Mater. inventar	Costr. appar.	TOTALE Compet.
2004	*5.5*	*8*	*31*	*0*	*0*	*0*	*1.5*	*0*	***46.0***
TOTALI	***5,5***	***8,0***	***31,0***				***1,5***		***46,0***

Mod EC./EN. 6 (a cura del responsabile nazionale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Struttura
BO

Codice	Esperimento	Gruppo
	NANOCHANT	5
Resp. loc.: F. Odorici		

COMPOSIZIONE DEL GRUPPO DI RICERCA

N	**RICERCATORE Cognome e Nome**	**Qualifica**				Affer. al gruppo	%
		Dipendenti		Incarichi			
		Ruolo	Art. 23	Ricerca	Assoc.		
1	Angelucci Renato				C.N.R	5	50
2	Cuffiani Marco			P.A.		1	50
3	Dallavalle G. Marco	I Ric				1	30
4	Malferrari Luciana	Ric.				1	70
5	Montanari Alessandro	Ric.				1	30
6	Montanari Christian				Dott.	1	50
7	Odorici Fabrizio	Ric.				1	30
8	Rizzoli Rita				C.N.R	5	50

Numero totale dei ricercatori	**8**
Ricercatori Full Time Equivalent	**3.6**

N	**TECNOLOGI Cognome e Nome**	**Qualifica**			%
		Dipendenti		Incarichi	
		Ruolo	Art. 23	Ass. Tecnol.	

Numero totale dei Tecnologi	**0**
Tecnologi Full Time Equivalent	**0**

N	**TECNICI Cognome e Nome**	**Qualifica**				%
		Dipendenti		Incarichi		
		Ruolo	Art. 15	Collab. tecnica	Assoc. tecnica	

Numero totale dei Tecnici	**0**
Tecnici Full Time Equivalent	**0**

SERVIZI TECNICI

	Denominazione	**mesi−uomo**
1	Elettronica	1.0

Annotazioni:

Osservazioni del direttore della struttura in merito alla disponibilità di personale e attrezzature

Mod EC./EN. 7 (a cura del responsabile locale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno ***2004***

Codice	Esperimento	Gruppo
	NANOCHANT	5
Rapp. Naz.: F. Odorici		

MILESTONES PROPOSTE PER IL 2004

Data completamento	**Descrizione**
30/06/2004	Bonding di un wafer di silicio opportunamente drogato con una matrice di nanocanali di allumina, riempiti con nanotubi di carbonio. La carica trasportata dai nanotubi e' letta tramite una pad metallica, collegata ad elettronica di amplificazione e readout.
30/09/2004	Verifica del funzionamento del rivelatore tramite irraggiamento con particelle alfa.

Mod EC./EN. 8 (a cura del responsabile nazionale)