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physics department

from nanomaterials to new sensor applications

António Luís Ferreira – alf@ua.pt

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research areas

materials physics/ nanosciences and nanotechnology

photovoltaic materials

optics and photonics

biophysics and medical physics

radiation detectors

complex system physics and physics of networks

astronomy and astrophysics

meteorology, climatology and oceanography

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RESEARCH, INNOVATION AND ENGINEERING APPLICATIONS

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ciceco
centre for research in ceramics & composite materials

research labs and research units

i3n, ciceco, cesam, cidtff

CESAM
Centre for Environmental and Marine Studies
www.cesam.ua.pt

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people

› **teaching staff: 48.6**

› **non-teaching staff: 14 (+1 I3N)**

› **researchers: 15**

› **postdocs: 25**

› **phd students: ~ 50**

research output

› papers : ~ 150 per year

research funding (2010)

› knowledge valorization	193 k€
› public national	2 052 k€
› EU	316 k€
Total	2 561 k€

› citations per paper 2005/10 : 5.8

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astronomy and astrophysics

› People

Alexandre Correia, Helena Morais, Cristian Giuponne

› **studies of evolution of planet rotation**
› **paleoclimatology of earth and mars**
› **search for extra-solar planets, stelar wobble**
› **tidal and core-mantle friction effects**

› some references

Correia and Laskar, Nature 429(6994): 848-850 (2004)

Lovis, C., et al. Nature 441(7091):305-09(2006)

Correia, Laskar, et.al. Celestial Mechanics & Dynamical Astronomy 111, no. 1-2 (Oct 2011): 105-30.

Morais, M. H., and Correia Astronomy & Astrophysics 525 (Jan 2011).

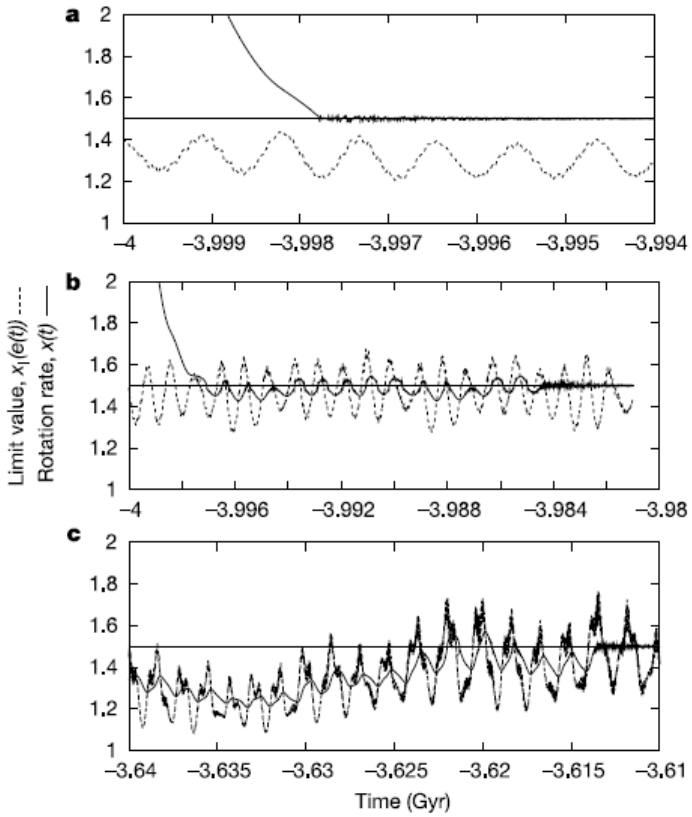

Figure 2 Typical cases of capture into the 3/2 resonance. The rotation rate $x(t)$ (bold curve) and limit value $x_1(e(t))$ (dotted curve) are plotted versus time (Gyr). **a**, Type I is the classical case[5]: As $e < e_{3/2}$, the limit value x_1 is always lower than 3/2. **b**, In Type II, at the time when x reaches the resonant value 3/2, e is oscillating around $e_{3/2}$, leading to multiple crossings of the resonance, with ultimately a capture. **c**, Type III corresponds to solutions that have not been captured during the initial crossing of the resonance, but later on, as the eccentricity increases beyond $e_{3/2}$.

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gravitation

› People

Carlos Herdeiro, Marco Sampaio, Carmen Rebelo

› numerical relativity for D dimensional space-times

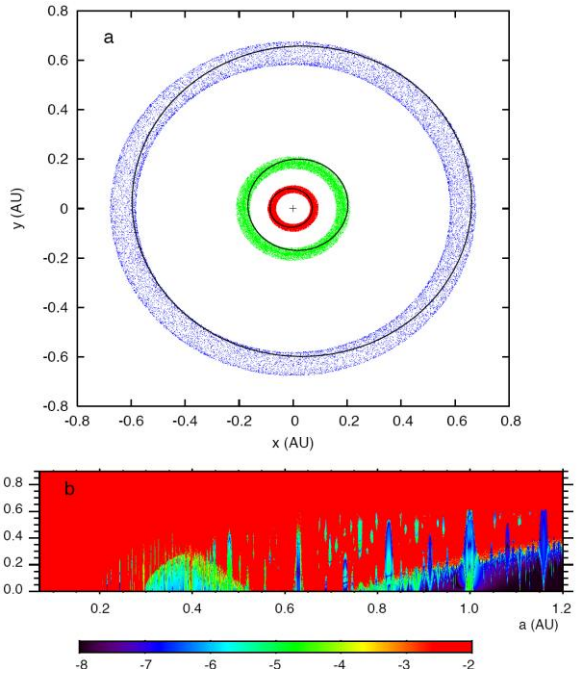
› collisions of black holes

› some references

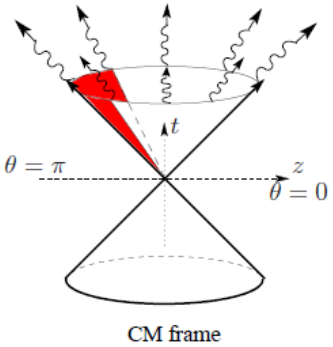
Witek, H., et. al, Phys. Rev. D 83, 044017 (2011).

Herdeiro, C, Sampaio M, and Rebelo C, J. High Energy Physics, 7 (2011).

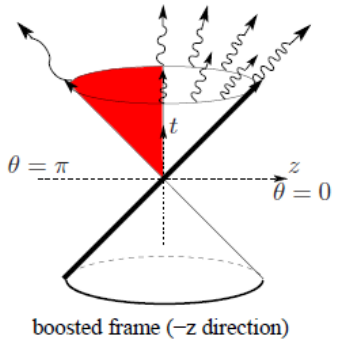
Avelino, P., et al. Physical Review D 84(2) (2011)



An extrasolar planetary system with three Neptune-mass planets



CM frame



boosted frame (−z direction)

MagLab
Materials research for magnetic sensors

› People

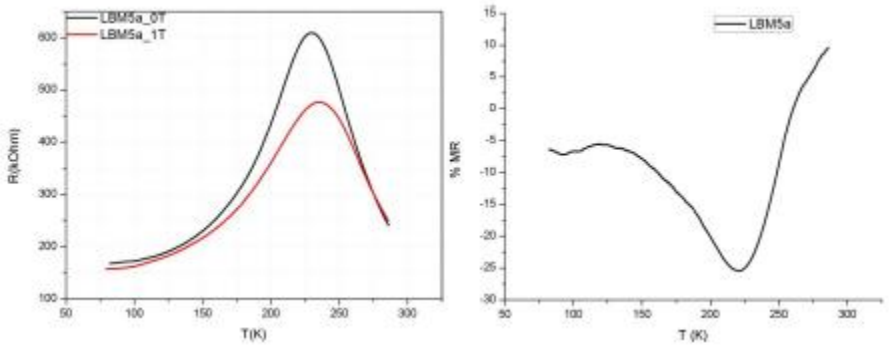
Vítor Amaral, Armando Lourenço, Nuno Silva,
João Amaral, Das Soma.
Fábio Figueiras, João Gonçalves

› magnetoresistance

› applications of magnetic fied sensors:

magnetic data storage in hard disks
strain measurement and actuators

Metal or oxide materials, in thin film, heterostructures and tunnel junctions are used, the choice depending on conditions



Example of temperature dependence of electric resistivity and magnetoresistance (at field 1 Tesla) of manganite thin film La-Ba MnO3

on-going work :

Magnetic Shape Memory alloy/Piezoelectric heterostructures
Ferromagnetic manganite oxide thin films for magnetoresistance

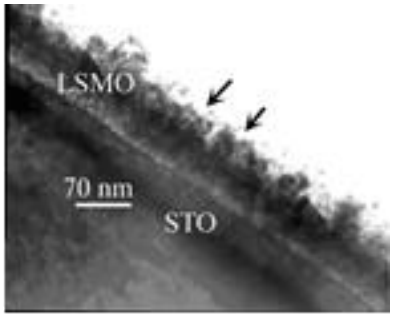
Ferromagnetic/ferroelectric multiferroic oxide heterostructures

MagLab

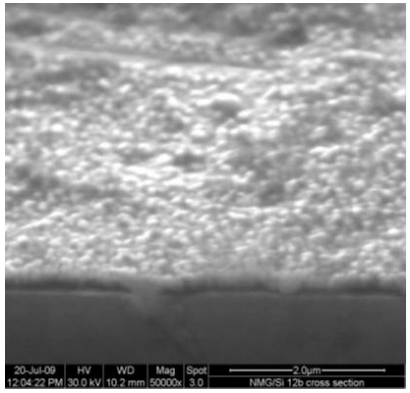
› **New approaches:** coupled ferroelectricty/ferroelasticity in multiferroic devices have been proposed. This opens also the possibility for combined electric field polarization.

› **studies and develops:** (epitaxial or policrystalline) thin films and structures by magnetron sputtering that can be used/optimized for magnetic sensing/actuating in varied temperature ranges (10-320K)

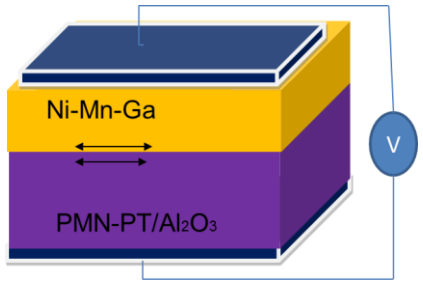
Transmission Electron microscope image of manganite thin film on oxide substrate



Example of heterostructure:
Scanning Electron microscope image of magnetic shape memory alloy film on silicon



Scheme of multiferroic structure with piezoelectric/oxide



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Wide band gap semiconductor oxides for optoelectronics and gas sensing applications

› People

T. Monteiro, A. Neves, J. Soares, R. Correia, J. Leitão, N Sobolev, F. Costa, A. Cunha, Marco Peres, L. C. Costa, etc

› wide band gap oxides

› semiconducting devices for gas detection.

gas adsorption onto a semiconductor produces a conductance change

ZnO – n type semiconductor

- **Materials**
- **ZnO, MgO, SnO_2, TiO_2, Fe_2O_3, Al_2O_3, $SrTiO_3$, $LiNbO_3$, Ta_2O_5, CCTO, and alloys**
- **ZnS, ZnSe, CdS, CdSe**
- **GaN, InGaN, AlGaN, AlN AlInGaN**
- **porous-Si, Si/Ge, nc-Si, InAs/InP**
- **nc-diamond, SWCT, MWCT**
- **nano metal-organic complexes**

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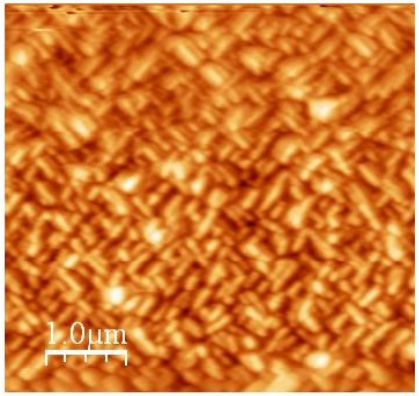
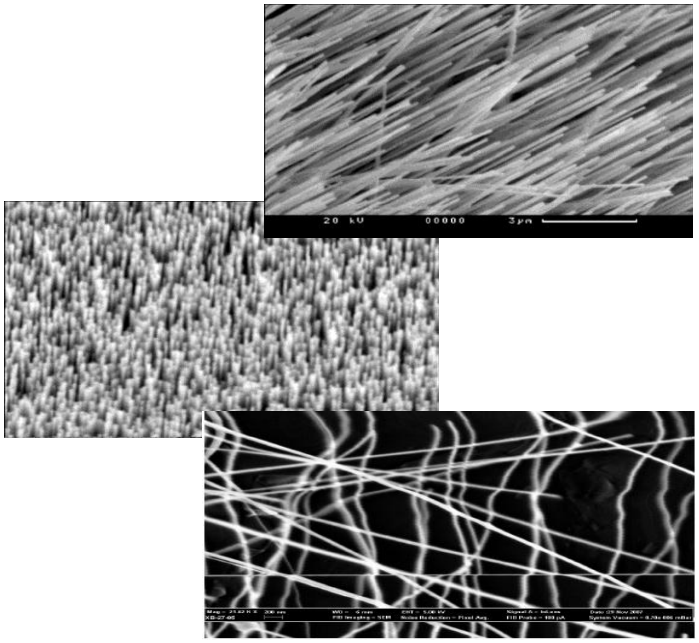
Wide band gap semiconductor oxides for optoelectronics and gas sensing applications

› **Oxygen-related gas sensing chemisorption of oxygen on oxide surface, followed by charge transfer during the reaction between the chemisorbed oxygen and target gas molecules, change the surface resistance**

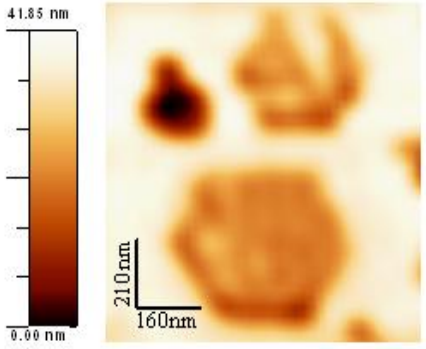


A. S. Lourenço, et *al.,* (2008)



ZnO

films
heterojunctions
nanoparticles
nanowires



M. Peres, et *al.,* (2008)

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Wide band gap semiconductor oxides for optoelectronics and gas sensing applications

› Issues:

Sensitivity
Gas Selectivity
Reproducibility
Rapid response time
Adequate operating temperature

Avoid long term instability and sensitivity to ambient humidity
Adding of catalysts

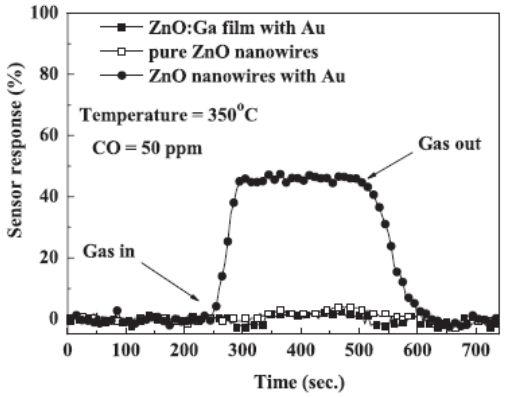

Figure 4. Detector responses of the ZnO nanowire-based CO gas sensors measured at 350 °C. Sensor response of the sample with only the patterned ZnO:Ga film and Au adsorption was also plotted.

device resistivity changes with changes in CO concentration

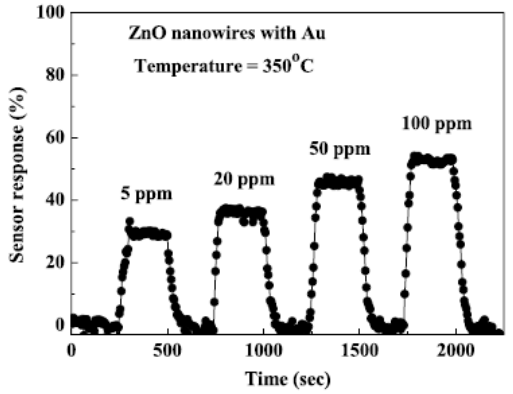

Figure 5. Response of the ZnO nanowire CO gas sensor measured with various CO concentrations.

ZnO nanowire based CO detector, S. Chang et al., Nanotecnology 19 (2008) 175502

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centre for research in ceramics & composite materials

Thermometry at nanoscale

GFHybrids
Group of Functional Organic-Inorganic Hybrids

› People

Luís Carlos, Patrícia Lima
Rute André, Carlos Brites, Vitor Amaral, Nuno Silva

Materials Views
www.MaterialsViews.com

Adv. Mater. 2010, 22, 4499–4504

ADVANCED MATERIALS
www.advmat.de

A Luminescent Molecular Thermometer for Long-Term Absolute Temperature Measurements at the Nanoscale

By *Carlos D. S. Brites, Patricia P. Lima, Nuno J. O. Silva, Angel Millán, Vitor S. Amaral, Fernando Palacio,* and Luís D. Carlos**

› Luminescent non-contact thermometers

Optical probes (organic dyes or trivalent lanthanides, Ln3+) emitting visible light (thermochromic materials)

Advantages

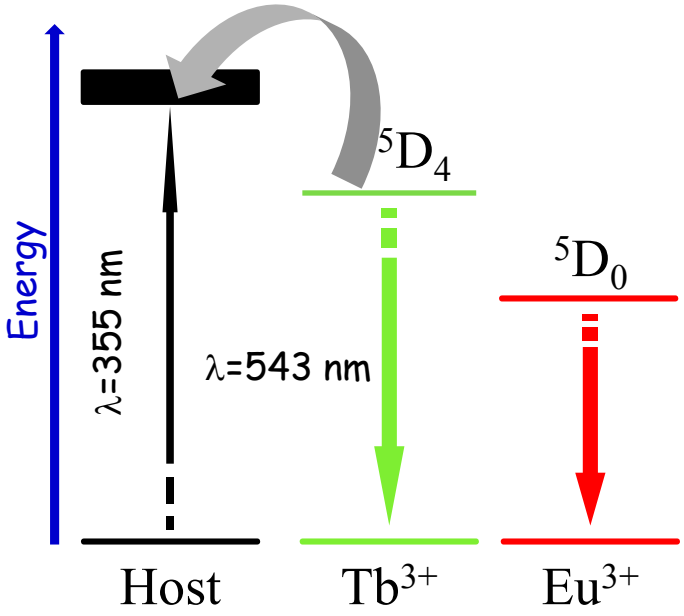
- Noninvasive and accurate technique that works remotely by way of an optical detection system, even in biological fluids, strong electromagnetic fields and fast-moving objects
- Intensity ratio of two emissions provide self-calibration

Disadvantages

- Some examples use complex analysis of lifetimes or emission quantum yields
- Intensity decreases drastically under continuous excitation (photobleaching): not suitable for long-term monitoring (organic dyes)

Eu/Tb luminescent nanothermometer

The breakthrough…



10–350 K
with a temperature uncertainty of 0.5K

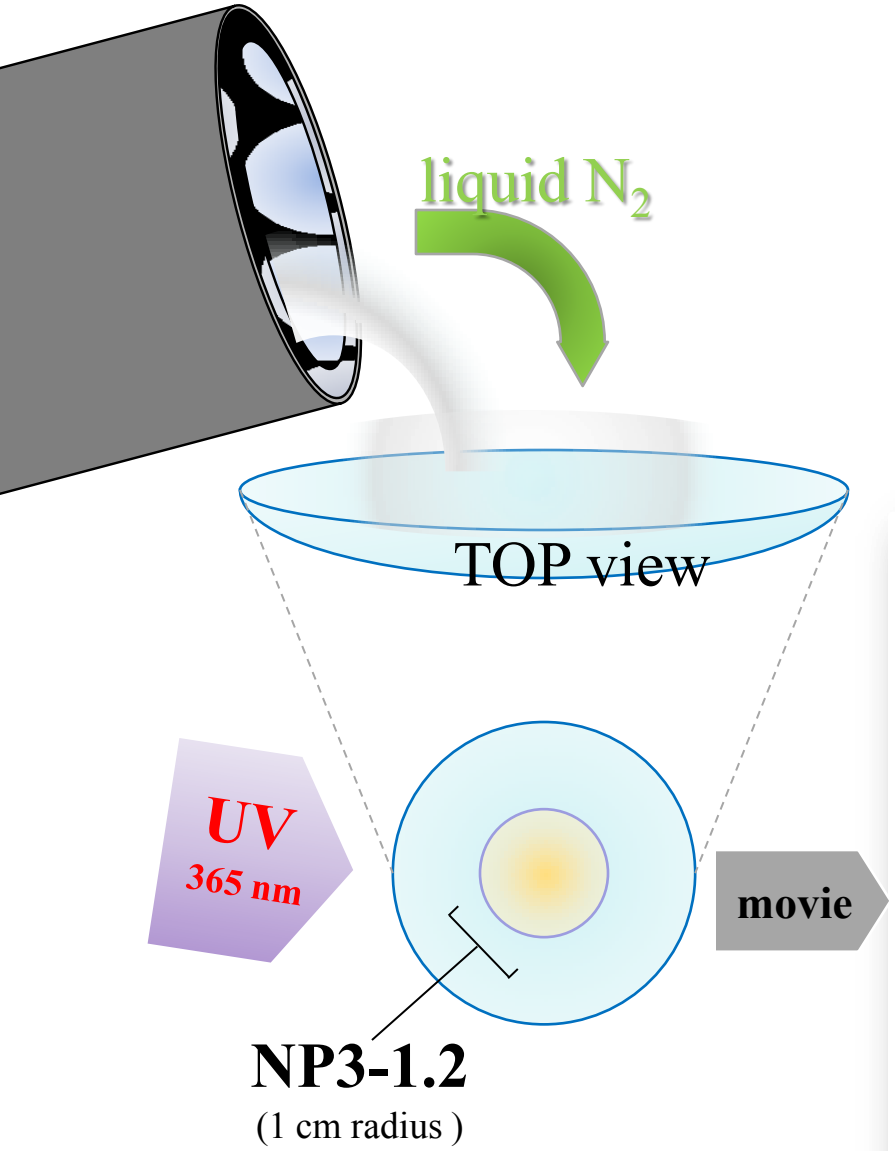
› ***Host rational design***; an excited triplet with energy above that of the Tb^{3+} $^5D_4$ state, thus warranting the occurrence of thermally-driven $^5D_4$→host energy transfer

› ΔE between that triplet state and the Eu^{3+} $^5D_0$ emitting level is too large to permit thermally-driven depopulation

› The Tb/Eu relative intensity guarantees **absolute measurement of temperature**

›**The self-calibration** (relative intensities) overcomes the well-known drawbacks of intensity-based measurements (*e.g.* sensor concentration)

Spain Patent P200930367, 2009; ***Adv. Mater.***, 2010, 22, 4499; **New J. Chem.**, 2011, 35, 1177



NP3-1.2 : color/temperature dependence

T <120K 150K 175K >200K

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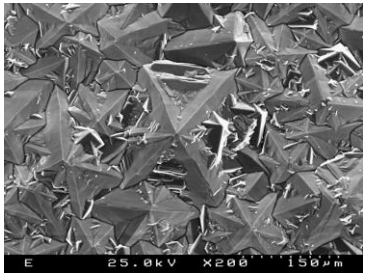
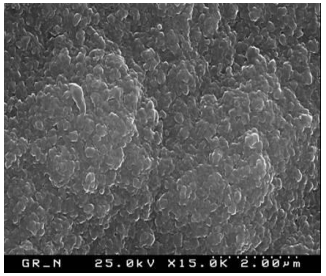
Micro-wave plasma chemical vapor deposition diamond MPCVD

› People

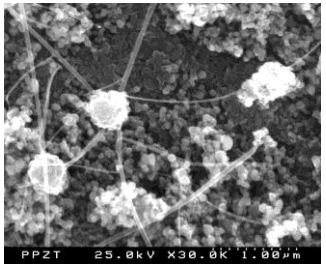
Florinda Costa, A. J. Fernandes,



Microcrystaline diamond



Nanocrystalline diamond



Composite of nanocrystalline diamond and carbon nanotubes

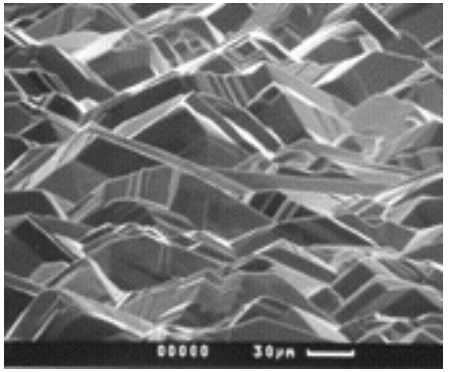
CVD diamond applications

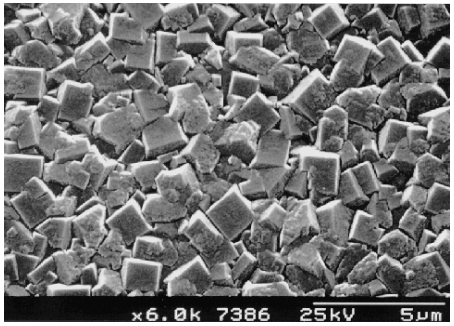
electronic devices: particle detectors for high energy, high power diodes, cold cathode and SAW filters (surface acoustic wave)

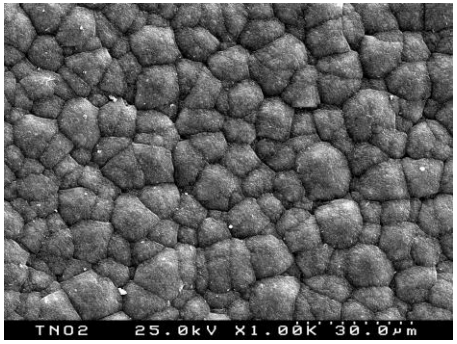
optical applications: optical transparency in a wide range in the electromagnetic spectrum, windows microwave and X-rays, screens and leds

sensors: detectors of radiation in a broad spectrum, optical fiber communications, detectors of nuclear radiation

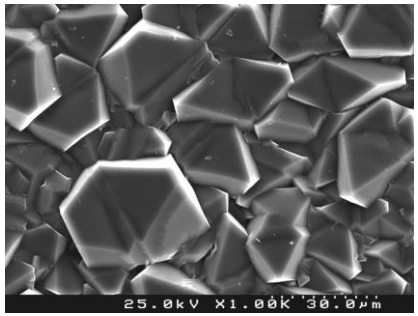
Dosimetry applications: dosimeters in radiotherapy, active exposure monitoring



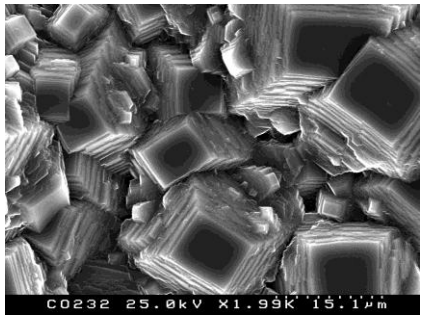




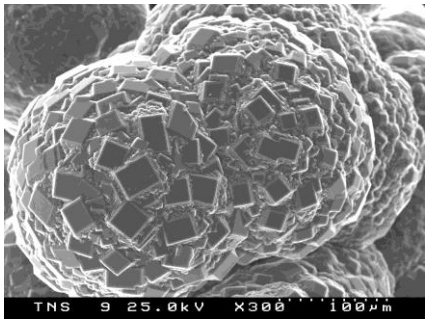
CVD diamond applications



acoustic applications: ultrasonic detectors for medical diagnostics and nondestructive quality control in the industry



hardware components: the high wear resistance opens the possibility of the hard disks and optical disks are coated with diamond.



applications in biomedicine: Due to the high chemical inertness and biocompatibility is used in implants and prostheses, combining the high wear resistance is used as surgical tools, orthopedic and dental drills

Nuclear applications: homeland security, nuclear reactors and fusion experiments

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applications NcD and NT

Microelectronics

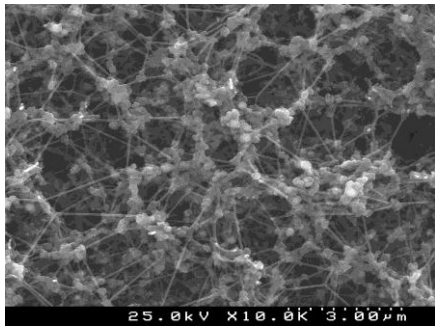
field emission devices, field shielding in MEMS/NEMS (Micro/Nano-Electro-Mechanical Systems)

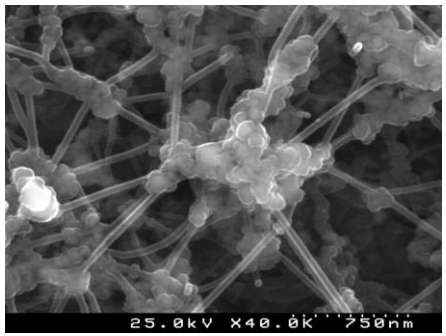
Electrochemistry

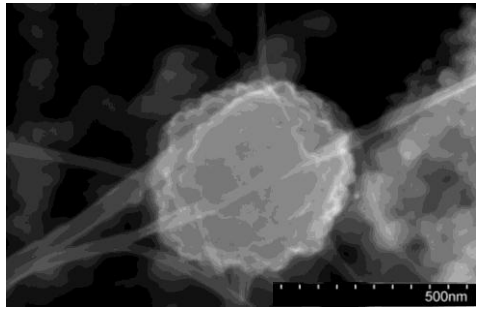
electrodes in supercapacitors, biomolecule sensors

Electronics

thermal management of ICs, thermionic energy generation







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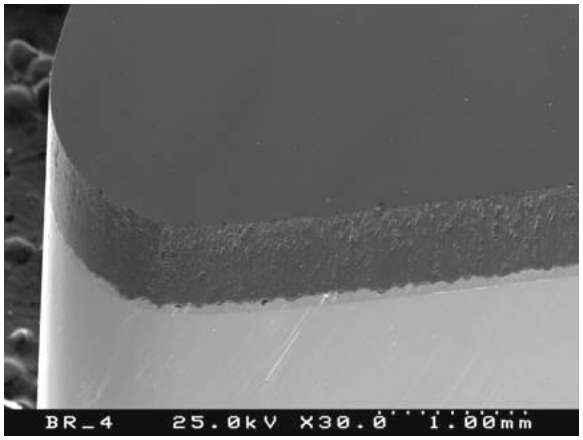
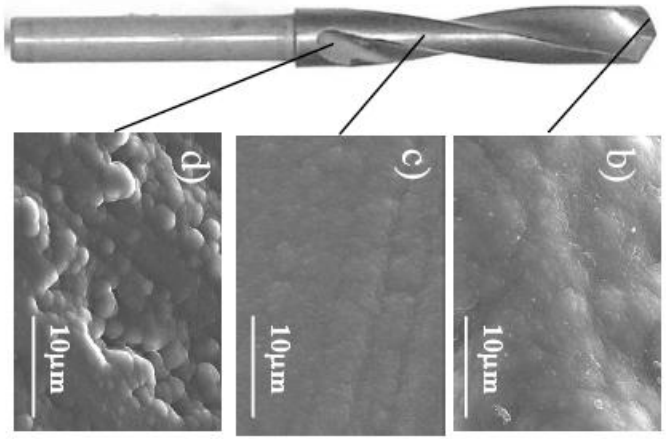
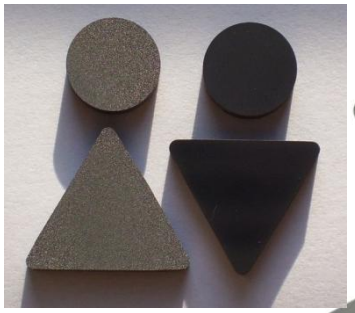
Cutting tools for non-ferrous abrasive materials: indexable inserts for turning and milling, drilling and milling machine



Coated ceramic tools



Details of the nanodiamond coating on Si3N4 drill



Brazed tools for turning

Mechanical seals