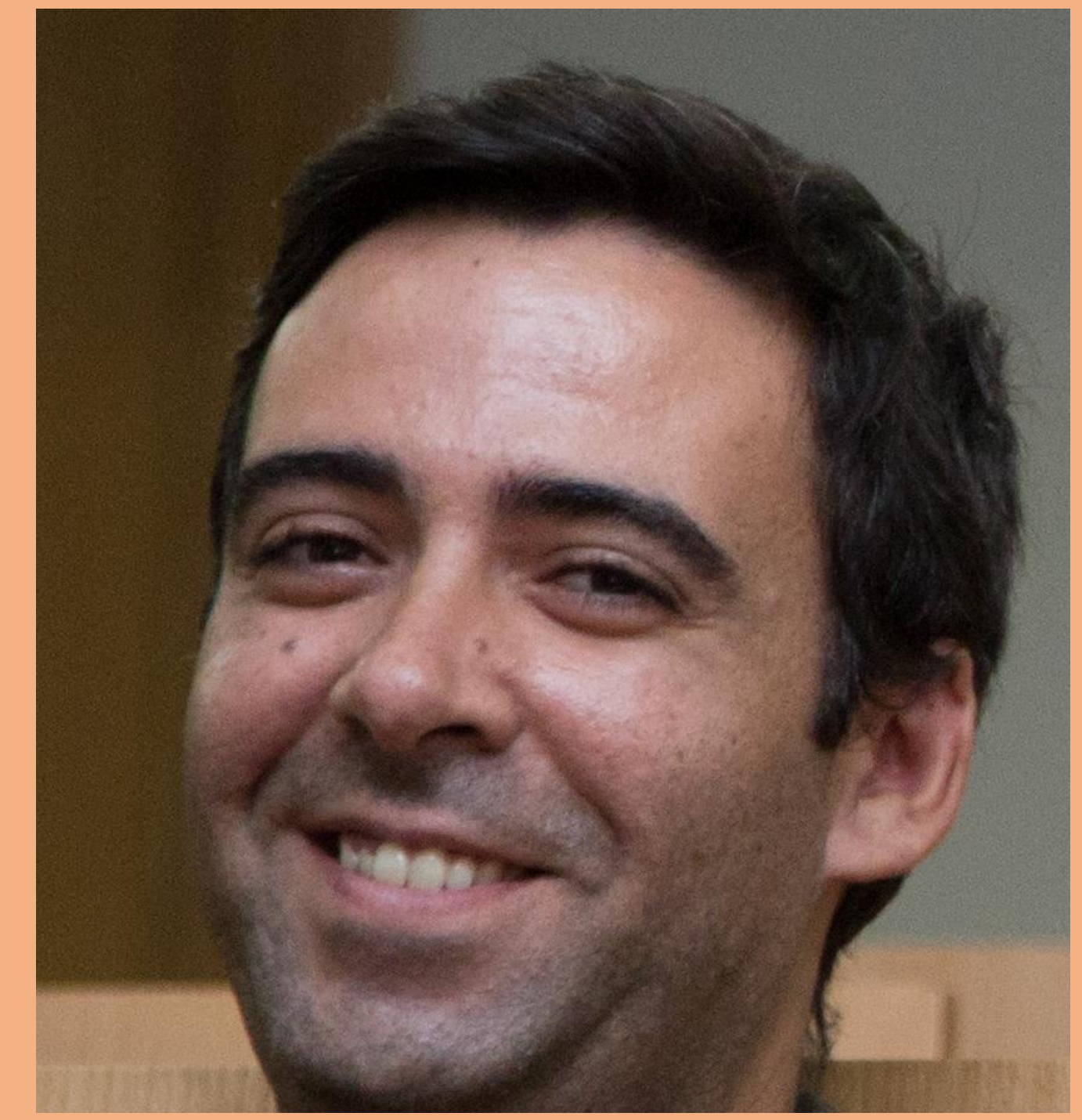
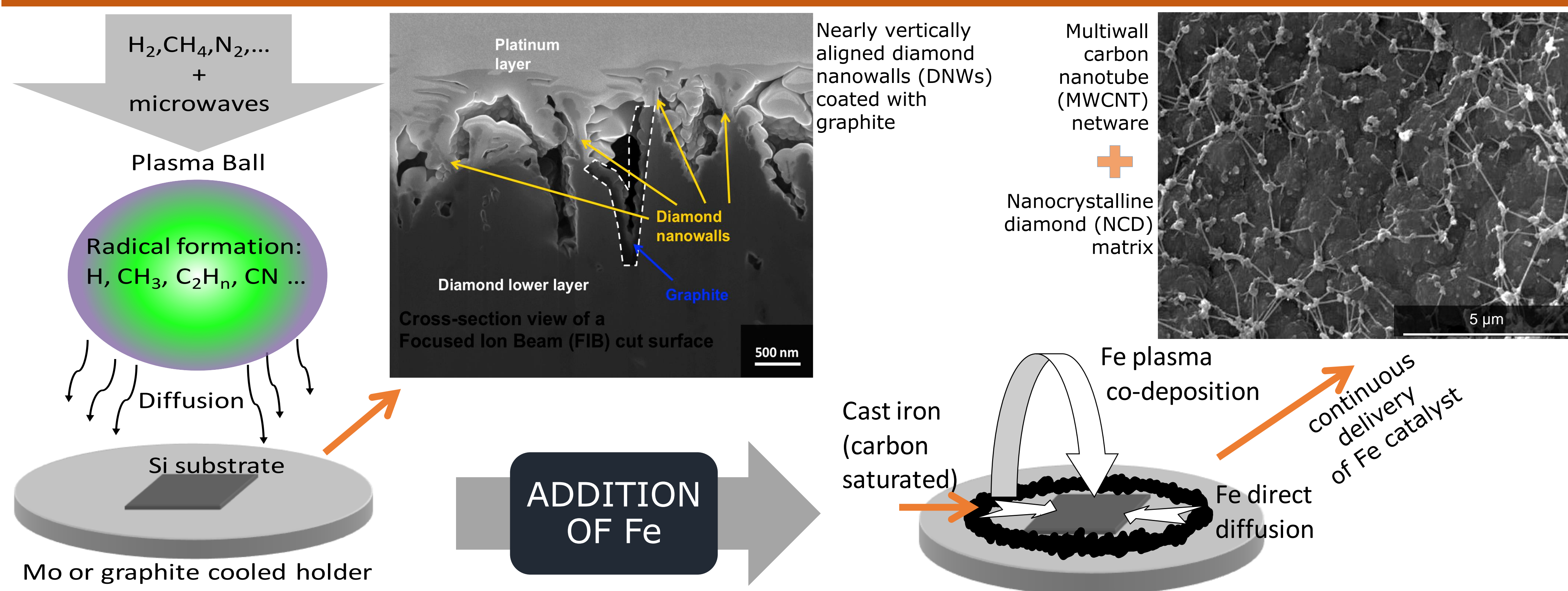


Nanocarbon hybrids for biosensors and microelectronics



N. F. Santos
PhD. Student

Supervisor: Prof. Florinda Costa

Objectives

- To produce strongly bonded, well intercalated sp^2/sp^3 hybridized phases, keeping good structural and functional properties.
- To obtain a synergistic combination of critical properties for applications in:
 - microelectronics** (stable and efficient field emitters, high Q-factor MEMS/NEMS,...)
 - electrochemistry** (high sensitivity/selectivity biosensors, supercapacitors, ...)

Methods and techniques

Microwave Plasma CVD

Parameter	DNWs/graphite	NCD/CNTs
Microwave Power (W)	1800-2200	1800-3000
Pressure (torr)	70-100	90-120
Time (min)	60-100	35-120
Gas mix (in H ₂) (% vol)	CH ₄	6-15 %
	N ₂	0-12%

- Dual Fe catalyst delivery mechanism for simultaneous synthesis of NCD and CNT.
- Characterization by:

NCD/CNTs [- SEM
- μ Raman
- TEM
- HR-STEM
- EF-TEM] DNWs/graphite/CNTs

Results

- Intimate mixtures of NCD and multi-walled CNTs was achieved in two main configurations:
 - A porous 3D-like network of CNTs interconnecting NCD clusters.
 - A CNT network partially embedded in NCD clusters tending to coalesce. Dense hybrid structures were punctually observed.
- Intense G-band, high G/D ratio and a strong symmetric 2D band suggest good MWCNT structural quality. The NCD presents good crystallinity (strong narrow peak at 1332 cm^{-1}), with the presence of the typical transpolyacetylene (TPA) bands.
- High aspect-ratio and nearly vertically-aligned DNWs as thin as 5 nm were produced without Fe catalyst. Dark field and low-loss EFTEM studies clearly distinguish the sp^3 bonding of the nanowall from the sp^2 bonding of the surrounding graphite. Crystal twinning was observed, typical of diamond (111) facets.

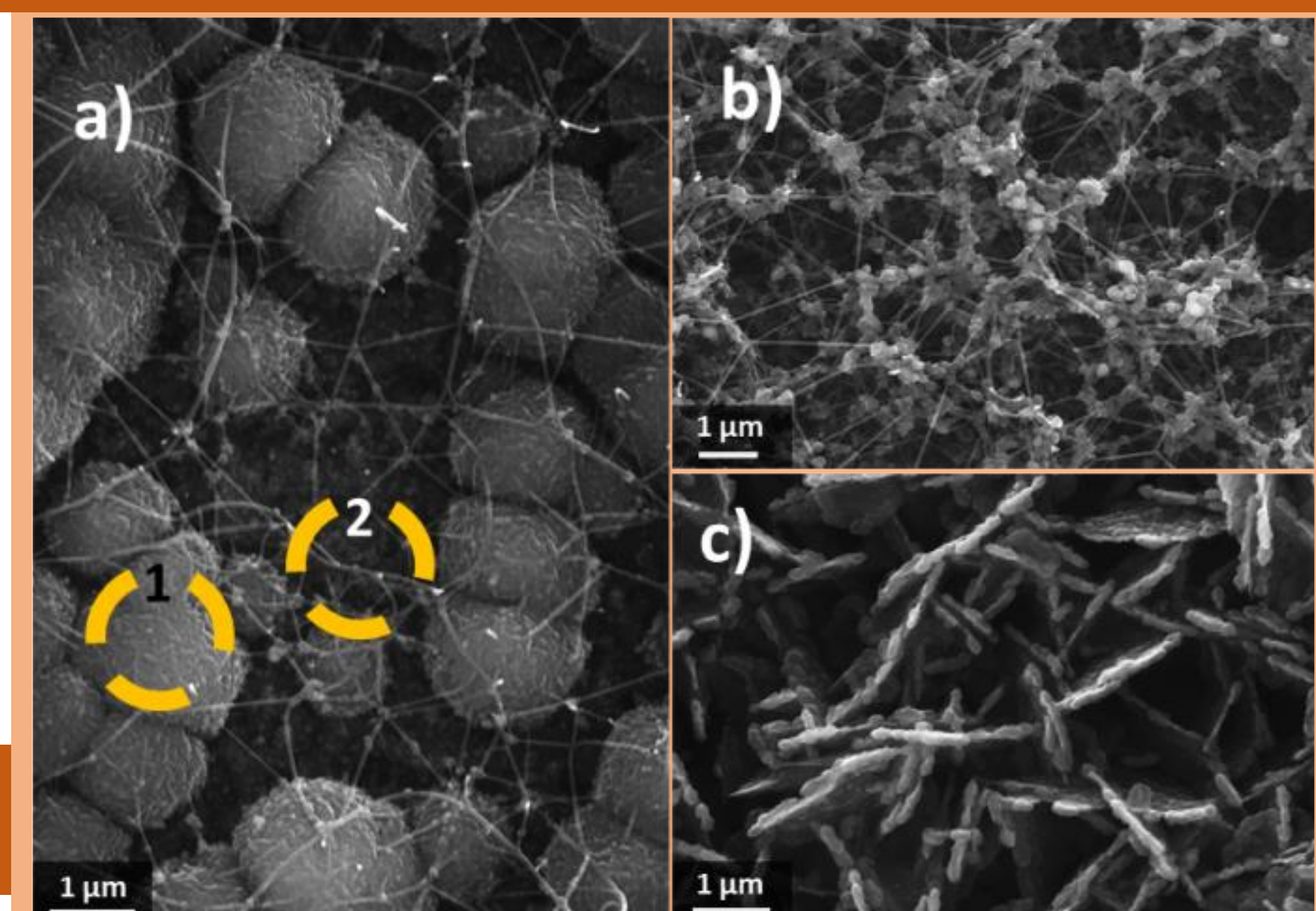


FIGURE 1: SEM micrographs of as-grown samples: a) and b) with the presence of Fe catalyst at high and low MW power, respectively, and c) without the presence of Fe catalyst.

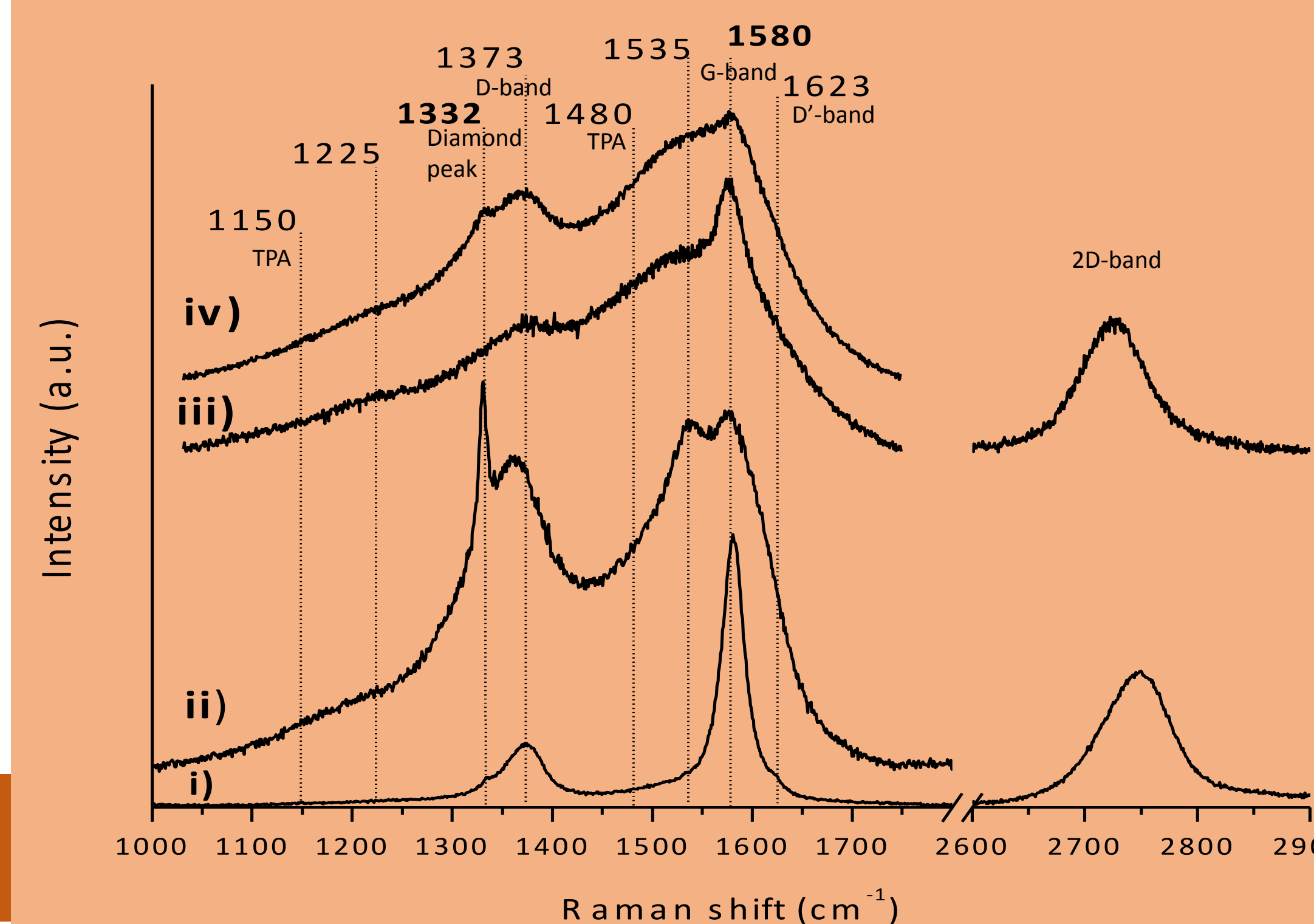


FIGURE 2: μ Raman spectra @ 442 nm of as-grown samples: i), ii) with Fe catalyst at high MW power, from region 2 and 1 (figure 1a), respectively, iii) with Fe at low MW power, and iv) without Fe.

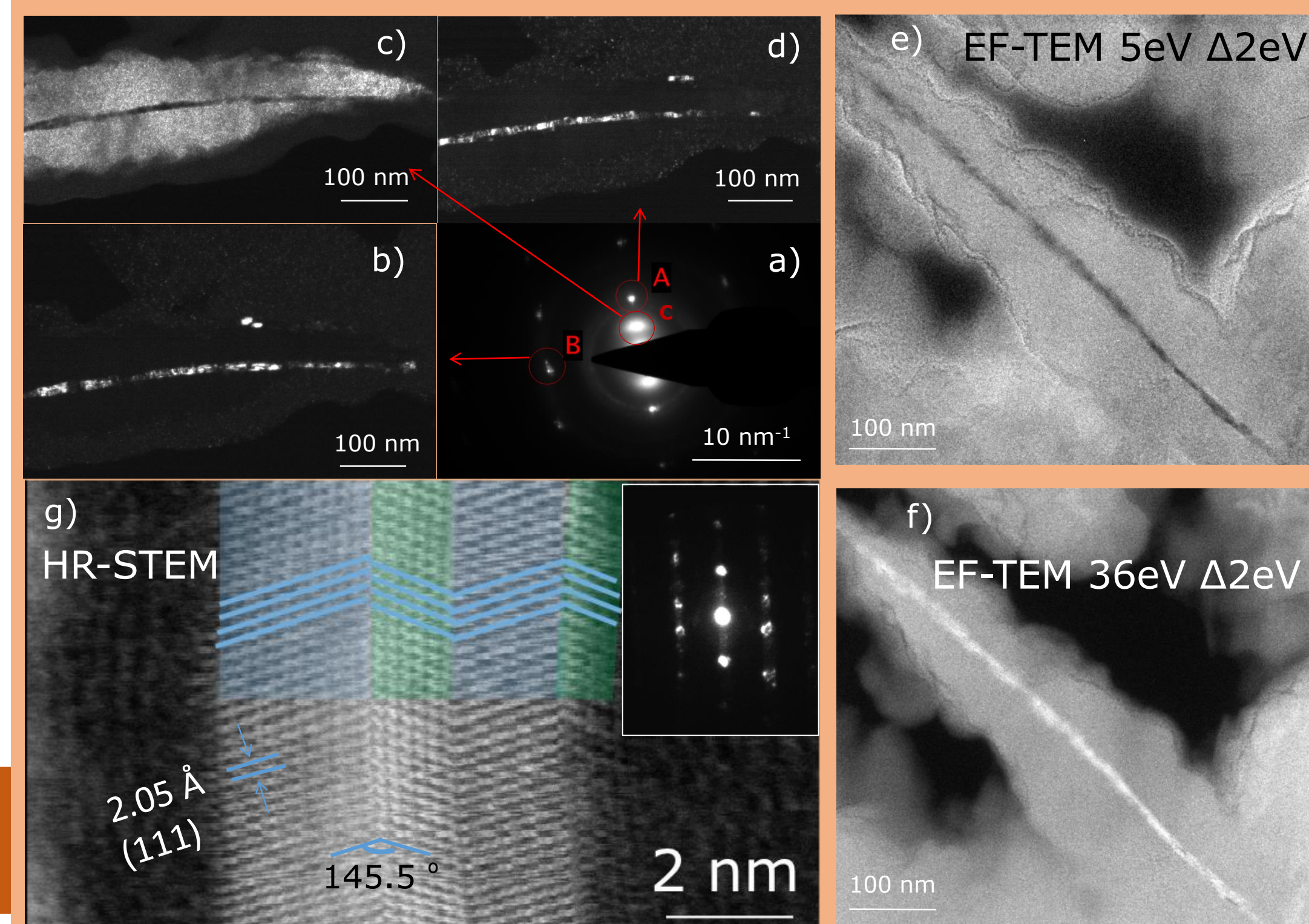


FIGURE 3: TEM cross section analysis of DNWs/graphite hybrid. a) diffraction pattern and b), c), d) dark field images formed using diffraction spots B, C and A, respectively. e) and f) EF-TEM images formed using inelastically scattered electrons from sp^2 and sp^3 phases, respectively. g) HR-STEM image of a DNW with the corresponding diffraction pattern as inset.

Publications

- SIMULTANEOUS CVD GROWTH OF NANOSTRUCTURED CARBON HYBRIDS, N.F. Santos, T. Holz, A.J.S. Fernandes, R.F. Silva and F.M. Costa. Accepted for publication in NATO ASI BOOK SERIES (2014).
- SIMULTANEOUS SYNTHESIS OF CARBON NANOTUBES AND NANOCRYSTALLINE DIAMOND BY MPCVD, N.F. Santos, J. Rodrigues, T. Holz, A.J.S. Fernandes, R.F. Silva and F.M. Costa, 13th European Vacuum Conference, 8-12 September 2014, Aveiro, Portugal (oral presentation).

Project in collaboration with Rui Silva (CICECO) and Carlos Achete (INMETRO, Brazil)