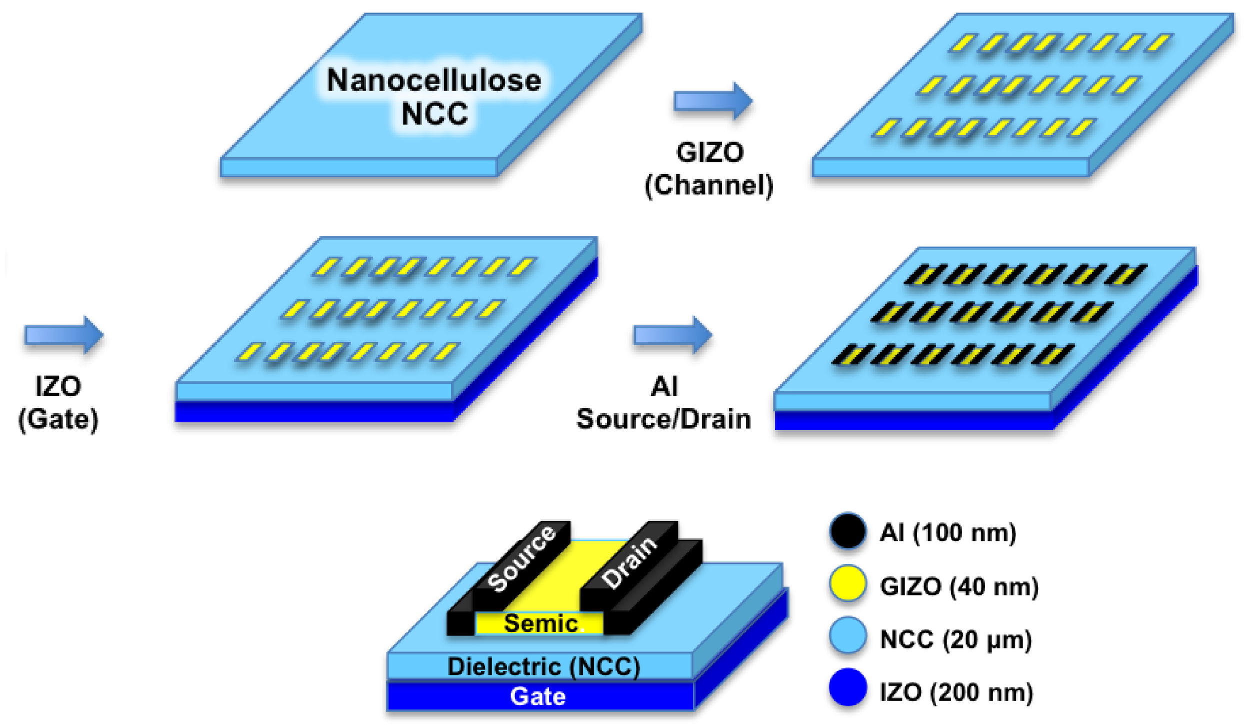
CENIMAT – Materials Research Centre, New University of Lisbon

Cellulose based substrates for application in electronic devices

Paper as electronic material

Flexible, lightweight, low cost and ecofriendly electronics



Diana Gaspar
PhD. Student

Supervisor: Prof. Luís Pereira
Co-supervisor: Prof. Rogério Simões

Objectives

This work aims to tailor the paper's bulk and surface properties in order to explore it as substrate and dielectric in electronic devices. The focus will be on bulk and surface functionalization/modification to assure proper operation of devices to be produced.

The specific objectives are:

1 – Tailoring of paper surface roughness, thermal and mechanical resistance, water permeability, surface polarizability, improving the scientific understanding of concepts associated with discrete dielectrics and fibers' charge accumulation;

2 – Deposition at temperatures compatible with paper of n- and p-type oxide layers with mobility above 40 $cm^2V^{-1}s^{-1}$ and 1 $cm^2.V^{-1}s^{-1}$, respectively;

3 – Production of transistors, memories and inverters on paper.

Methods and techniques

Paper tailoring – The work being developed involves paper's tailoring, including fibers' type/size and modification of bulk and surface properties in order to use it as substrate and dielectric in electronic devices. Plasma treatment (changing the hydrophilicity/hydrofobicity of the fibers' surface), addition of extra ionic charge and functionalization/passivation of the fibers' surface with inorganic thin films/nanoparticles are the approaches being used. (Fig. 1 and 4)

Devices production – Transistors with different layout/dimensions are being produced using cellulose fibers as dielectric and PVD deposited conductive and semiconductor oxides. (Fig. 2. 3 and 5)

Results

Paper engineering

- The FETs produced on micro/nano fibrillated cellulose (M-NFC) paper exhibit a saturation mobility up to 16 $cm^2.V^{-1}.s^1$ and an I_{On}/I_{Off} ratio around 10^5, being simultaneously less sensitive to abrupt changes in the relative humidity than conventional pulp papers. The small fibrils (width in the nanoscale range) and their surface properties (compact and smooth) strongly bind water to M-NFC paper.
- Gate leakage current in paper FETs can be reduced using a dense micro/nano fibrillated cellulose (M-NFC). (Fig. 4 and 5)

Devices engineering

- Planar dual-gate oxide-based transistors are being produced on paper, using it simultaneously as substrate and dielectric. The devices present good electrical properties with I_{On}/I_{Off} of 4 orders of magnitude and saturation mobility of ≈ 3 $cm^2.V^{-1}.s^1$.
- When using this kind of configuration we are able to tune the on-voltage of the transistors by almost 20 V, depending on the applied voltage at the secondary gate (from +15 V to -15 V). This makes this devices particularly attractive for logic and biosensors applications. (Fig. 2 and 3)

Publications

•D Gaspar, S N Fernandes, A G de Oliveira, J G Fernandes, P Grey, R V Pontes, L Pereira, R Martins, M H Godinho and E Fortunato, Nanocrystalline cellulose applied simultaneously as the gate dielectric and the substrate in flexible field effect transistors, Nanotechnology 25 (2014) (doi:10.1088/0957-4484/25/9/094008).

•L Pereira, D Gaspar, D Guerin, A Delattre, E Fortunato and R Martins, The influence of fibril composition and dimension on the performance of paper gated oxide transistors, Nanotechnology 25 (2014) (doi:10.1088/0957-4484/25/9/094007).

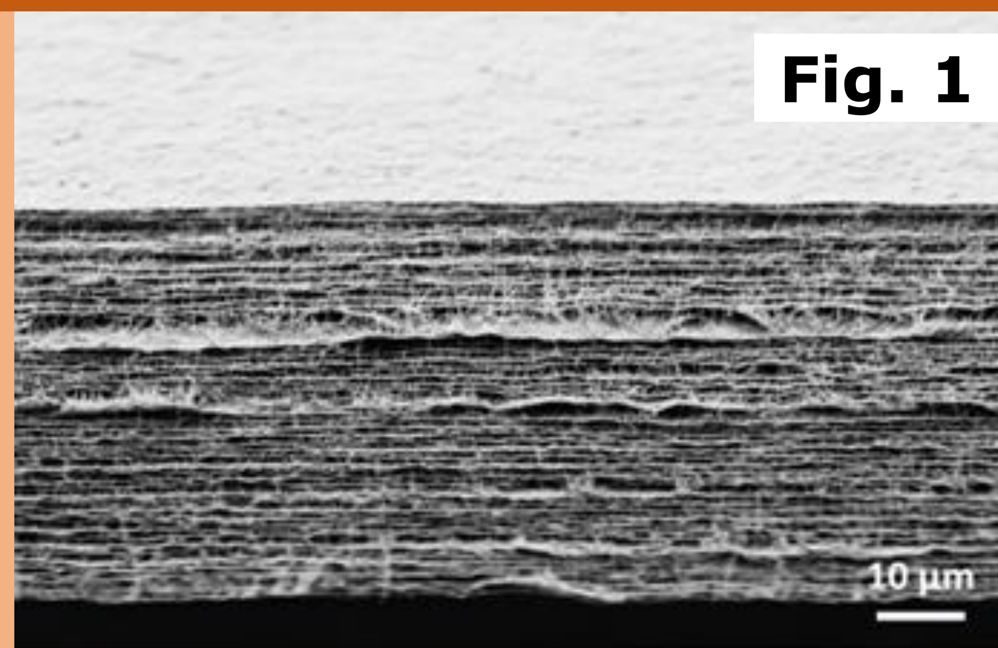


Fig. 1

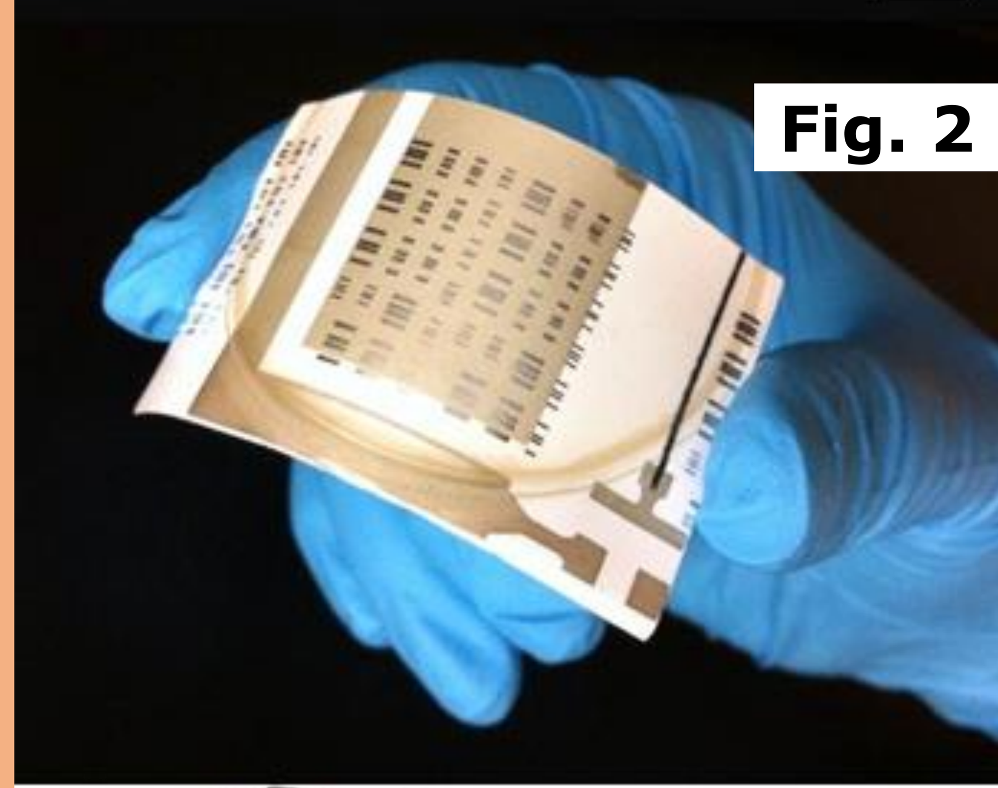


Fig. 2

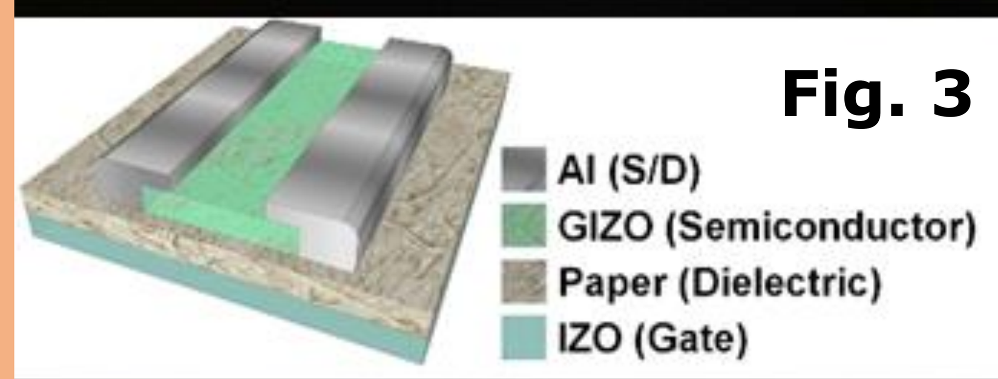


Fig. 3


Fig. 4

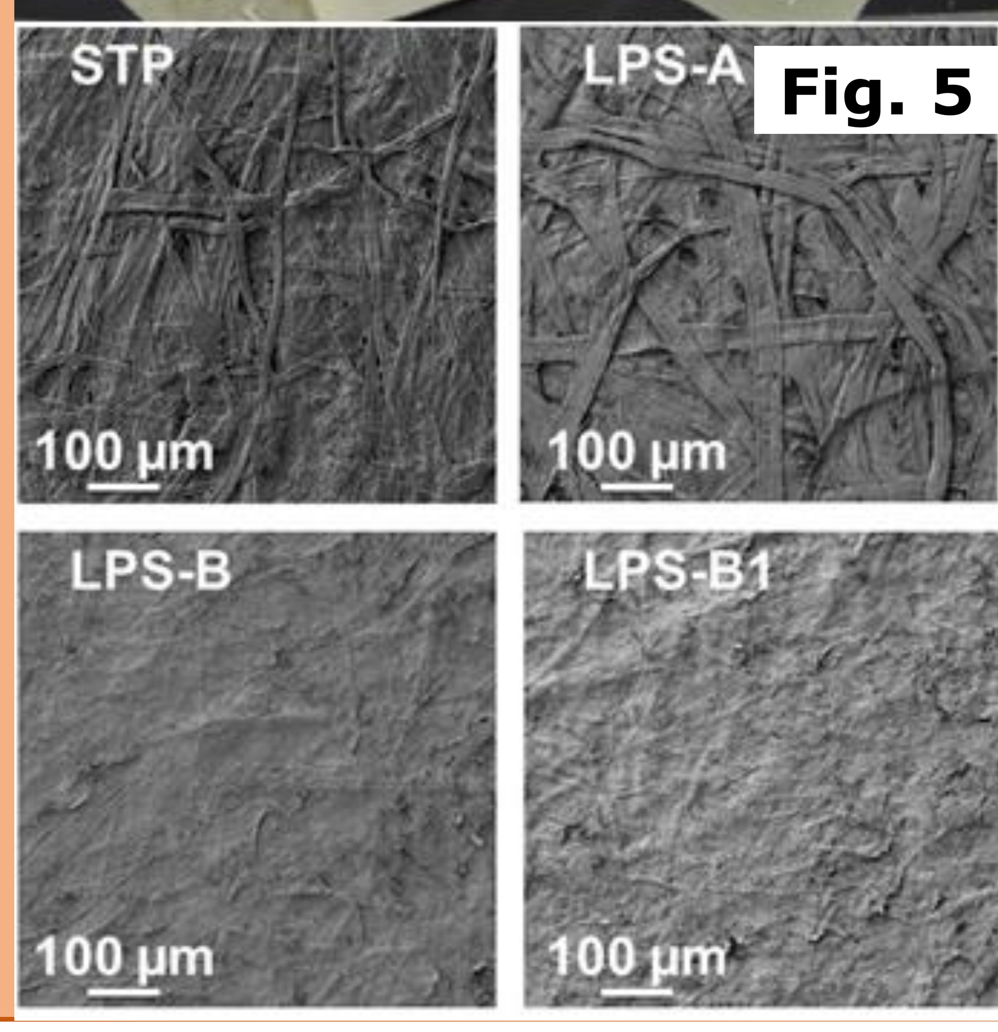


Fig. 5

i3N INSTITUTE FOR NANOSTRUCTURES, NANOMODELLING AND NANOFABRICATION

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR
PD+F PROGRAMAS DE DOUTORAMENTO FCT
UNINOVA CEMOP
ctp centre technique du papier