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Innovative Low-Cost Plastic Optical Fiber Sensors for Gas Monitoring

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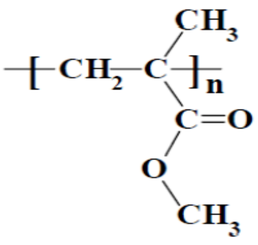
Plastic Optical Fibers (POF)

○ **POF consists of:**

- **PMMA Core**: (Polymethyl-methacrylate) 980 µm, refractive index = 1.49
- **Fluoropolymer cladding**: up to 1000 µm, refractive index = 1.40
- **Coating jacket**: to protect the cladding-core structure.

○ **POF Features**

- **Large core diameter (0.25 – 1 mm) & High Numerical Aperture (NA = 0.5)**
  - High light collecting capability
  - Easy to align and to connectorize
- **PMMA core (polymer)**
  - Easy to handle
  - Easy to cut
  - Low cost

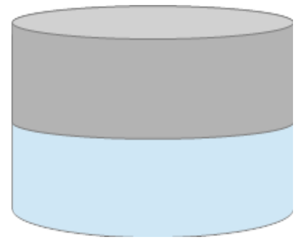


- **POF Multi Mode**
  - Low cost optical sources, non-coherent source (LED)

Fiber Preparation and Sensor Design - I

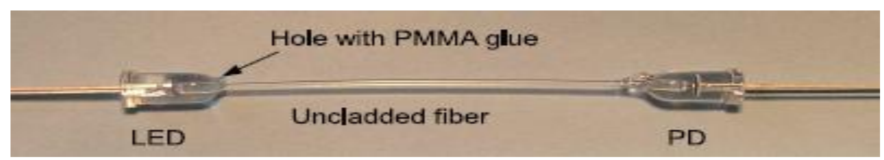
commercial step-index POF

Removing the cladding by using Ethylacetate



Ethylacetate (40 sec)

Fiber ends were polished with grinding paper

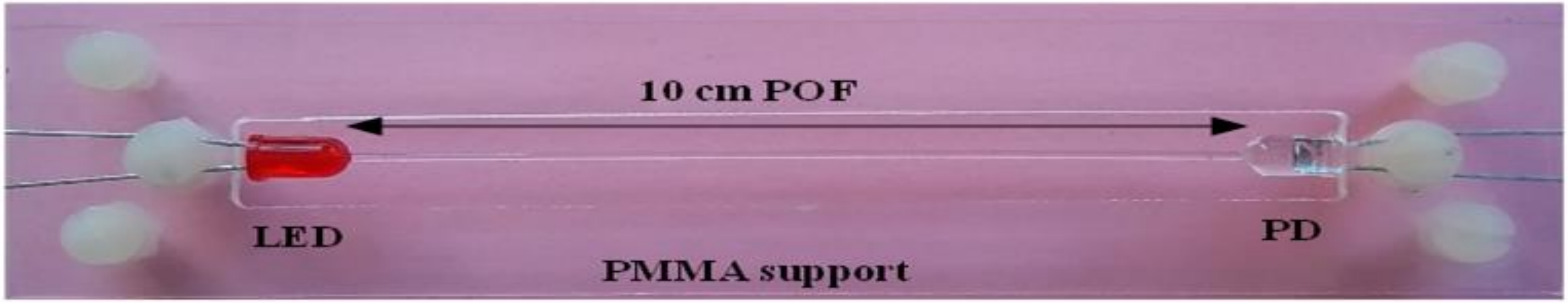


Sensor Assembly is composed of: plastic fiber with length about of 10 cm, a light emitting diode (LED), and a photodiode (PD).

The fiber is cured in an oven at 60–70°C for 60 hours to ensure complete polymerization of the liquid PMMA

Fiber Preparation and Sensor Design - II

Sensor assembly bonded to a PMMA support



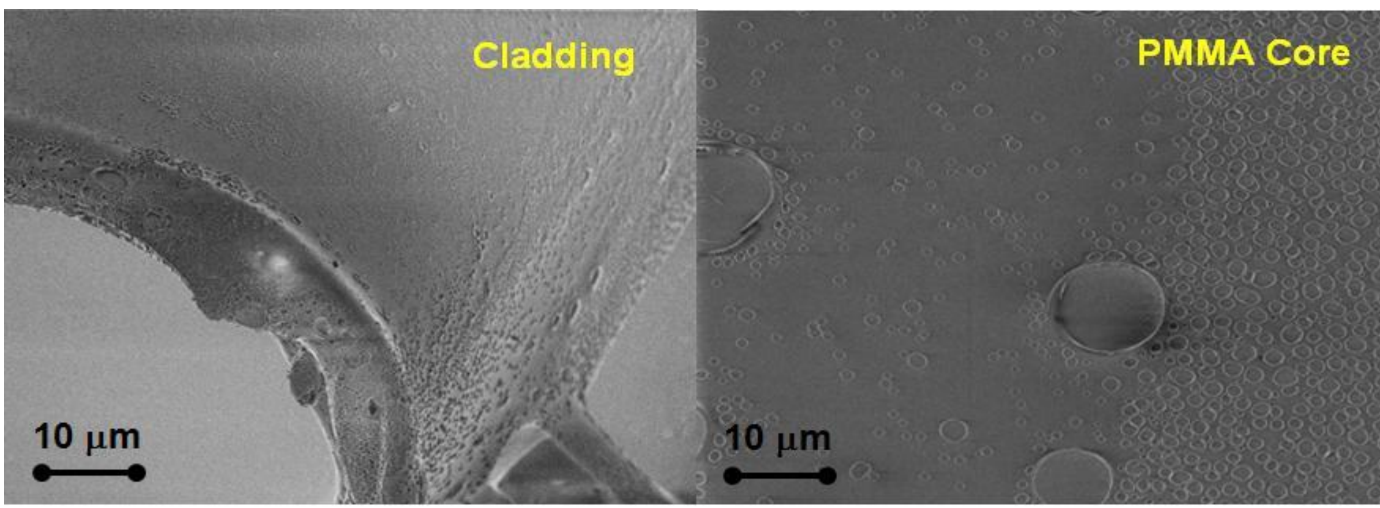
Intrinsic POF Sensor

- ☺ Low cost: less than 1 €
- ☺ Small sensor dimension
- ☺ Easy to obtain high detection capabilities via cumulative output responses
- ☺ Capability to use the same fiber both for sensing and transmission
- ☺ Under harsh environments:
  - Strong electromagnetic field (EMF)
  - High temperature
  - Chemical environments
  - Ionizing radiation

Fiber Preparation and Sensor Design - III

1. **Removing** of the fiber cladding - (**ethylacetate**) not more than 40 second; avoiding damaging the PMMA core.

increase the sensitivity



FESEM image shows that on a fiber etched for 40 s the cladding has been completely removed without affecting the PMMA core structure.

Fiber Preparation and Sensor Design - V

2. **Deposition** onto the fiber core of a **sensitive layer** capable of reacting with the gas "**HF vapors**" by means low-pressure PECVD

Plasma Enhanced Chemical Vapor Deposition (PECVD) Reactor

Fiber Preparation and Sensor Design - IV

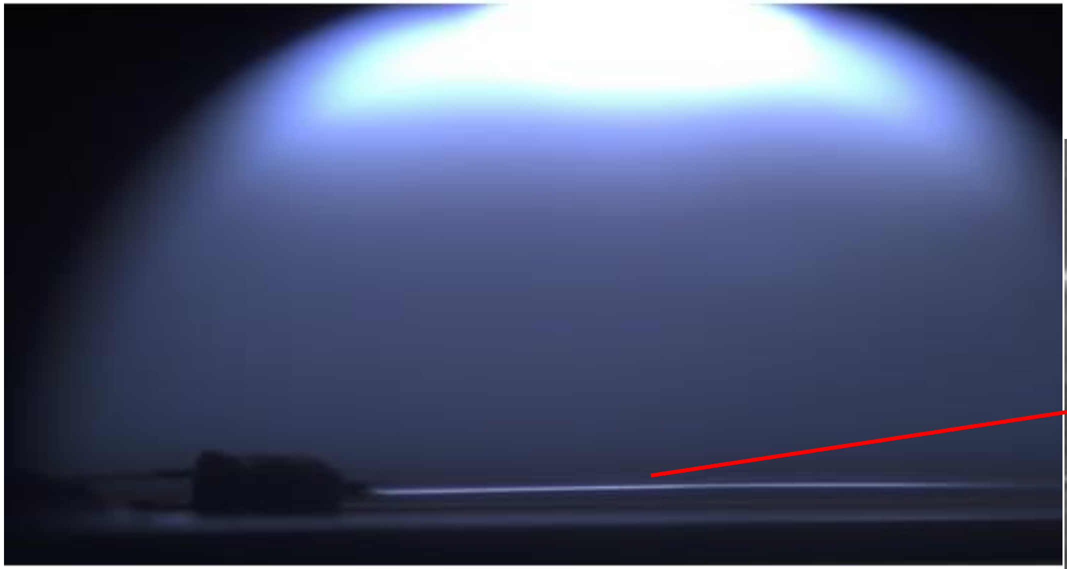
SiO_x layer (a glass-*like* layer)

SiO_x by PECVD of organosilicon compounds

TEOS + Ar + O_2

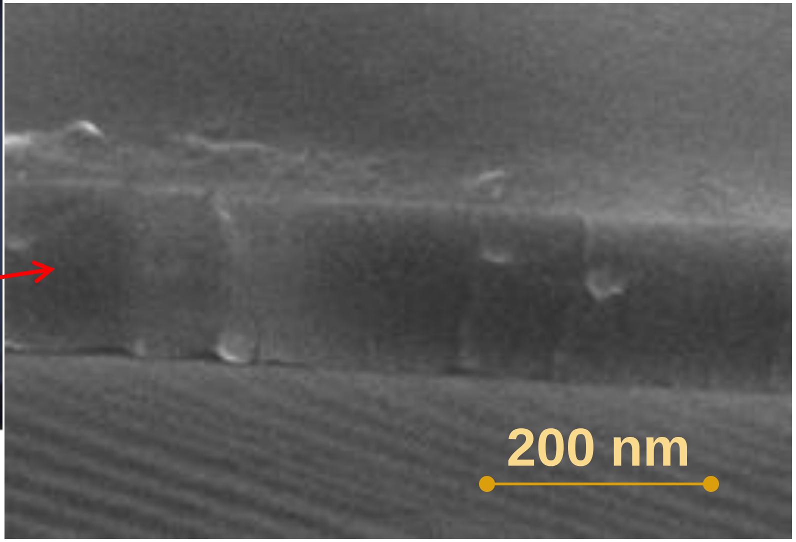
@ 5 Pa, 50 - 100 W supplied power

13.56 MHz RF power generator



Fiber inside PECVD reatocr

TEOS: Tetra-Ethyl-Ortho-Silicate
monomer

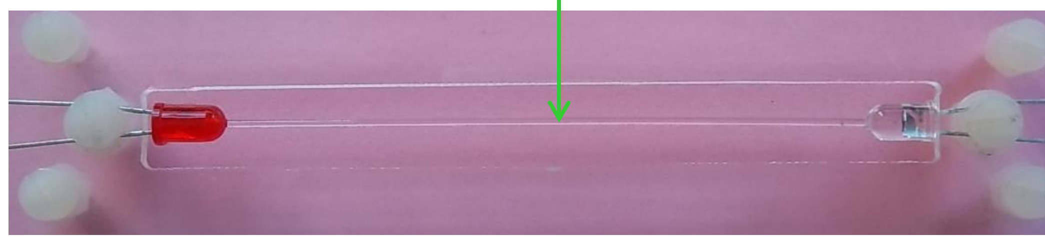


FESEM image SiOx

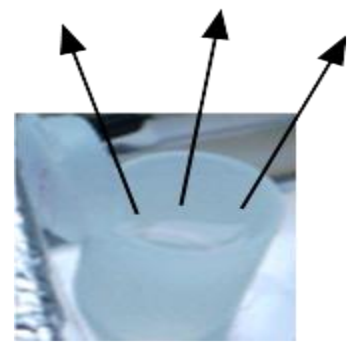
Sensor Working Principle

The chemical reaction between the sensitive layer (glass-*like*) and the pollutant (HF vapors) must alter the fiber light transmittance capability.

SiO_x coated fiber

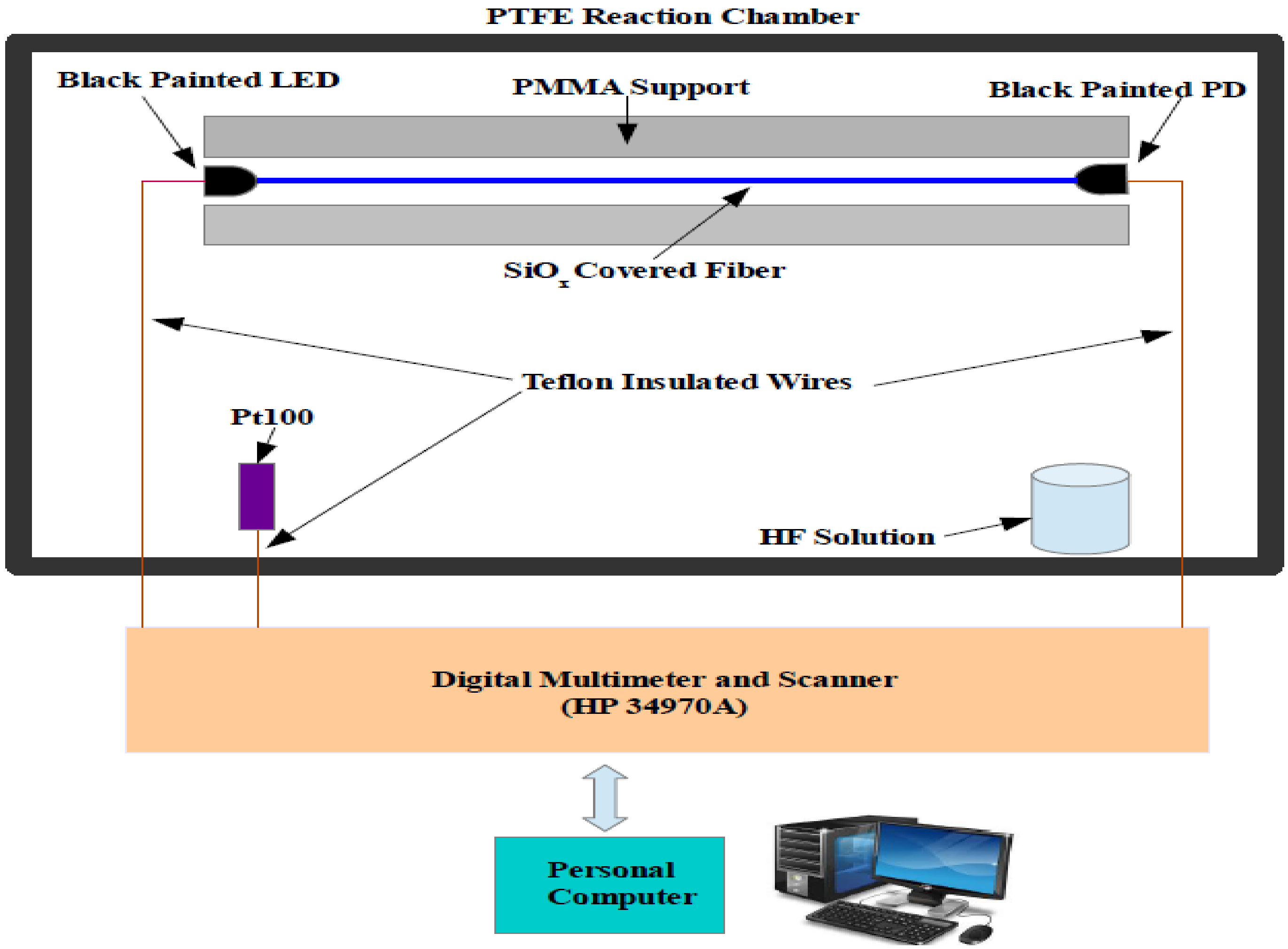


HF vapor



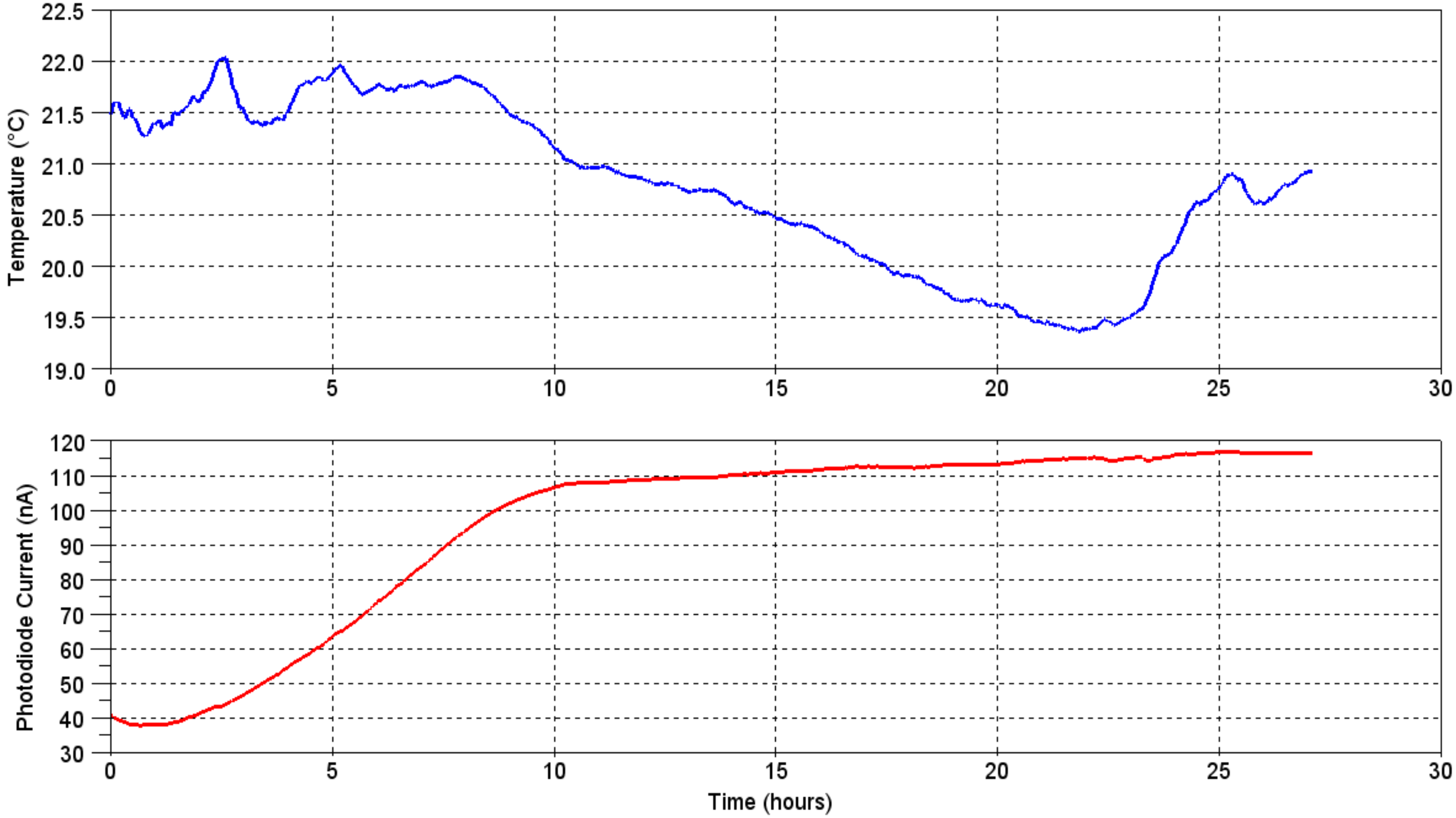
HF solution

Sensor Measurement Set-up



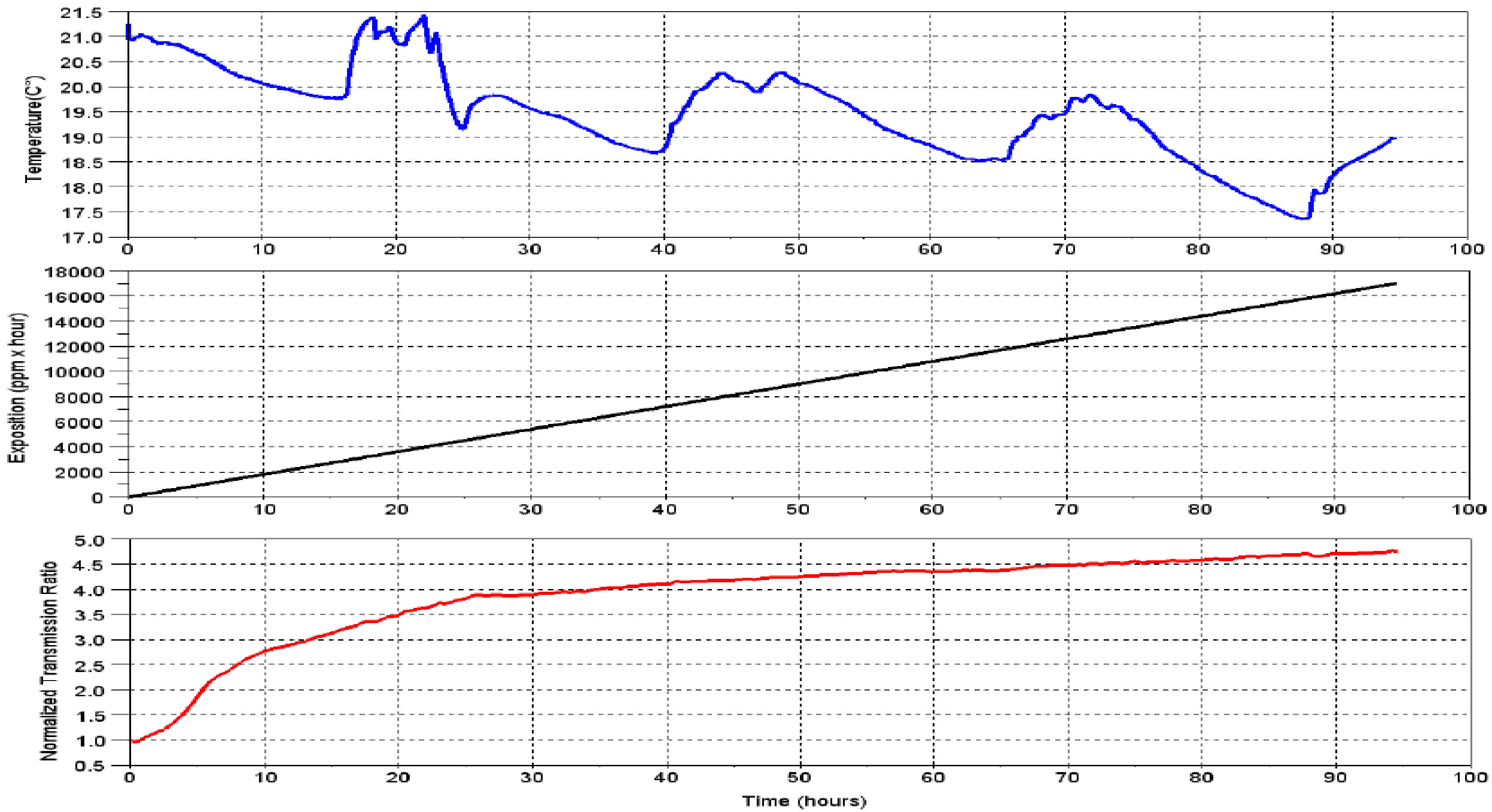
Experimental Results - 1

1. Exposition to HF



Photodiode current change due to the HF reaction on the SiOx layer deposited on the fiber. It is clear how the degradation of SiOx layer due to HF results in an increase of the photodiode current. The current increases until the external coating reaches a stable degradation state after about 25 h.

Experimental Results - 2



Coated fiber response to HF exposition. Top trace: The temperature during the test measured with the Pt100 sensor. Middle trace: exposition computed as the integral of the vapor concentration. Bottom trace: fiber transmittance ratio normalized to its initial value.

Experimental Results - 3

3. Fiber non-texturing effect

	Uncladding	Nano-textured PMMA	Coating glass-*like*	Exposing to HF
Nano-textured fiber	1	0.96	0.069	0.69
Non treated fiber	1	0	0.059	0.11

The nano-textured PMMA core fiber, which has a high equivalent surface area with respect to the non treated fiber, significantly increases the sensors sensitivity compared to untreated PMMA surface core.

Conclusions

- Plasma modified POF can be successfully used to detect of fluoride concentration in gas mixtures.
- POF sensor able to detect low concentrations of hydrogen fluoride (ppm).
- The sensors are cumulative so they directly measures the total exposure to HF vapors.
- Sensor prototypes showed a good sensitivity.
- The nano-textured PMMA core fiber, significantly increases the sensors sensitivity compared to untreated PMMA surface core.

Thank You very much