

SURFACE MODIFICATION OF PVC ENDOTRACHEAL TUBES: OXYGEN PLASMA TREATMENT AND AGING EFFECTS

D. Balazs¹, D. Favez¹, Y. Chevolot¹, N. Xanthopoulos¹,

C. Granges², B.-O. Aronsson², F. Sidouni², P. Descouts² and H. J. Mathieu¹

¹ *Materials Science & Engineering Dept., EPF Lausanne,*

² *Group of Applied Physics-Biomedical, University of Geneva*

INTRODUCTION: Nosocomial pneumonia is a major medical problem which causes high mortality in intubated and mechanically ventilated patients. A study involving 4500 infected intensive care patients from all over Europe, demonstrated that *Pseudomonas aeruginosa* is one of the most important Gram-negative pathogens, responsible for 30% of nosocomial infections [1]. Colonization of the intubation device and the trachea by *P. aeruginosa* occurs in over 90% of ventilator-associated pneumonia (VAP), with a mortality exceeding 60% despite aggressive antibiotic therapy. Bacteria and material will interact through physico/chemical interactions at the surface of the material. It is through 1) comprehension of these interactions 2) and modification of the material's surface that one may control biofilm formation. Therefore, a new approach is sought to reduce the incidence of *P. aeruginosa* VAP. In the following paper, surface modification with oxygen plasma is investigated as a possible solution. We present ATR-FTIR, XPS and contact angle data pertaining to the surface chemistry of our native and oxygen-modified tubes.

METHODS: Control samples were 1cm² sections cut from Mallinckrodt Medical endotracheal tubes. These samples were then modified with an oxygen glow discharge plasma² excited by a direct current (DC) with a voltage of 2 kV, and a gas pressure of 20 Pa. Samples were treated for varying exposition times, including 60 s and 120 s.

For contact angles a water drop of 3.0 μ l was deposited on the surface and imaged with a CCD on an optical microscope. The left and right side angles between the water droplet and the surface were then measured. The standard error made with this method is estimated to be $\pm 5^\circ$.

XPS analysis was performed using a Kratos AXIS hemispherical analyser with a monochromatic Al K $_{\alpha}$ x-ray source.

ATR-FTIR measurements were done on a Perkin-Elmer infra red spectrometer equipped with a Goldengate total reflection diamond crystal. 64 spectra in the range 4500-500cm⁻¹ are recorded with a resolution of 1cm⁻¹ and averaged.

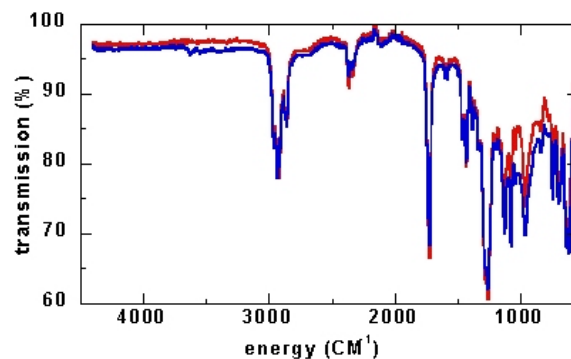


Fig. 1: ATR-FTIR spectra of native PVC (red) and O₂ plasma modified PVC (blue), demonstrating that plasma modification does not alter the bulk material.

RESULTS: The ATR-FTIR analysis demonstrates that oxygen plasma treatment does not alter chemical composition of the bulk material when compared to the native control (Figure 1). This was confirmed for various exposure times (60 s, 120 s, and 240 s; data not shown).

Figure 2 shows the deconvolution of the C 1s peak for native PVC and a sample which had been exposed to an O₂ plasma for 120 s. The figure

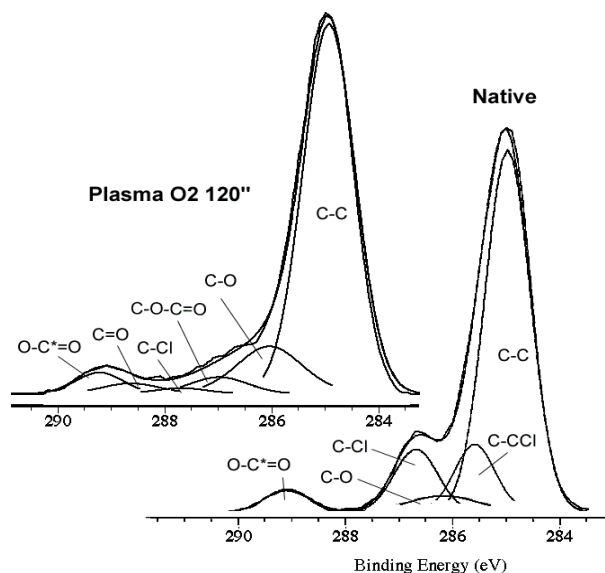


Fig. 2: Deconvolution of C 1s peak for both native (right) and O₂ plasma modified PVC (left), showing the dechlorination of the plasma-modified sample, as well as an increase in oxygenated functional groups.

demonstrates an increase in oxygenated functional groups, with the creation of carbonyl groups (3% for O₂ plasma, 0 % for native) as well as 4-fold increase in the quantity of the C-O contribution (*Table 1*). The C 1s deconvolution also shows a dechlorination, as the C-Cl contribution of the plasma modified sample decreases to 0.8 % from the 9.0 % value of the native sample (*Table 1*)

Another interesting observation with XPS lies in the detection of O-Fe contribution in the O1s peak for the plasma modified sample (figure not shown). This contribution appears because the anode used in the plasma apparatus is composed of stainless steel.

Contact angle measurements demonstrate a sharp increase in hydrophilicity of O₂ plasma-modified PVC, compared to native samples. After 120 s of exposure to the oxygen glow discharge the contact angle decreases to $20 \pm 5^\circ$, whereas the native sample yields a value of $77 \pm 5^\circ$.

Table 1. Relative quantities of different functional groups present in native PVC and O₂ plasma-modified PVC, after XPS analysis

	C-C	C-O	C=O	O=C-O	C-Cl	O-Fe	Zn-Cl
Native	82.3	3.8	0.0	3.8	8.9	0.0	1.3
O ₂ Plasma	75.0	12.6	3.1	4.9	0.8	2.6	1.0

DISCUSSION & CONCLUSIONS: The three aforementioned techniques, ATR-FTIR, XPS, and contact angle permit the characterization of native and of O₂ plasma-modified PVC, at varying depths from the surface. ATR-FTIR, the least surface sensitive of the three techniques, demonstrates that there is essentially no modification of the bulk material following oxygen plasma treatment, as expected. XPS permits the analysis of the chemical composition of the first 10 nm of the surface. This method demonstrates that O₂ plasma-modification does indeed yield an incorporation of oxygenated functional groups, which should in turn increase the surface wettability³. XPS also demonstrates a dechlorination following plasma treatment. Finally, contact angle measurements, the most surface sensitive, demonstrate that the exposure to the oxygen glow discharge greatly increases the surface wettability, yielding a highly hydrophilic surface ($<20^\circ \pm 5^\circ$).

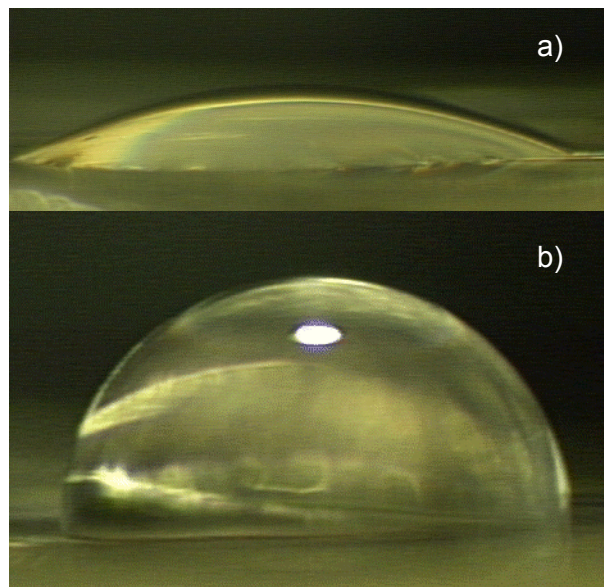


Figure 3. Water interaction on a) O₂-plasma treated PVC and b) native PVC. Angles are about 20° and 77°, respectively.

REFERENCES:

- 1 J. L. Vincent, D. J. Bihari, P. M. Suter et al (1995) *JAMA* **274**: 639-644
- 2 B.-O. Aronsson, J. Lausmaa, and B. Kasemo, *J. Biomed. Mater. Res.* (1997) **35**: 49-73.
- 3 N. Inagaki, *Plasma surface modification and plasma polymerization.* (1996)

ACKNOWLEDGEMENTS:

We greatly acknowledge the financial support of the Common Program on Biomedical Engineering and Research, University of Geneva and EPFL, (1999-2002)