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## From electrochemical behaviour to biotribocorrosion of metal alloys dedicated to joint prostheses

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### ► To cite this version:

A. Impergre, Ana-Maria Trunfio-Sfarghiu, Christelle C. Der Loughian, Benoît Ter-Ovanessian, Aline Bel-Brunon, et al.. From electrochemical behaviour to biotribocorrosion of metal alloys dedicated to joint prostheses. 4th International Conference on BioTribology, Sep 2018, Montréal, Canada. hal-02526010

**HAL Id: hal-02526010**

**<https://hal.science/hal-02526010>**

Submitted on 31 Mar 2020

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## Introduction

**Total Ankle Replacement (TAR)**

- High rate of reoperation :
  - 20% after 5y<sup>1-2</sup>
  - 10-30% after 10y (sometimes 50%)<sup>3-5</sup>

The mobile-bearing Buechel-Pappas TAR. Metallic tibial and talus components and a UHMWPE bearing.

**Body's response:**

- Inflammation
- Cystic osteolysis
- Pseudotumors
- Aseptic loosening

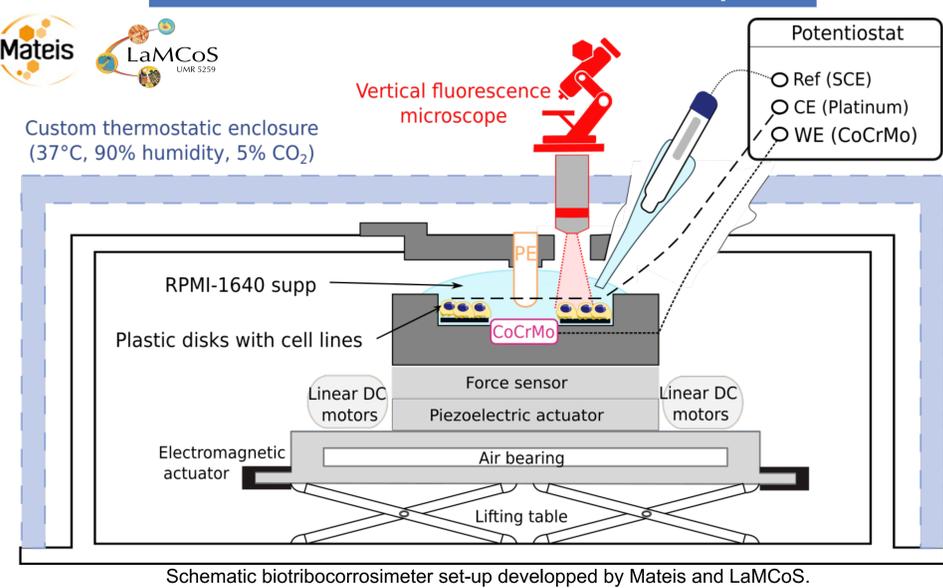
**Causes:**

- Metal ions release<sup>6</sup>
- Metallic and polymeric micro/nanoparticles<sup>7-8</sup>
- But the entangle of mechanisms remain unclear**

▶ Differences between in-vivo and in-vitro conditions  
▶ Tribocorrosion test method need to be adapted to match cell culture conditions

Develop a custom Biotribocorrosion test rig taking into account the biological, mechanical and chemical factors  
Understand the role of synergistic interaction of wear and corrosion in the case of CoCrMo/PE implants

## Biotribocorrosion set-up



## Experimental conditions

UHMW-PE pin  
Standard double mobility prosthesis inserts (HDM248, TORNIER)

CoCrMo disk  
(Biodur® CCM®, Carpenter) ASTM-F1537-11 ISO 5832-12:2007

Mechanical contact, force and displacements applied

Cell culture medium : RPMI-1640 + 10% Fetal bovin serum + 1% Antibiotics

Murine macrophages RAW 264.7  
Human osteoblasts hFOB 1.19  
Cell seeding density : 5.10<sup>4</sup> cells/cm<sup>2</sup>

Fluo. marker: intracellular pH (pHrodo™ Red AM, Thermofisher)

**Biotribocorrosion sequence**

**Electrochemical meas. :**  
Evolution of open circuit potential E<sub>OCP</sub> and voltage drops.

**Biological meas. :**  
Visualization of living cells and acidification: specific sensor of endocytic (ions) and phagocytic (debris) internalization.

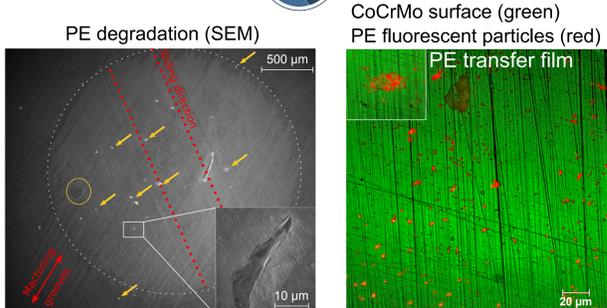
Surface and debris analysis (SEM, IFM)

Mechanical sequence : Init : Initialization phase, CSR : Compression Stress Relaxation, Rh : Rheology, Slid : Sliding phases. V<sub>slid</sub> : 0.5-2 mm/s

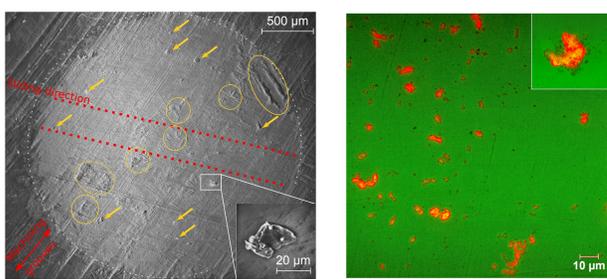
## Results

Test N°	CoCrMo surface	V <sub>sliding</sub> (mm/s)	Cell line
1	SiC 1200	0.5	Macrophages
2	Mirror polishing	2	Osteoblasts

### Tribology

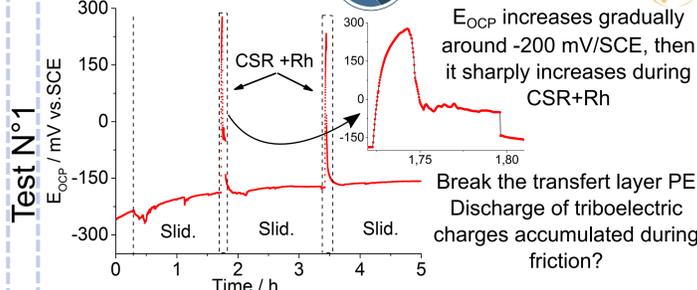


Numerous and round particles ejected out of the contact due to rough rugosity of CoCrMo. PE layer adherent and pulled. Adhesive wear



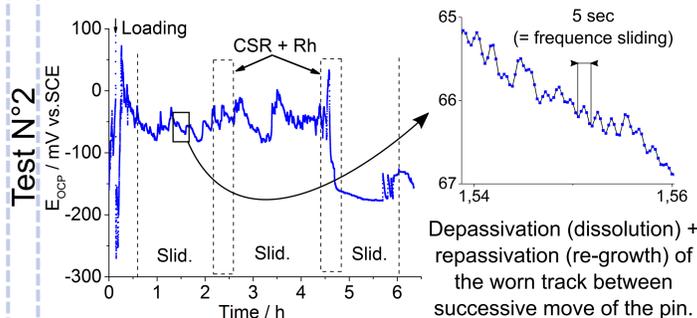
Test N°1: PE adhesive layer, adhesive wear  
Test N°2 : Third-body thick, hydrodynamic  
Confirmed by :  
COF 1 (0.076) > COF 2 (0.054)  
V<sub>Wear</sub> 1 (0.019 mm<sup>3</sup>) > V<sub>Wear</sub> 2 (0.009 mm<sup>3</sup>)

### Electrochemistry



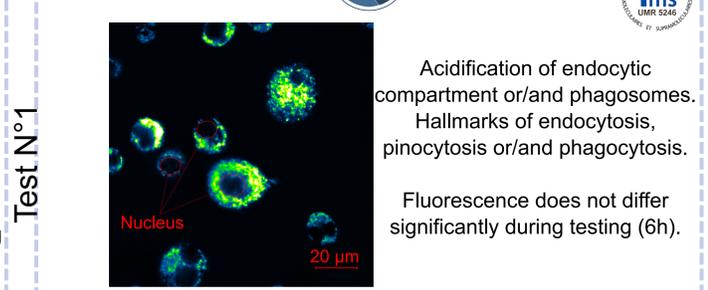
ICP-MS analysis after testing confirms no significant dissolution of CoCrMo.

Element (ppm)	Co	Cr	Mo
Test N°1	0,29	0,01	0,01

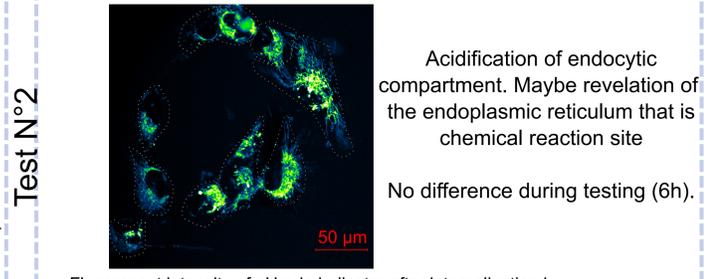


Test N°1 : Slow ionic dissolution. Low V<sub>slid</sub> induces an accumulation of electrostatic charges on PE pin  
Test N°2 : High V<sub>slid</sub> causes dissolution and then repassivation of worn track. Ions ++

### Biology



Fluorescent intensity of pHrodo indicator after internalization by living macrophages. Green intensity represents acidification (pH 4.7-5) in acidic endosomes, lysosomes and phagosomes.

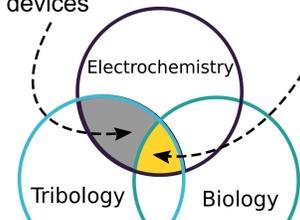


Fluorescent intensity of pHrodo indicator after internalization by living osteoblasts. Green intensity represents acidification (pH 4.7-5) in acidic endosomes and lysosomes.

Revelation of acidification: ions internalization by endocytosis, pinocytosis. Phagocytosis ?  
Provide follow-up after 24, 48 hours of incubation.

## Conclusion

### Common tribocorrosion devices



### Biotribocorrosion

Development of a biotribocorrosion apparatus to understand the synergistic effects between mechanical, chemical and physiological reactions:

- Mechanical contact identical to that of a prosthesis: PE/CoCrMo
- Direct contact of metal ions and wear debris with the cells
- Cell culture conditions fulfilled with fluorescence monitoring of living cells

