Optimisation of the corrosion rate of Fe-based alloys for bioresorbable stent applications by surface acidification

S Reuter[1], C Georges[2], D Mercier[3], M Duportal[4], A Oudriss[4], C Savall[4], P J Jacques[1]

[1]*Université catholique de Louvain, Institute of Mechanics, Materials and Civil Engineering, IMAP, Louvain-la-Neuve, Belgium* [2] *Centre for Research in Metallurgy – CRM Group, Liège, Belgium* [3]*Chimie ParisTech-CNRS, PSL Research University, Institut de Recherche de Chimie Paris (IRCP), Physical Chemistry of Surfaces Group, Paris, France* [4]*Laboratoire des Sciences de l'Ingénieur pour l'Environnement, UMR CNRS 7356, Université de La Rochelle, Avenue Michel Crépeau, La Rochelle, France*

INTRODUCTION: Bioresorbable stents could prevent late complications such as late thrombosis [1]. Stents need to be mechanically strong, making steel a good candidate. But steel does not corrode sufficiently fast. Furthermore, during corrosion in the blood environment, different layers form on top of the metal. This hinders the oxygen diffusion towards the metal, slowing down the corrosion [2]. Therefore, a way to increase the corrosion rate needs to be found. The pH of the environment greatly influences the presence of these layers; an acidic pH favours their dissolution [2,3,4], which could help in activating the corrosion. However, the blood environment needs to keep a pH close to physiological pH (7.4) and thus only the near stent surface can undergo an acidification. The present work investigates the influence of hydrogen on the Fe-based alloy surface evolution.

METHODS: Hydrogen charging was conducted either electrochemically or thermally on Fe-based alloys. The influence of the hydrogen concentration on the corrosion mechanism in SBF (simulated body fluid) is assessed by means of immersion tests that mimic closely what happens *in vivo*. Potentiodynamic polarisation tests as well as Electrochemical Impedance Spectroscopy (EIS) were also conducted to highlight the influence of the chemical composition on the corrosion rate. GD-OES and ToF-SIMS were used to analyse the chemical composition of the upper surface.

RESULTS: Samples that were electrochemically charged with hydrogen show an increased corrosion for higher hydrogen contents after one day of immersion. However, after three days of immersion, the corrosion rates are similar for different hydrogen contents. It was also observed that the hydrogen present in a sample at time 0 disappeared after three days at room temperature. The EIS measurements showed a resistance reduction by 50% after an electrochemical charging (Figure 1). ToF-SIMS and GD-OES showed a different impact of hydrogen on electrochemically charged samples compared to thermally charged samples (Figure 2).

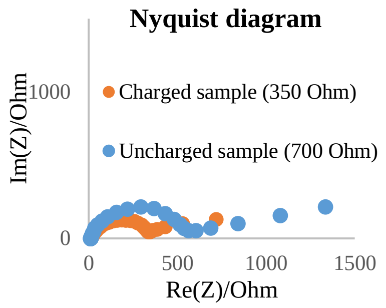

Fig. 1: Nyquist diagram

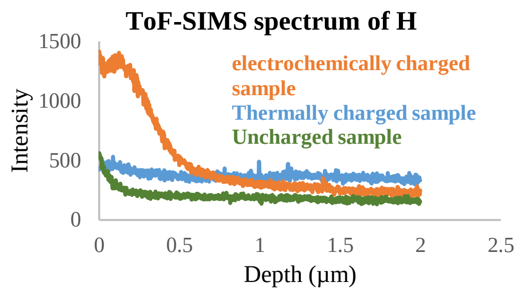

Fig. 2: ToF-SIMS spectrum of H

DISCUSSION & CONCLUSIONS: The ToF-SIMS and GD-OES results show that hydrogen charging affects the metal surface, leading to modified corrosion mechanisms. However, electrochemically charged hydrogen is progressively evaporated so that similar corrosion rates are observed after three days of immersion. The bioresorbable stents made of steel could become a solution to avoid late complications due to the presence of a foreign body in the blood environment. In order to accelerate the corrosion of steel, surface acidification can be implemented, leading to a dissolution of the corrosion layers that hinder the oxygen transport and thus decrease the corrosion rate.

REFERENCES: [1] T. M. Jeewandara, et al. (2014) *Materials* **7**(2):769–786. [2] A. H. Md. Yusop, et al. (2015) *Scientific Reports* **5**:11194. [3] M. Z. Yang, et al. (1999) *Journal of the Electrochemical Society* **146**(6):2107-2112. [4] J. Flis, et al. (1999) *Electrochimica acta* **44**(23):3989-3997.

ACKNOWLEDGEMENTS: The FRIA and ARC are thanked for funding this research.