Experiments and numerical simulations to evaluate peeling properties of polymeric coatings for degradable Mg stents

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INTRODUCTION: Biodegradable stents attracted the attention of many researchers since they can absolve their specific function for the expected period of time and then gradually degrade. Up to now biodegradable stents made of polymers or magnesium (Mg) alloys have been proposed. However, both the solutions have limitations. The polymeric stent have limited mechanical properties and barely withstand the natural contraction of blood vessels. The magnesium stents dissolve too fast in the human body. Our past studies were focused on: i) the selection of a Mg alloy suitable for stent production, having sufficient strength and elongation capability; ii) the optimization of the stent geometry to minimize stress and strain after stent deployment and improve scaffolding ability; iii) the selection of a polymeric coating able to assure enough corrosion resistance; iv) laser cutting and surface finishing of Mg stents. In this work we present some results of an experimental and numerical ongoing study aiming to the development of biodegradable stents made of Mg alloy coated with a degradable polymer with an improved corrosion resistance.

METHODS: PCL (poly-caprolactone, Mn = 80 000 g/mol, Sigma-Aldrich, product number 440744-250G) coatings were obtained by a dipping procedure. PCL was dissolved in chloroform at a concentration of 5% w/v and was dropped onto AZ31 samples (70mm x 4mm x 2mm). Samples were left under a hood for 24 hours to allow the complete solvent evaporation and a uniform PCL coating with a thickness of 0.01 mm was obtained. Finite element analyses (FEA) with cohesive zone method were carried out with the commercial code ABAQUS (Dassault Systèmes, Simulia Corp., USA). Experimental tests were performed to find the cohesive element parameters to be used in the model. A 90-degree peeling test (Fig. 1 left) was carried out on a MTS Synergie 200H testing machine (MTS Systems Corporation, Minneapolis, MN,USA) with a 100 N load cell. Test was performed in triplicate. The experimental tests were reproduced numerically by FEA (Fig.1 right). Subsequently, a 2D stent strut model with a polymer coating was extracted from a 3D stent model previously developed (Fig.2 left). A symmetrical boundary condition in Y-direction was applied to one strut end and a displacement in Y-direction was applied to the other end to simulate the stent expansion to a final diameter of 3 mm. After expansion, the cohesive elements were stretched and the coating had different separation ranges according to the location.

RESULTS: None of the 2D stent strut simulations reached the tensile limit stress obtained in the peeling experimental tests; hence, the estimated coating damage was 0 as reported in Fig. 2 (right).

DISCUSSION & CONCLUSIONS: The simulations suggest that under the studied conditions the peeling should not occur to the coating of the investigated stent design. Tests are under investigation to verify our numerical findings. Such a model might be used to optimize the design of a degradable coated stent.

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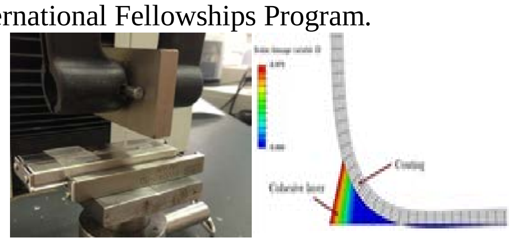

Fig. 1: Experimental (left) and numerical (right) peeling test on AZ31 sample coated with PCL.

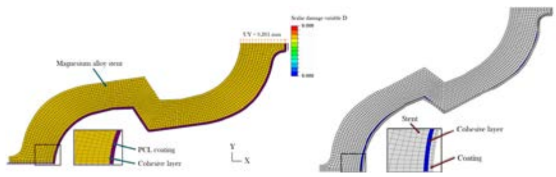

Fig. 2. FEA 2D model of a coated stent strut (left) and final configuration after stent expansion with results in terms of damage parameter in the coating (right).