Remote Monitoring of Biodegradable Cardiovascular Stents using mm-waves

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***Abstract*—In this paper, we present a corrosion monitoring scheme for biodegradable cardiovascular stents composed of magnesium alloys. We show that the structural integrity of such mesh-type tubular stents can be evaluated using millimeter-scale electromagnetic waves. The electromagnetic scattering from the simulation results indicates that the resonant frequency decreases as the structure thickness degrades with time.**

biodegradable cardiovascular stents, non-destructive evaluation, millimeter waves

I. Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide, and it accounted for an estimated 30% of all deaths in the year 2013 globally [1]. Clogging of the heart vessels is the biggest factor responsible for the development of the CVD. These days, it is a common clinical practice to reopen the heart vessels through balloon angioplasty, and place a mesh-type metallic scaffolding tube called a stent to reinforce the vessel walls. However, due to the long-standing presence of a metallic foreign object in the form of a stent, serious health complications arise chief among which is the reclogging of the vessels in the long term, especially in the vicinity of the stent. From a medical perspective, an ideal stent would be the one that serves its purpose of reopening and stabilizing the heart vessels and then disappear [2]. The biodegradable stents precisely offer such a possibility where the scaffold structure completely corrode away after performing the reinforcement of the heart vessel walls [3].

Research into biodegradable polymers and metals has been on-going, but the inherent superior mechanical properties of metals make them more attractive for biodegradable stent application compared to polymers [4]. Among metals, zinc and magnesium-based alloys have both shown promise for degradable stent applications, but as of today, only Mg-based biodegradable stents have been clinically tested in humans [5], [6]. More importantly, Mg is also vital in maintaining a healthy heart, and given the weight of a typical coronary stent is in the range of $3\,\mathrm{mg}$–$5\,\mathrm{mg}$, the release of Mg ions is unlikely to cause any adverse effects.

One of the biggest engineering challenges presented with the use of a biodegradable stent is that its structural integrity must be maintained until the stent completely breaks down and is metabolized in to the bloodstream. To ensure this, the stent and its biodegradation due to corrosion needs to be monitored through non-invasive means. In this paper, we propose an electromagnetic monitoring scheme that monitors the structural integrity of a biodegradable stent using millimeter waves (mm-waves). Compared to the microwave wave imaging, mm-wave provide higher spatial resolution. On the other hand, mm-waves can penetrate deeper into the human tissue compared with the optical frequency counterparts. Using full-wave 3D electromagnetic simulations, we show that the stent corrosion can be determined with the help of the frequency change in the scattering properties.

II. Methodology

To simulate the biodegradation of a cardiovascular stent, we used the *Open stents* [7] models that are customizable due to their inherent parameterization. The stent length was set to $25\,\mathrm{mm}$ with the diameter in the expanded form equal to $4\,\mathrm{mm}$, as shown in Fig. 1.

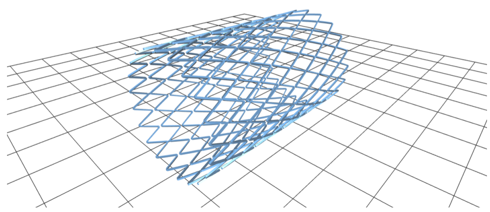

Fig. 1. An open stent design in the expanded state

III. Conclusion

For all further questions please read first the WORD template that is also provided on the EuCAP 2019 website, before consulting the local organising committee.

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