Investigating Interface Corrosion in Active Implantable Medical Devices (AIMD) via Diffusion Mechanism

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A pinnacle of medical development and innovation are Active Implantable Medical Devices (AIMD), which comprise implantable Cardiac Pacemakers, Neurostimulators or Hearing Devices. These devices have to fulfill strict norms and undergo multiple safety tests. Nevertheless, AIMD have a non-negligible risk of failure caused by the permeation of body fluids and the subsequent diffusion of ions through the protective polymer layer. This process may cause delamination at the polymer-metal interface of the electrode material followed by corrosion, leading to malfunctions and potential harm for the patient [1].
In order to address this problem, a testing system comprised of a wafer coated with a thin platinum layer is crafted. On top, copper indicators are placed, enabling a simple reaction of copper with low molecular weight sulfur components. The entire system is then embedded in highly hydrophobic Sylgard to simulate a protective coating layer. The environmental influence can be varied by adding different solutions made of amino acids, proteins and salts, which in approximation resemble body fluids [1]. A suitable technique to detect the corrosion process on the metal layer is Confocal Raman Microscopy (CRM) which is based on Raman scattering, an inelastic interaction between light and the sample. CRM offers detailed chemical information about the sample combined with high spatial resolution, creating high-resolution Raman images. This enhances the characterization of diffusion and further corrosion mechanisms.
Initial experiments show high permeability of sulfidic components through the Sylgard towards the metal- polymer interface, visualized by a clear color change towards black (Figure 1a). Additionally, Confocal Raman Microscopy provides evidence for the diffusion of sulfides in the polymer and indicates an unequal deposition of CuS. Green areas in Figure 1b illustrate the presence of CuS. To further investigate the diffusion and delamination mechanisms, additional high-resolution Raman Imaging using an optimized testing setup needs to be performed.

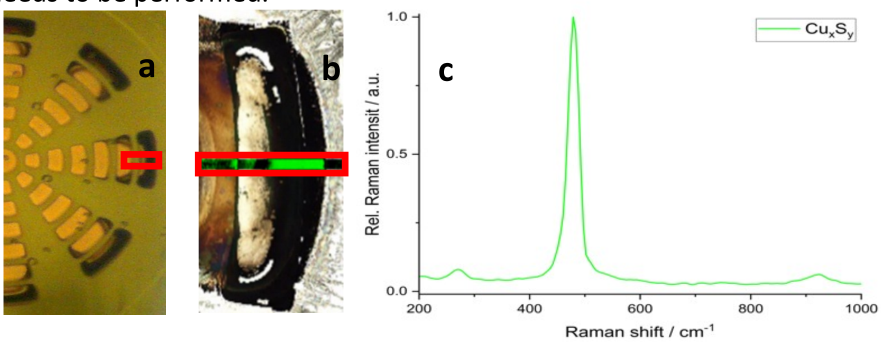

Figure 1: Microscopic image showing the test sample with its indicator structures made of Cu after immersion in potassium sulfide solution. Black areas indicate the formation of CuS (a). The red rectangele illustrates the measurement area for Confocal Raman Microscopy (CRM). Green areas in image (b) indicate the distribution of CuS verified by CRM. The corresponding spectrum is given in image (c) with bands at 265 and 475 cm^{-1}.

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References

[1] Onken A., et.al., Predicting Corrosion Delamination Failure in Active Implantable Medical Devices: Analytical Model and Validation Strategy. *Bioengineering* **2022**, *9(1)*, 10.