pH micro-biosensor for implantable medical devices

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The monitoring of the pH milieu inside the body is critical to the functions associated with implantable medical devices. By monitoring the variation of pH in real-time inside the body, we are capable of identifying the body response to the implant, the probability of infection, calibrating sensors and monitoring complications such as internal bleeding or anastomotic leakage [1,2]. Here our pH sensor consists of a working electrode and a counter electrode of Ag/AgCl fabricated to allow the signals to be collected and compared to a reference value [3]. For the working electrode, we chose Polyaniline (PANI) and Polyurethane (PU) [4] as sensing material. Upon exposure to different pH solutions, PANI (the active sensing material) acts as an ion-selective membrane, the concentration gradient of ions across the membrane generates a potential difference. The key advantage of the two-electrode sensing system is that it requires no power supply for the sensor operation (passive), enabling its use in implantable technology where the power budget is limited.

The fabrication of such pH sensor is straightforward. We first fabricate microscale interdigitated electrodes in Ag by photolithography, Ag e-beam deposition, and Ag liftoff. Then we coated a conducting hydronium-sensitive layer of PANI or PU by electro-polymerization onto the active electrode. Then we placed the second electrode into a solution of KCl to apply a thin layer of AgCl on the electrode, creating the Ag/AgCl reference electrode. The potential for the polymerization to provide the most stable active layer and the Nernstian potential was optimized. Moreover, the porosity of the active layers has been modified to allow the highest concentration of hydronium ions to diffuse to the electrodes, maximizing the signal stability. This bio-compatible electrodeposited polymer layer also protects the electrode from cellular attacks and biofouling [5].

Figure 1 showed the fabricated interdigitated electrode with PANI. The fabricated device was used to monitor changes in pH in biological fluids such as gastric juice, simulated blood, and peritoneal fluid. The device was capable of monitoring changes in pH with a Nernstian potential of 68mV/pH [6]. In addition, the active layer demonstrated an active lifetime of 29 days where the electrodes were capable of collecting data continuously during the active period. Figure 2 showed the data collected from the pH sensing electrodes, within the region of pH 2 and pH 12 (which are the typical limits of the pH's that could exist inside the body), demonstrating a Nernstian potential of 68 mV/pH.

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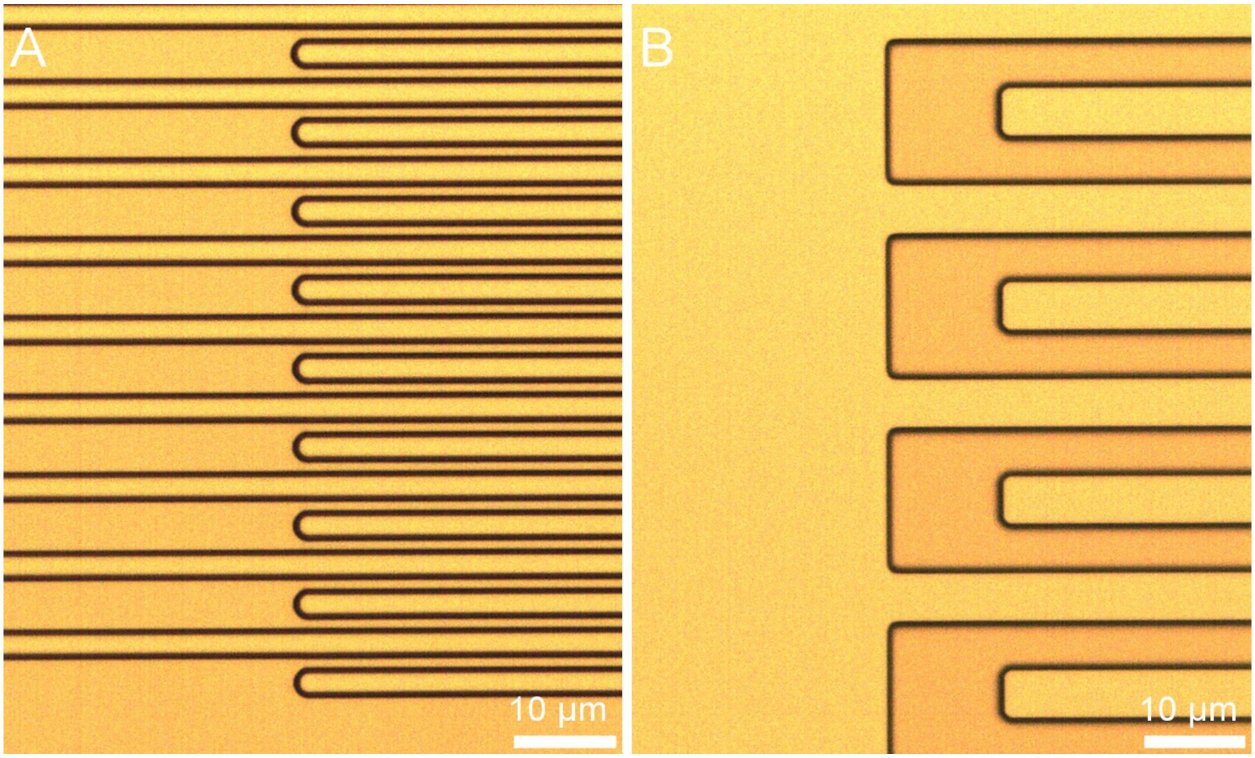

Figure 1. Optical Images of the fabricated Ag sensing electrode. The left electrodes have a 20nm of PANI applied on them the right electrode has a 1nm layer of AgCl. A) 2µm linewidth electrode B) 5µm linewidth electrode

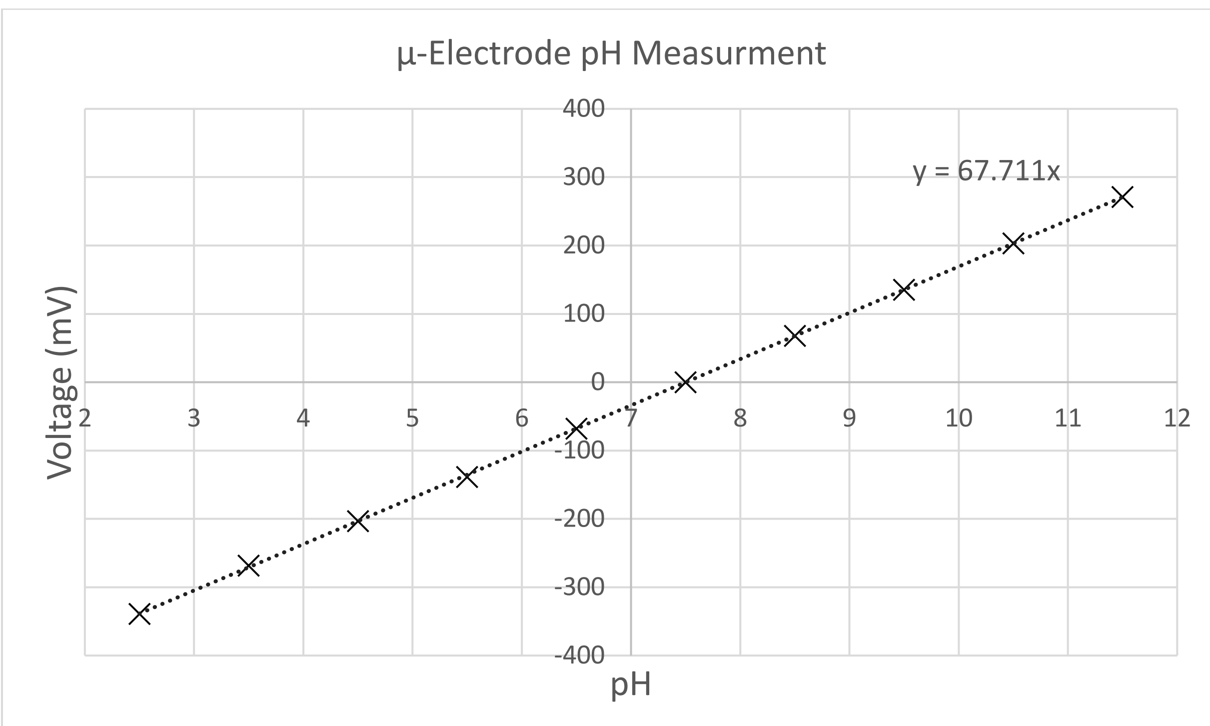

Figure 2. The Nernstian response for the pH changes has been measured to be 68mV/pH