High-efficiency Water Electrolysis based on Nanoelectrodes

Y.F. Wang, W. Wu*
Department of Electrical Engineering - Electrophysics, University of Southern California, Los Angeles, CA 90089
**wu.w@usc.edu*

Industrial approaches of hydrogen production mainly include steam-reforming[1] and water electrolysis. Steam-reforming technology utilizes natural gas as sources therefore greenhouse gases are byproducts. Water electrolysis does not have such problems. However, it has much lower efficiency because of Ohmic loss from the electrolyte ionic current connect the two half reactions at two electrodes, especially when current density is increasing. We here reduce the distance between two electrodes below the Debye screening length of pure water (around 60nm in air), to eliminate the need of electrolyte, and hence reduce the total Ohmic loss and achieve a much higher efficiency for hydrogen generation (Figure 1). Moreover, we provide a portable hydrogen generation solution.

The fabrication process is shown in Figure 2. First, cathode metal (Ti/Pt) was deposited on thermally grown silicon dioxide by e-beam evaporation. Then silicon nitride was deposited by PECVD (Figure 2(a)), with thickness from 50nm to 500nm. The anode (Ti/Au or Ni) was fabricated using photolithography, e-beam evaporation and lift-off (Figure 2(b)). Eventually the silicon nitride layer was etched with anode metal as etching mask (Figure 2(c)), and by using low-DC bias RIE process, which could avoid short-circuit between cathode and anode metal layers due to the sputtering and deposition of metal on the sidewall of the silicon nitride spacer. The fabrication result is shown in Figure 2(d).

Bubbles were generated during water electrolysis based on our devices (Figure 3). Figure 4(a) shows the results of I-V curves measurement from the samples with the same pattern but different thickness of silicon nitride (*i.e.* different distances between electrodes). We found that when silicon nitride is thicker the threshold voltage is larger. This means the method to decrease the distance between two electrodes could reduce the external power as expected. When the distance between two electrodes is 50 nm the threshold voltage is 1.55V, which is almost the same as the theoretical limit of 1.47 V. Figure 4(b) shows the results from the samples with the same thickness of silicon nitride but different grating pitches of the pattern. It indicates that the current increases linearly as the total number of edges of the gratings increases. However, in experiments we found that both Ni and Ti/Au as anodes would be corroded (Figure 5) during water splitting, which will lead to short-circuit between electrodes. We are investigating on improving the reliability by replacing the metal by indium tin oxide (ITO) or coating one ultrathin layer of dielectric for anode protection.

---

[1] **J.D. Holladay**, **J. Hu**, **D.L. King**, **Y. Wang**, An overview of hydrogen production technologies, *Catalysis Today* 139: C244-C260, 2009.

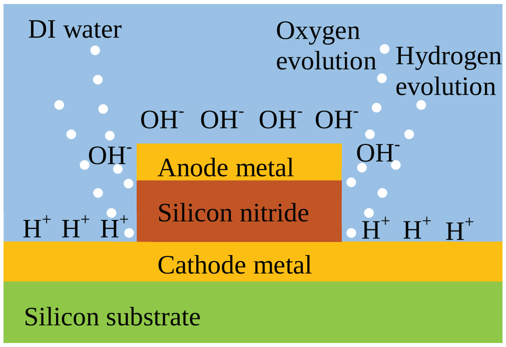

Figure 1: Water electrolysis by nanoelectrodes. Control the thickness of silicon nitride to reduce the distance between two electrodes.

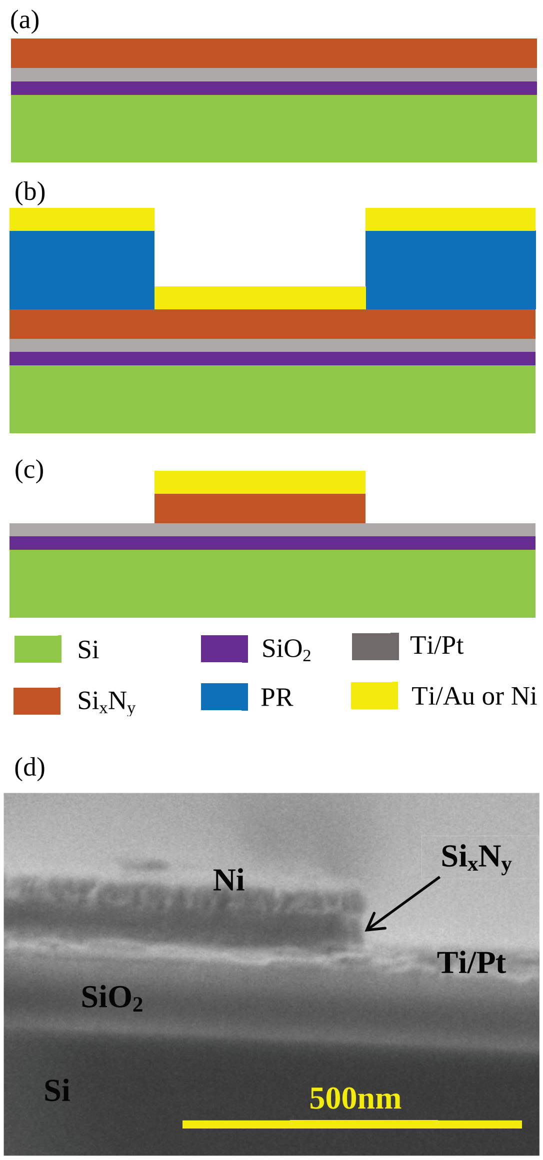

Figure 2: Diagram of the fabrication process and the fabrication result of the nanoelectrode devices.

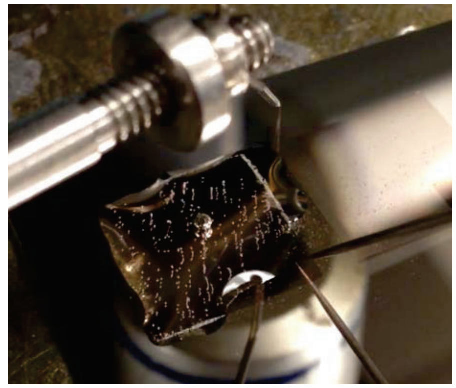

Figure 3: Bubble generation during water electrolysis

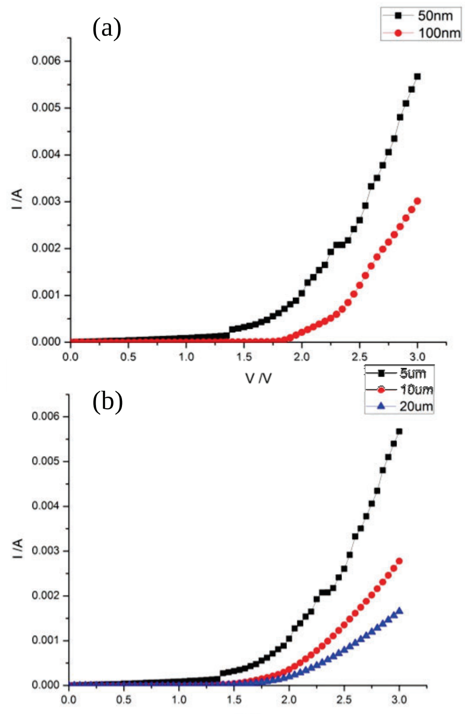

Figure 4: I-V curves measurement for water electrolysis

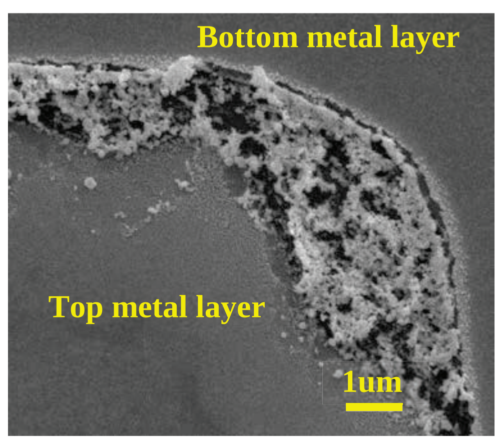

Figure 5: Corrosion of anode metal during water electrolysis.