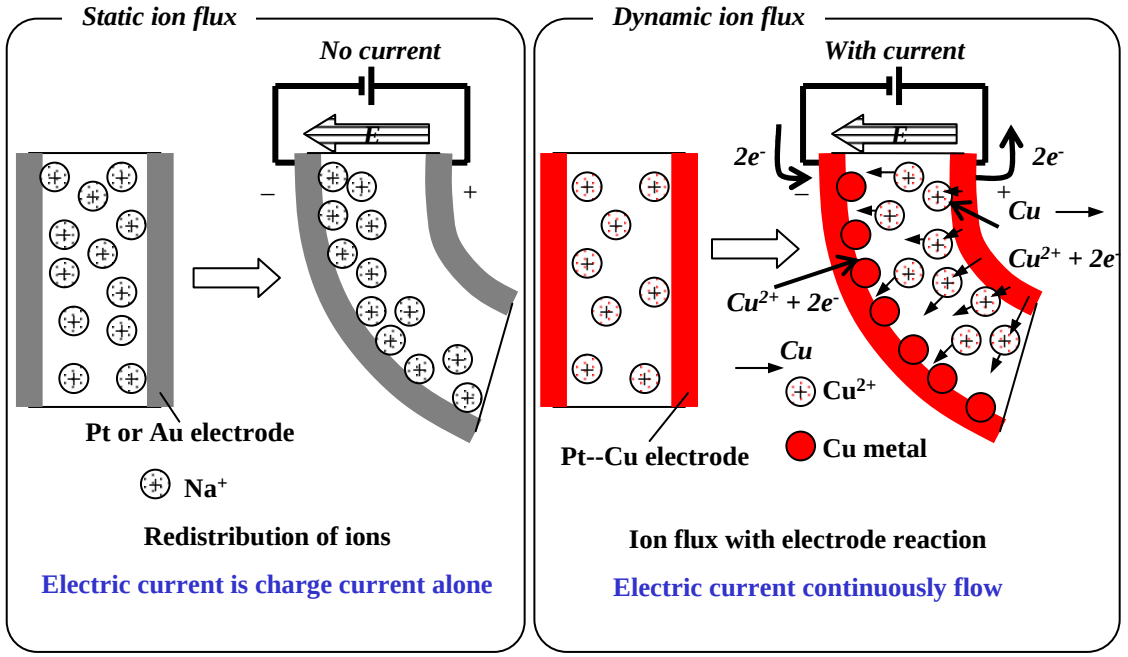
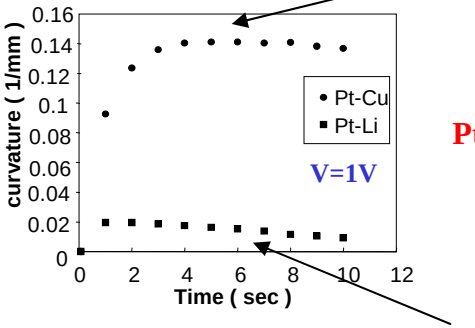
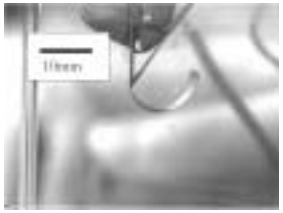
A New Nafion Actuator

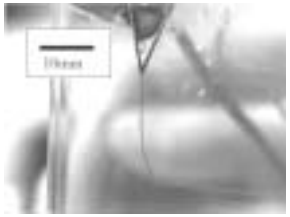
We developed a new Nafion actuator with enhanced deformation. This actuator is based on a double layer Platinum Copper electrode and uses the oxidation-reduction of Copper to get a dynamic ion flux upon polarity change. This results in enhanced current and displacement of the actuator.





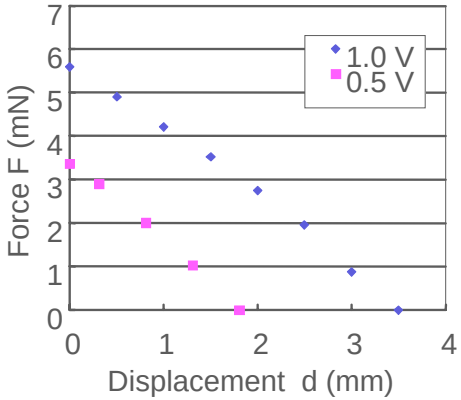


Pt-Cu electrode with copper ion



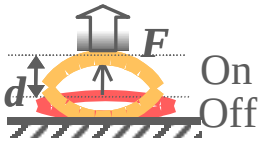
Pt electrode with Lithium ion

We developed a loop actuator based on our double layer Platinum Copper electrode actuator. Here are performance data, photos and sketch of the loop actuator.

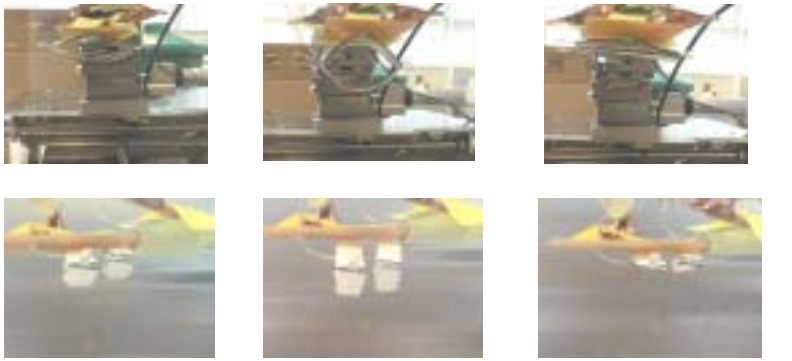


Off

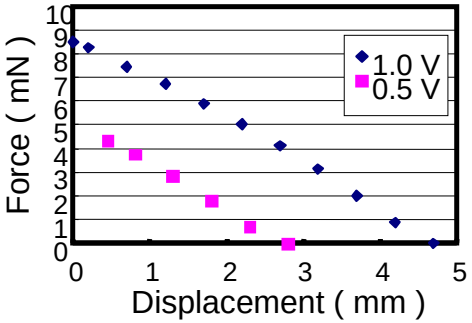
On



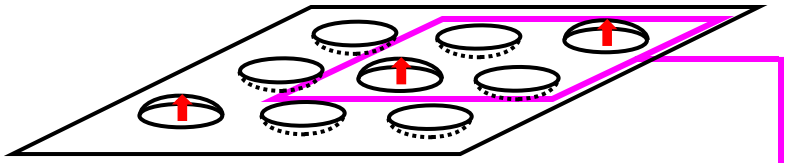
To increase the force we designed a parallel device in which two loop actuators are set in parallel. Here are photos and performance data of the parallel device.



OFF Positive (expand) Negative (Shrink)



Design of a Nafion Actuator Array

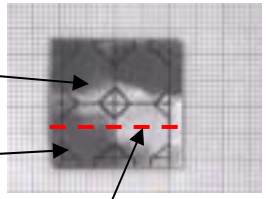


We designed an actuator array using the out of plane deformation of the Nafion membrane and electrode patterning.

First a square of Nafion 117 membrane was Platinum plated. Then metal was removed in the desired pattern with a sharp tip; four octagonal electrodes connected to the edge of the membrane were created on both sides of the membrane. Finally each cell was individually copper electroplated and the whole array was soaked in $CuSO_4$ solution for ion exchange to Cu^{2+}. Each octagonal actuator could be actuated individually.

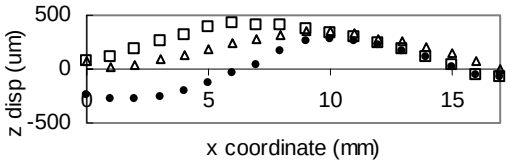
Platinum Plating on Nafion

Patterning (electrode boundary)



Picture of 1st generation array (2x2)

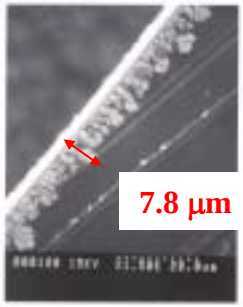
We scan across the two lower cells for the out of Plane displacement with the laser displacement meter while cycling the voltage applied to the left one.



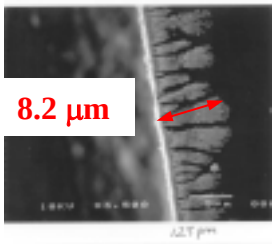
- Initial profile
- Maximum upward profile
- Maximum downward profile

We switched to gold electrodes and studied the influence of membrane thickness on actuation. We prepared gold plated Nafion 112 (50-micron thick), 115 (125-micron thick) and 117(180-micron thick). The amount of gold deposited after one plating is proportional to the volume of the membrane so we had to do 6 plating cycles on the thinnest one to ensure conductivity.

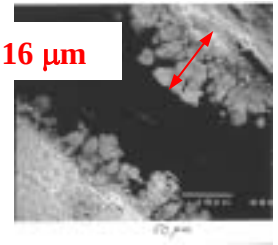
Structure of the gold electrode (SEM)



Nafion 117
after 2 plating

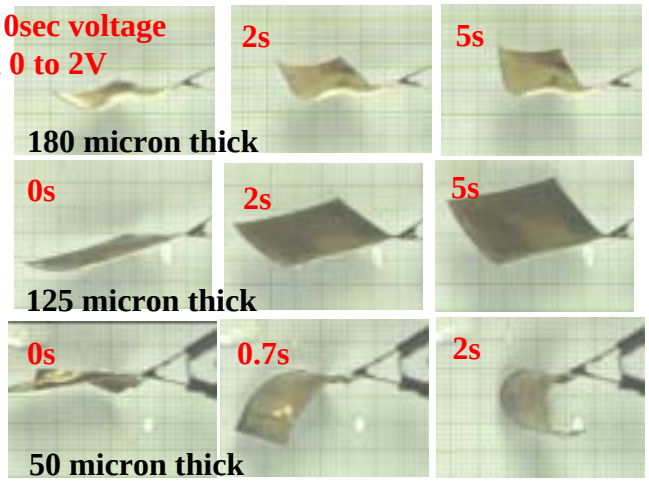


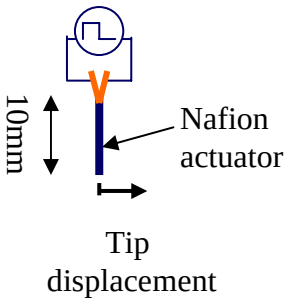
Nafion 115
after 3 plating

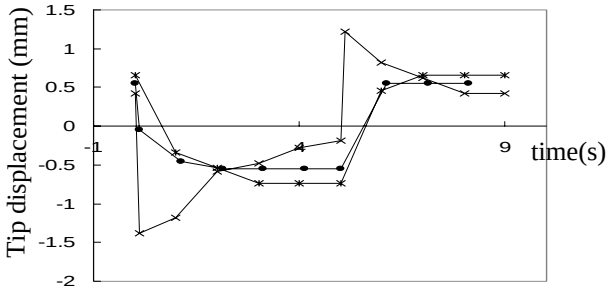


Nafion 112
after 6 plating

Membrane thickness has a large influence on actuation. The thinnest membrane Nafion 112 deforms the most and the most quickly.



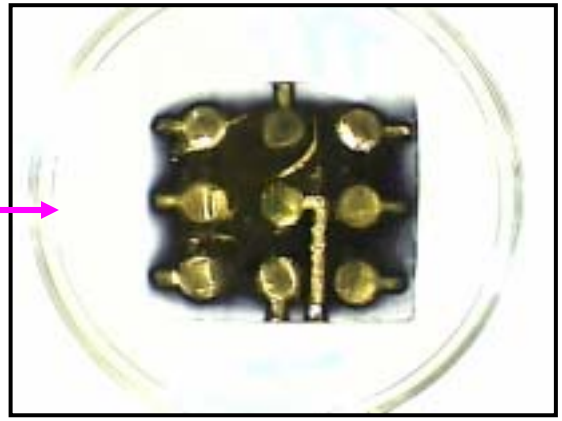


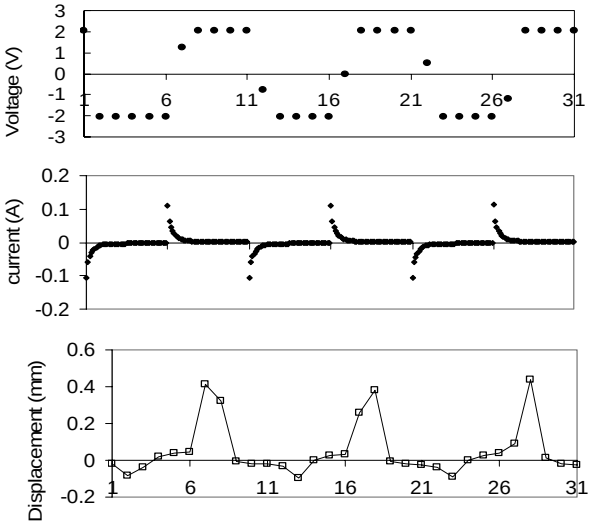


180µm(disk), 125µm(star), 50µm(x) after 2, 3 and 6 plating cycles respectively.

We prepared a 2nd generation actuator array (3x3) from Nafion 112. The electrode patterning was done using hydrophobic masks during gold plating. Some preliminary results on the actuation of the cells are given here.

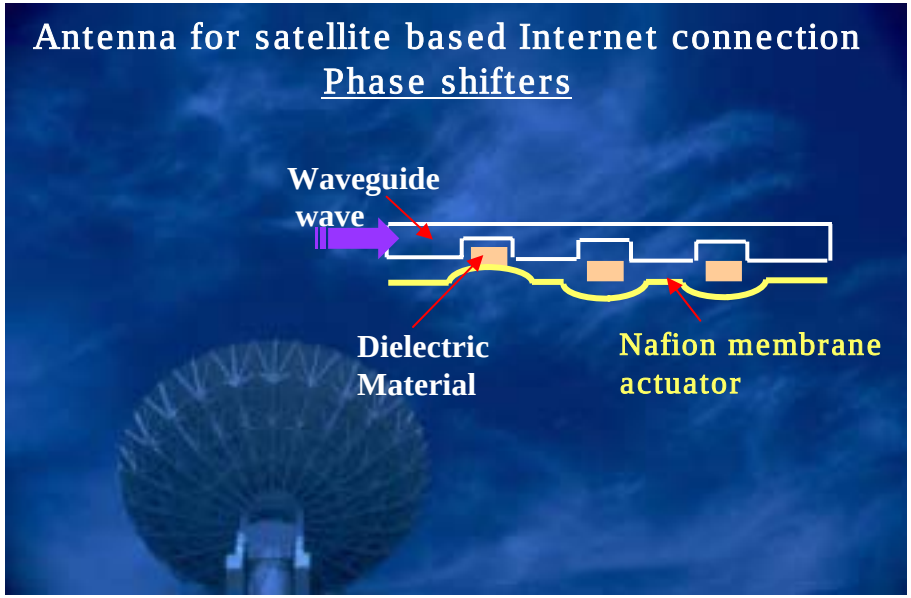
Picture of 2nd generation array (3x3)





Voltage, current and displacement versus time of one cell

Application for the actuator array



Publications

M. Uchida and M. Taya, “Solid polymer electrolyte actuator using electrode reaction”, Polymer **42**, 9281-9285, 2001.
M. Uchida, C. Xu, M. Le Guilly and M. Taya, “Design of Nafion Actuator with Enhanced Displacement”, Proc. SPIE – The International Society for Optical Engineering, **4695**, to be published June 2002.
M. Le Guilly, M. Uchida and M.Taya, “Nafion Based Smart Membrane as an Actuator Array”, Proc. SPIE – The International Society for Optical Engineering, **4695**, to be published June 2002.