

## Overview of results

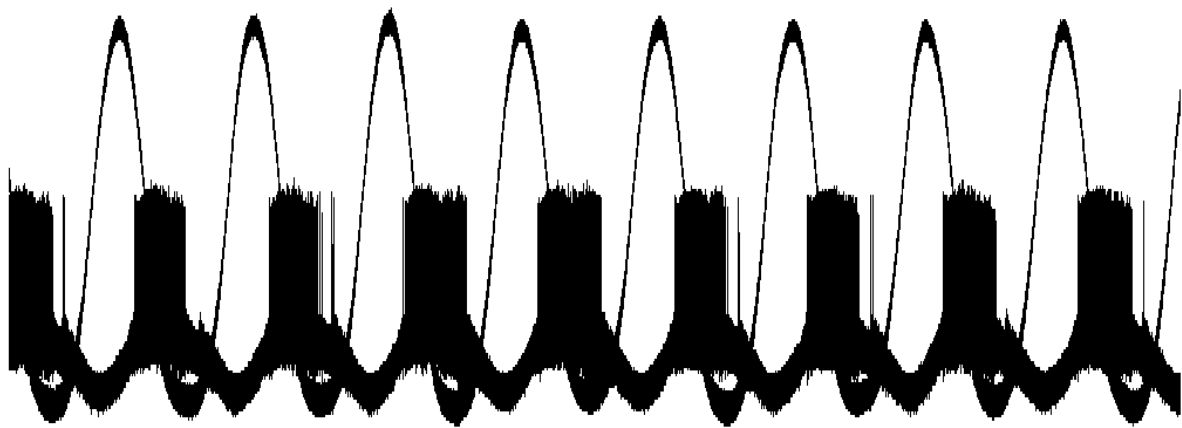
### 1. Realization of an artificial hair cell capable of detecting changes of pressure 11 orders of magnitude smaller than atmospheric pressure with sharp frequency selectivity.

Hair cells in biological hearing organs transform mechanical stimuli into neuronal signals with great sensitivity, sharp frequency selectivity, and wide range of intensity. By combining the principle of adaptation in hair cells with electronic engineering to obtain negative stiffness, we have produced a biomimetic force sensor showing all these features. For the nano-Newton force signal, the biomimetic sensor showed that more than an order of magnitude increases in sensitivity and frequency selectivity compared to the passive sensor. The nonlinear amplification mechanism in the hair cell is demonstrated showing that the hair cell can precisely detect pulse signals weaker than noise.

### 2. Realization of a flexible amplifier to regenerate electric pulses in artificial neurons

We have demonstrated negative differential resistance in a silicone/graphite composite and have obtained flexible oscillators. This material will be substituted to tunnel junctions to regenerate spikes in artificial neurons made of any material – not only GaAs. This has the advantage that FitzHugh-Nagumo type neurons that we have studied so far in the (expensive) GaAs/AlGaAs multilayers can now be realized in virtually any type of structure including those prepared on soft substrates.

### 3. Detection of cochlear hair oscillations through the firing of an artificial neuron



The artificial hair cell was connected to the neuron. The above figure shows the sinusoidal voltage stimulating the hair cell. The oscillations of the hair cell are converted to an electrical signal which stimulates the neuron. The lower curve shows neuron bursts when the hair cell reaches its maximum excursion. This result shows that this machinery could be used in a cochlear implant using the artificial neuron to stimulate auditory pathways.

## Impact

1. The technology can provide a gain of sensitivity for cochlear implants. The stimulation of the hearing pathway by neuron-like spike burst rather than by an electrode could also give improved sensitivity. These claims would need to be confirmed and refined by clinical trials.
2. The project strengthened research collaboration between Korean and European researchers, a timely initiative as American research centers have traditionally been partnering Korean academics. Two Korean students stayed in Bath to learn nanofabrication and to experiment on semiconductor neurons. The fellow established further collaborations with scientists at UCL, Bristol University, Chalmers University, the Max Planck Institute for Complex Systems in Dresden, the Ecole de Physique-Chimie in Paris. The fellow organized a workshop at the Asia Pacific Center of Theoretical Physics in Pohang where several European experts on Nano-electromechanical systems gave talks

and had the opportunity to meet representatives of Korean companies, academics and medical doctors.

3. Three papers have appeared in press at the end of the project. One patent application has been filed.