脳機能模倣素子など次世代微細素子の開発

滋賀県立大学
THE UNIVERSITY OF SHIGA PREFECTURE

関連するSDGsの国際目標

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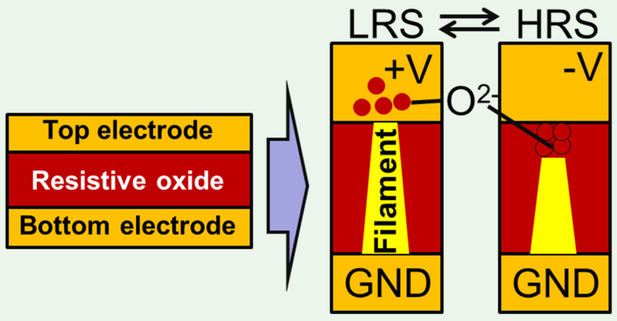
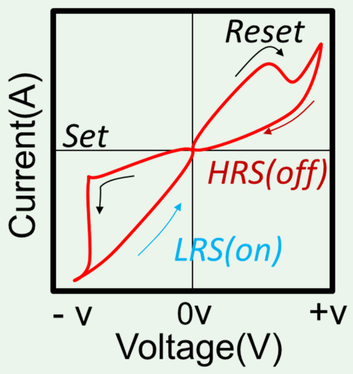
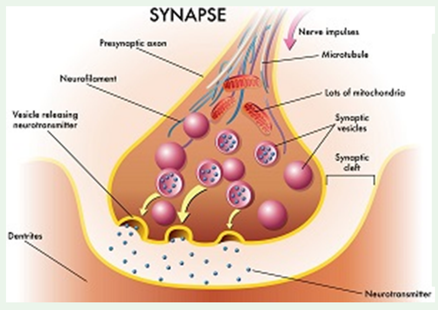
研究分野：半導体デバイス、記憶素子、ナノ粒子、2次元材料

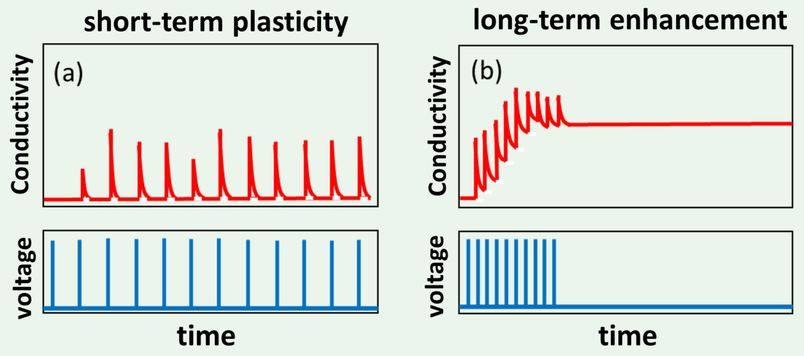
Resistiv Memory





Electrical behavior of synapses and synaptic device





Constituted of metal oxide showing resistance change by voltage application.
Formation of filaments by movement of oxide ions.
•Low voltage（1～3 V）and High speed operation（<10 nsec）•Scalable

Higher performance driving elements for handling complicated information, demands on memory devices.
→ Attention to elements and circuits imitating the human brain.

Bio Nano Process (BNP)

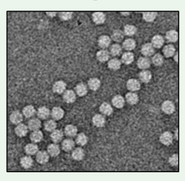
- Promising bottom up process which overcomes the scaling limit of top down process.
- Biological method to produce nano functional structure using biomineralization of the supramolecular protein.

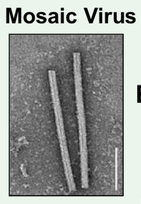
Supermolecular protein → Nano Structure → Devices

- Structural uniformity
- Biomineralization
- Self-organization
- Selective adsorption
- Memory(FGM, ReRAM)
- Solar cell
- Bio-sensor

Ferritin protein

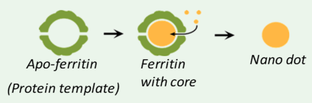
Tobacco Mosaic Virus

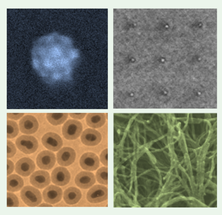


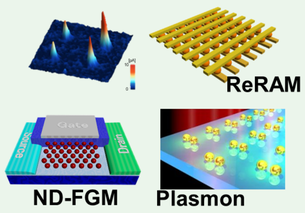


Ferritin has a spherical cage structure with inner and outer diameters of 7 nm and 12 nm, respectively. Ferritin can crystallize various inordanic nanoparticles(NPs) such as FeOx, CoOx, NiO, CuS, AuS, PtS, TaOx.

Biomineralization



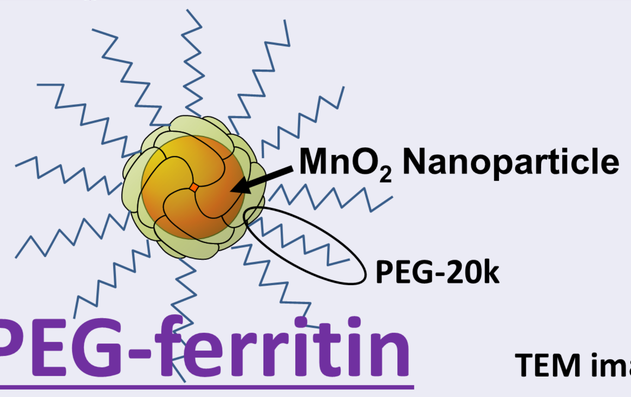


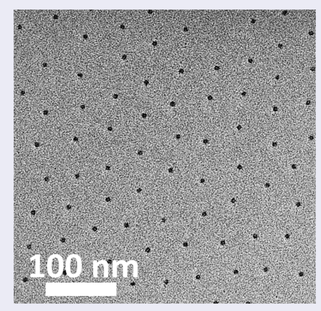


Object

Fabrication of synapse-like device using resistive memory

⇒Using bio material about PEG-ferritin



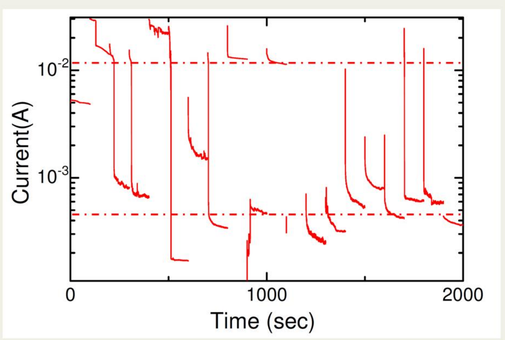


TEM image of 2D array of PEG-ferritin

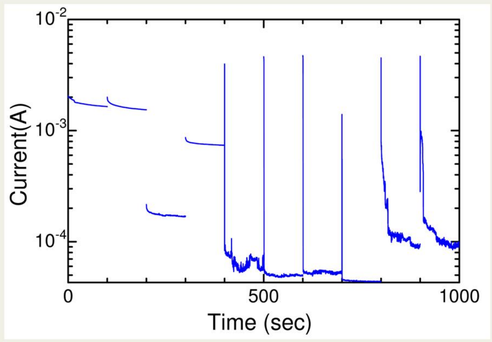
Results

Electrical characteristics of synaptic device

Short-term plasticity

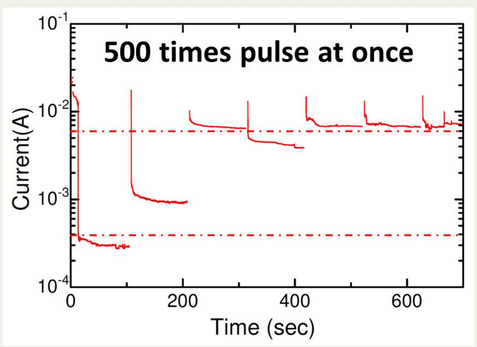


With MnO_2 film

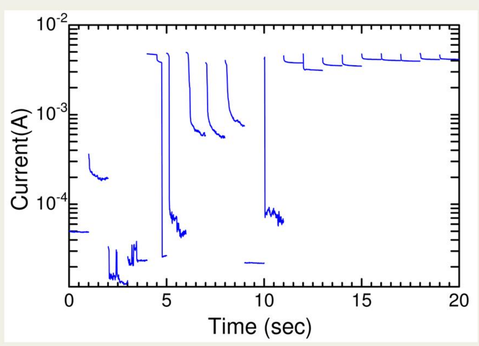


With MnO_2 nanoparticles

Long-term enhancement



With MnO_2 film

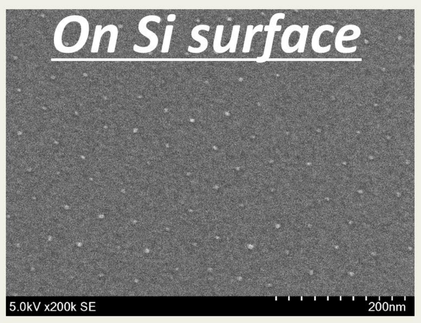


With MnO_2 nanoparticles

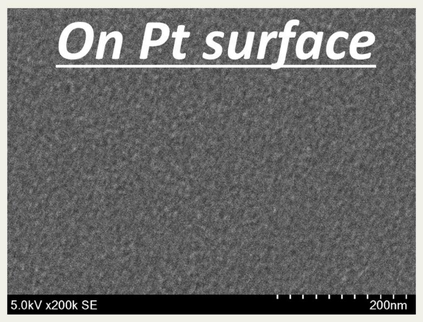
- ✓ Comparison of devices using MnO_2 film and MnO_2 NPs.
- ✓ After applying a pulse of 100 ns width of 5 V, apply a bias of 1 V and observe the current value.
- ✓ Immediately after the pulse, it changes to low resistance.
- ✓ It changes to high resistance by applying 1 V bias.
- ✓ When current flows in MnO_2, it turns into Mn_2O_3 and oxygen is supplied to Ta_2O_5 and reoxidation.
- ✓ At 100 s intervals, short-term plasticity was confirmed with both film and nanoparticles.
- ✓ In the film, long-term enhancement can not be seen unless a pulse is applied 500 times at a time.
- ✓ For NPs, long-term enhancement was confirmed by applying pulses at 1 second intervals.

SEM observation of 2D array of MnO_2

On Si surface

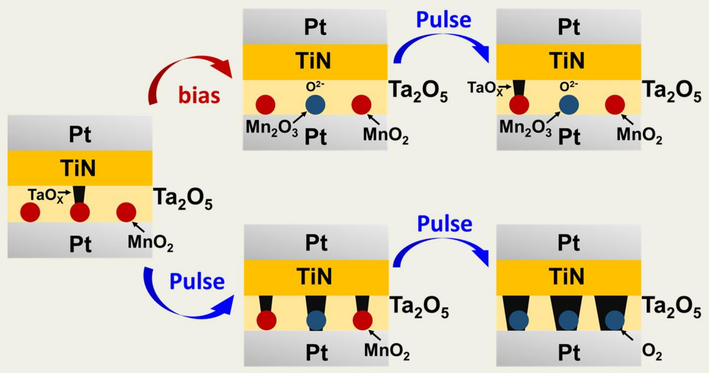


On Pt surface



- ✓ Confirmed that the NPs are arranged at 50 nm on Si.
- ✓ An electrode with a diameter of 300 μm, there are about 4×10^7 NPs.
- ✓ Although it is difficult to confirm on Pt, since it is on the same substrate, NPs might be arranged just like on Si.

Operation assumption chart



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