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FABRICATION AND MODELLING OF TITANIUM DIOXIDE MEMRISTORS

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Concept – Including Filamentary Conduction in the Mem-Con Theory of Memristance Improves the Model for 'Triangular' Memristors

Introduction: Memristors are the novel 4th fundamental circuit element predicted to relate the magnetic flux, φ, to charge, q, via $d\varphi = M(q)\,dq$, where M is the memristance [1]. Memristors can act as artificial synapses in brain-like computer architectures. Our memristors are made of sputter-coated aluminium electrodes and 40nm thick layers of titanium dioxide sol-gels [2,3].

Characterization

Two types of memristor were seen:

A. 'Curved'-type which have off and on states in the same order of magnitude, see fig. 2A.

B. 'Triangular'- type which have off and on states in different orders of magnitude, see fig. 2B.

- The curved switching is caused by bulk movement of oxygen ions creating volumes of doped $TiO_{(2-x)}$
- It is believed that the triangular switching is caused by the fusing and breaking of filaments of very low resistance titanium dioxide.

Theoretical Modelling

The mem-con theory [4] is a new model of memristance based on the chemistry of the device by describing the magnetic field associated with the flow of oxygen ions and relates memristance, M, and magnetic flux, φ, to experimental measurables.

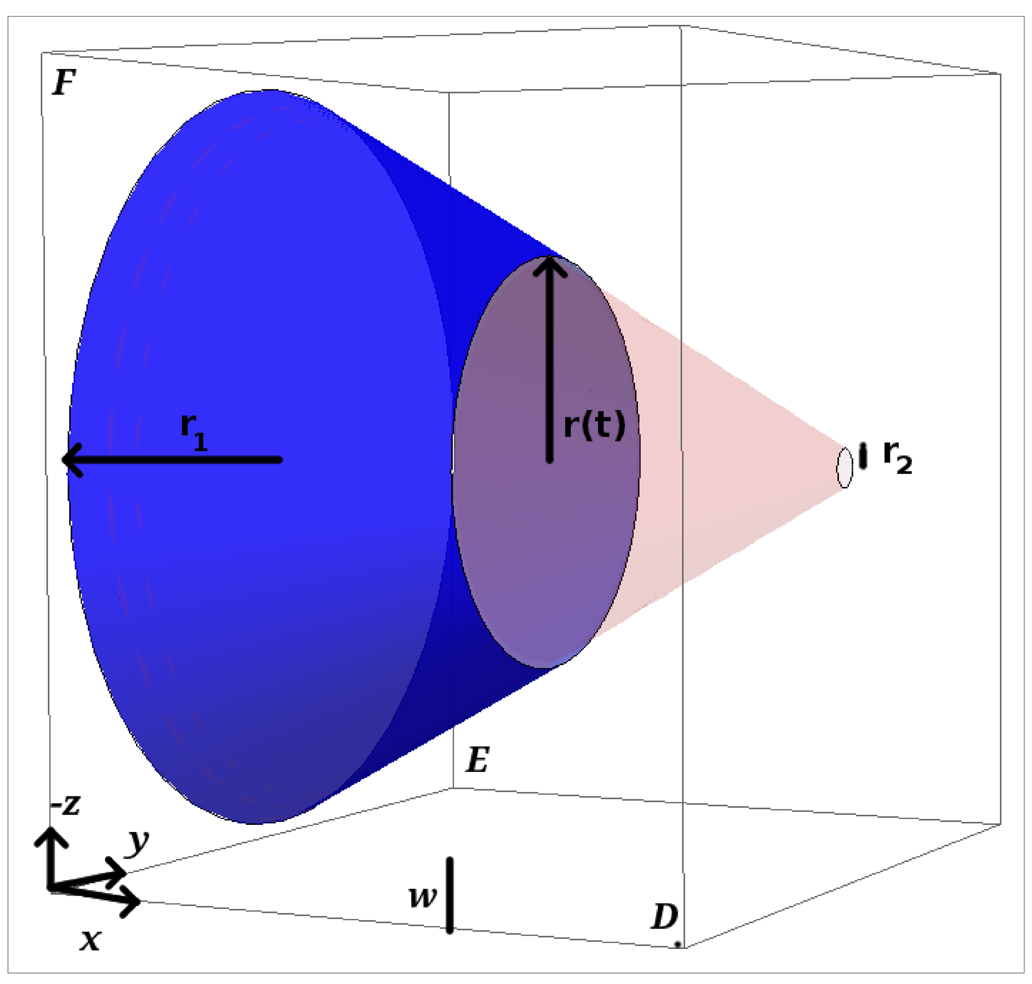

Figure 1. Schematic of conducting filament

Results

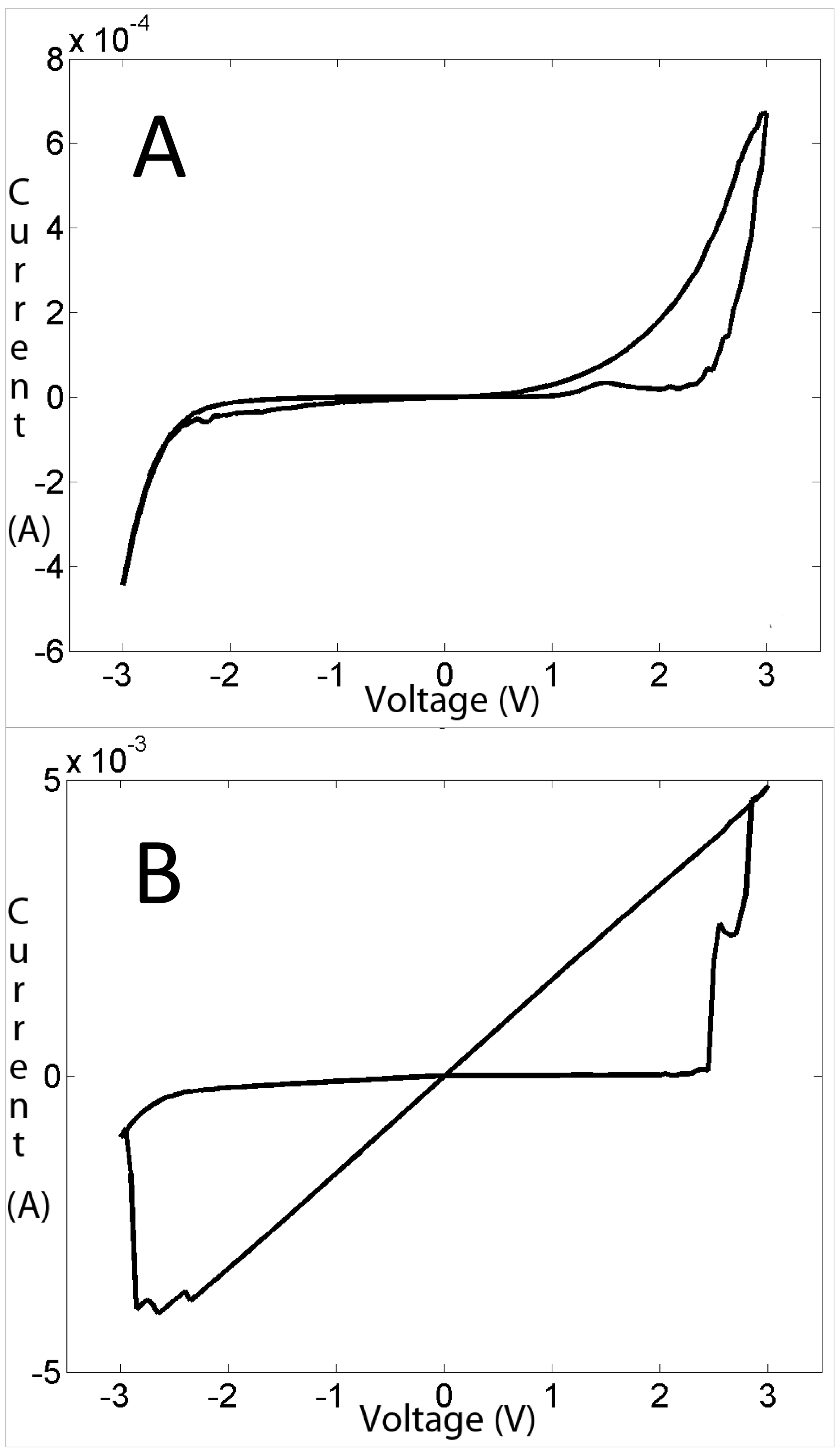

Figure 2. Experimentally measured I-V curves obtained from TiO_2 sol-gel memristors. The 'curved' type, A, have R_{off} and Ron in the same order of magnitude, the 'triangular' type, B, has R_{off} and R_{on} separated by several orders of magnitude.

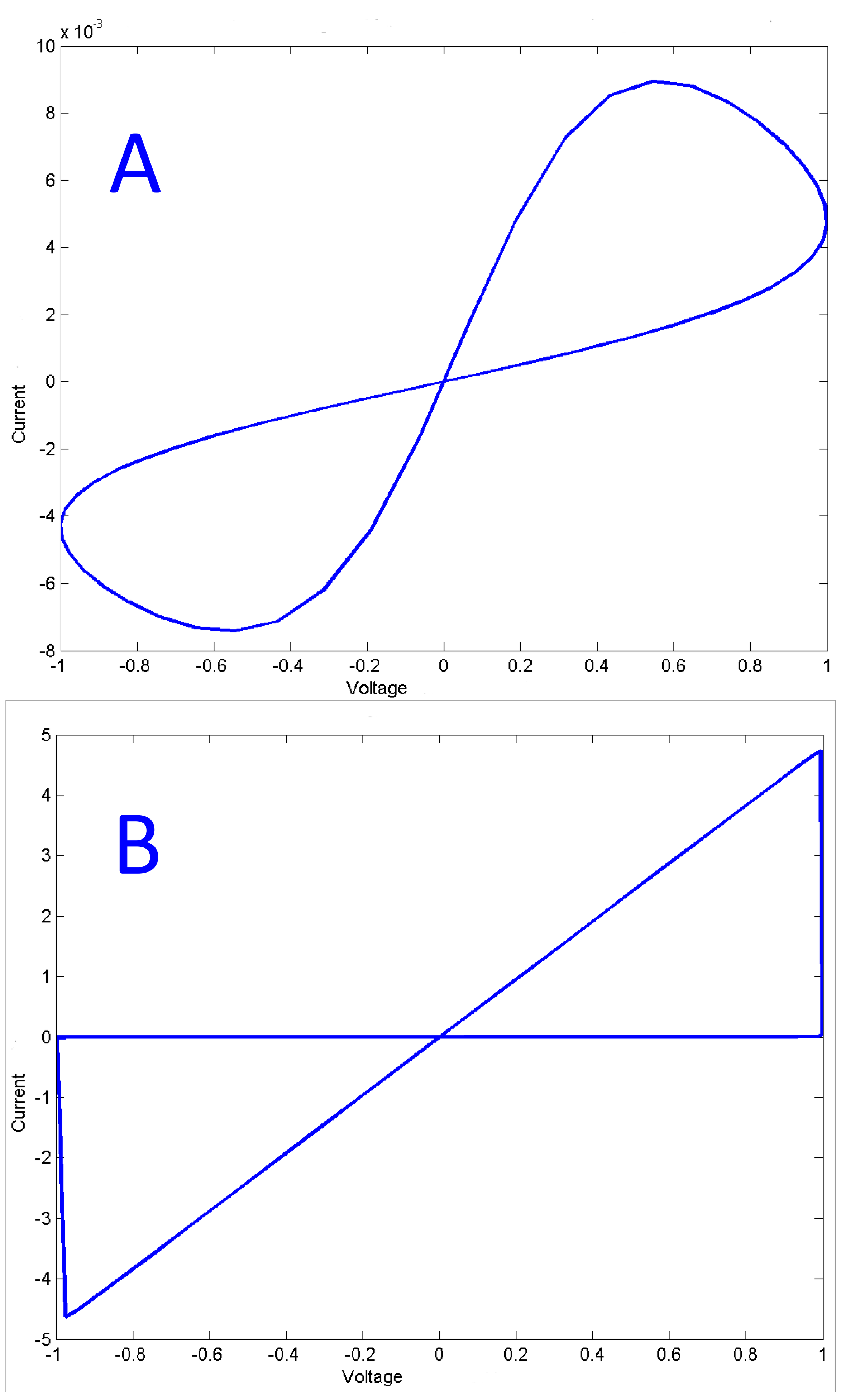

Figure 3. Simulated curves from the mem-con theory, A, and the filamentary extension to the mem-con theory, B.

Filamentary Memristance

The filament is modelled as being in parallel with the bulk movement of oxygen ions within the conical frustrum envelope seen in fig. 1. The total system memristance, R_{Tot}, is given by:

$$R_{Tot} = \frac{1}{\frac{1}{F_{Mem} + F_{Con}} + 2H\,(w - D)\,\frac{1}{R_{fil}}},$$

where F_{Mem} is the memory function, F_{Con} is the conservation function, R_{fil} is the resistance of the filament. The Heaviside function, H, is used to model the connection and rupture of the filament. The filament connects when the drifting ions reach D.

Conclusions

- The 'bulk' Mem-Con model, fig. 3A describes the qualitative characteristics of the 'curved' memristor switching, fig 2A.
- The addition of a switching filament to the model, see fig. 3A, improves the description of triangular switching, see fig. 2B

This result adds to the evidence that triangular switching memristors operate via a filamentary mechanism. This extended theory provides us with a more physically relevant model for use in neuromorphic computing simulations to test and refine our experimental designs.

References:

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