Study of Vanadium Electrolytes for the Integration of Flow Batteries in Thermal Applications

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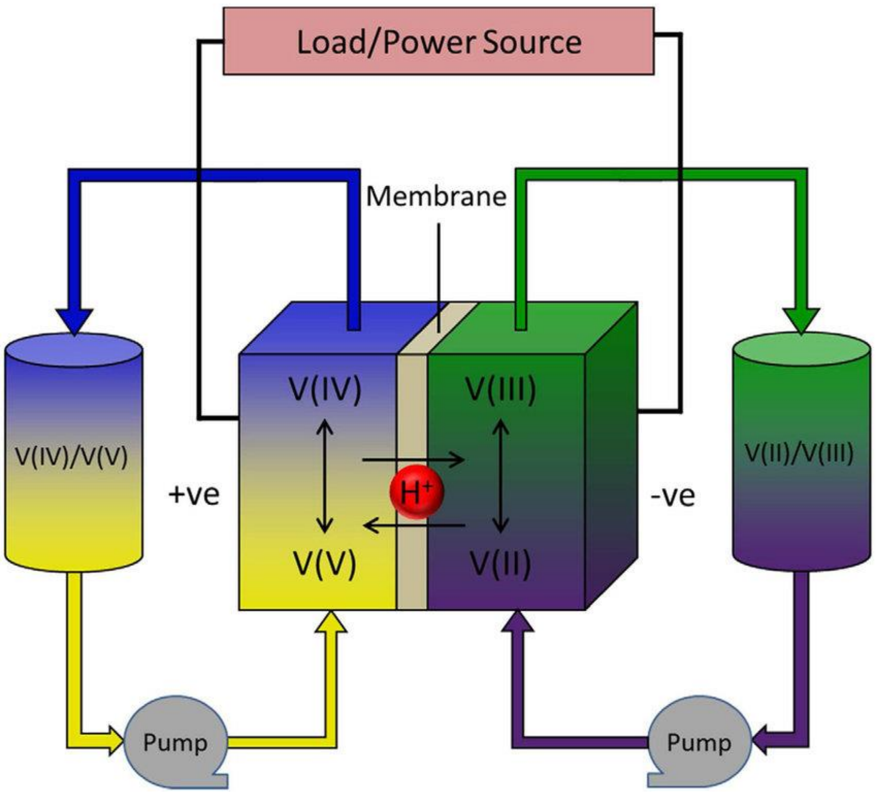
Outline

- INTRODUCTION
- OBJECTIVES
- METHODOLOGY
- WORK PLAN
- RESULTS

Principle of a VRFB



- RFB systems operate with electrolytes containing a vanadium concentration between 1.6 and 1.8 M
- Electrolyte needs cooling and heating systems to maintain the temperature between 15 and 40ºC
- Used for large scale energy storage applications

Hybrid Energy Storage Systems – Combine thermal applications with redox flow batteries

Adaptation of vanadium batteries to an extended temperature range

- **conventional flow batteries are not totally functional**
- **Improvement of electrolyte stability to an extended temperature range is needed**
- **Enhancement in the energy density is needed**

Objetives

- **Selection of advanced additives to be used for the capacity enlarging strategy to enhance the operational temperature range of the VRB for emerging applications**
  - ➢ **Screening of compounds and reagents to be included in the electrolytes**
- **Development of an enhanced vanadium electrolyte for emerging applications characterized by better performance in wider temperature ranges**
  - ➢ **Evaluation the compounds in a vanadium electrolyte environment to determine potential capacity increase**
- **Proof of concept**
  - ➢ **Integration of electrolytes in a flow cell focusing on the proof of the novel energy storage concept**

Methodology

1. Step: Physicochemical and electrochemical characterization

- Stability
- Vanadium concentration analysis
- Viscosity
- Density
- Electrical conductivity
- pH
- ORP
- Thermal conductivity
- Kinetic Parameters

SOC:
10%, 30%, 50%, 65%

Temperatures:
5ºC, 25ºC, 40ºC, 50ºC

Vanadium concentrations:
1.6M, 1.8M, 2.0M

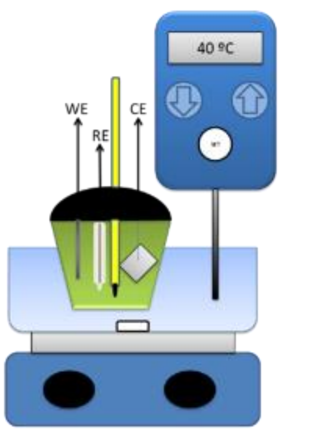
Methodology

2. Step: Selection of compounds for capacity enhancement

Requirements:

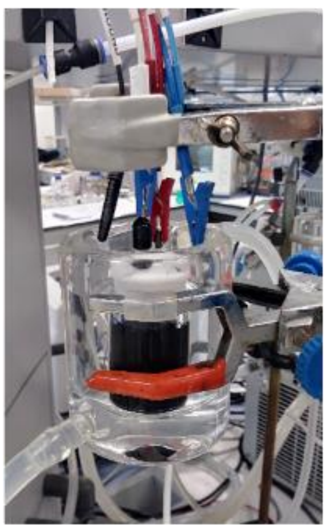
- **Solid in pH 0**
- **Redox potential < 1 V for activation of mediating properties in charge**
- **Redox potential > 1 V for activation of mediating properties in discharge**

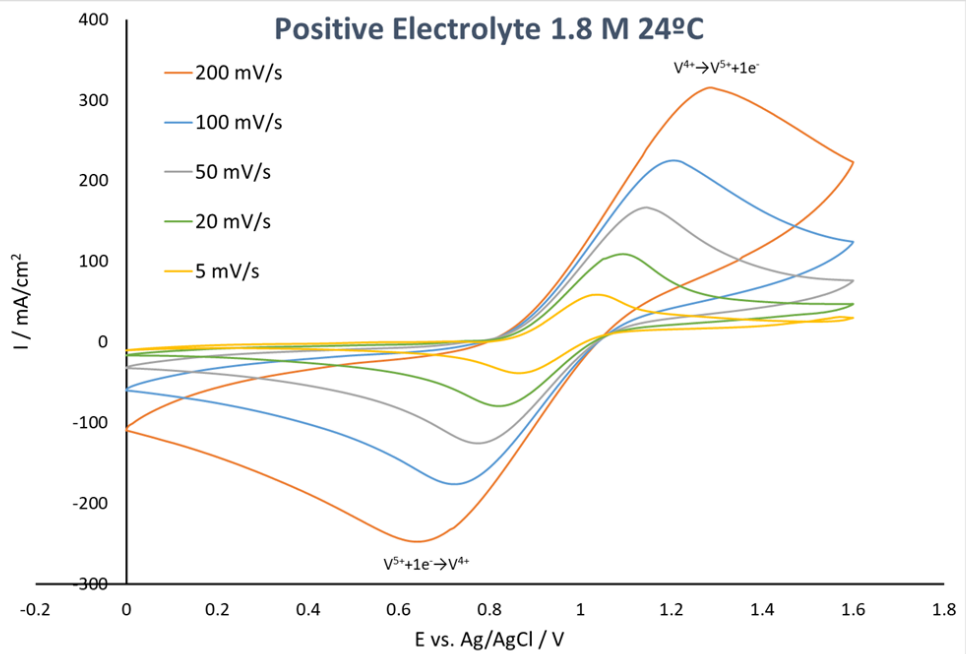
Tests with Cyclic Voltammetry



TEMPERATURE RANGE: **5-50ºC**

SCAN RATE: **5-200 mV/ s**





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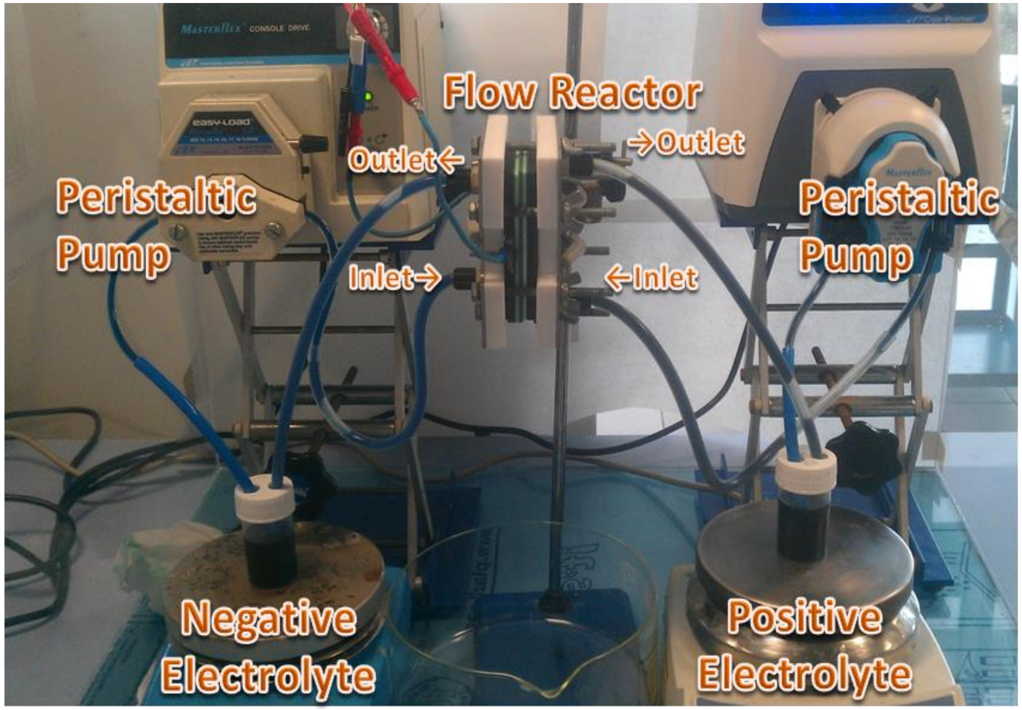
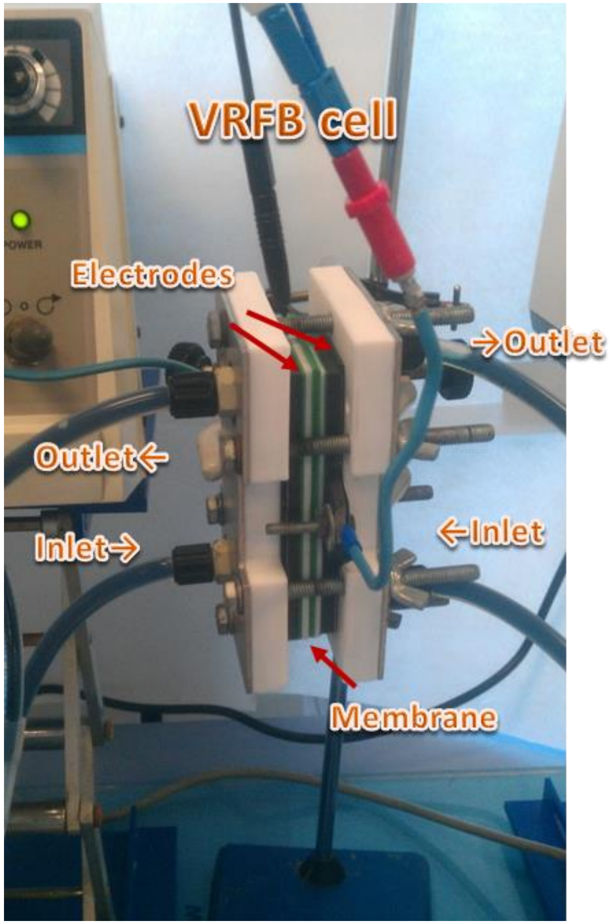
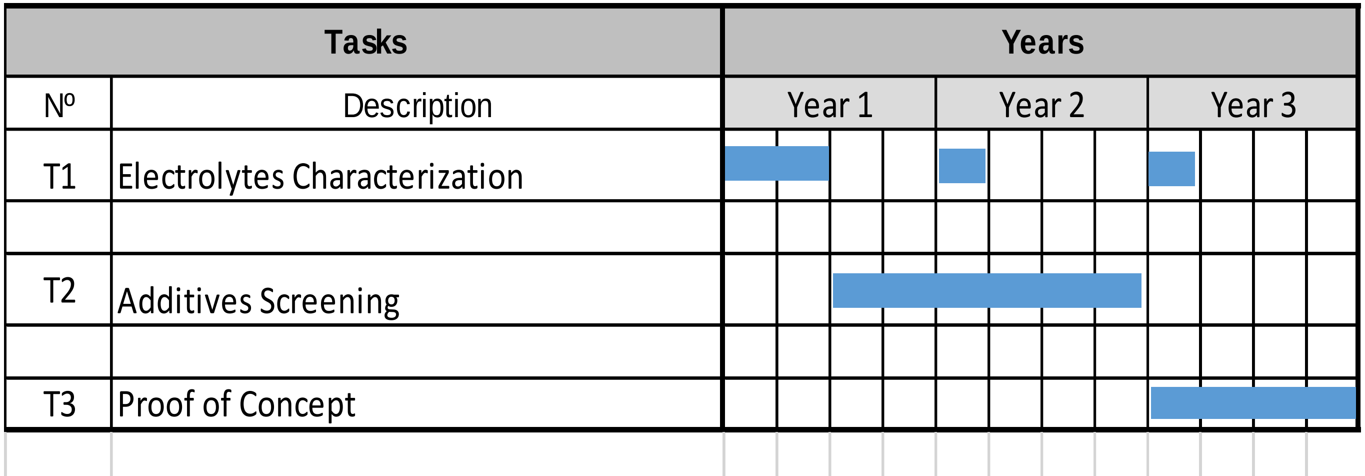
3. Step: Proof of concept: Validation of the capacity enhancement

Charge and Discharge Cycles with a laboratory scale set-up at different operating conditions





Work Plan



T1: Physicochemical and electrochemical characterization of electrolyte from 5ºC to 50ºC for different vanadium concentrations: determination of the limits of the operational range

T2: Selection of compounds for capacity enhancement. This step includes an extensive literature research to screen organic and inorganic materials to be used as additives with the possibility for a capacity increase in the positive and/or negative electrolyte.

T3: Proof of concept to validate the capacity enhancement. The tests will be conducted in a simplified laboratory setup, Tests will be carried out to obtain basic operating data such as capacity, energy efficiency and the number of cycles at different operating conditions from 5 to 50ºC.

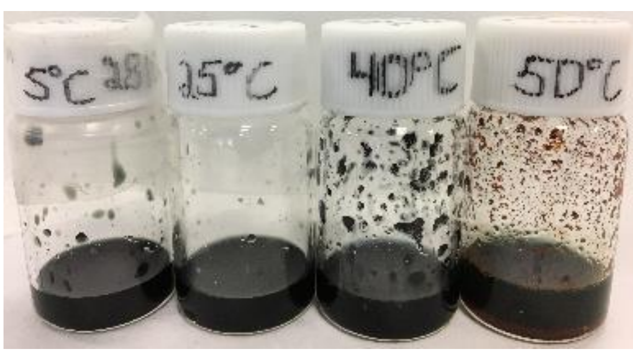
Stability of Vanadium Electrolytes

1.8 M

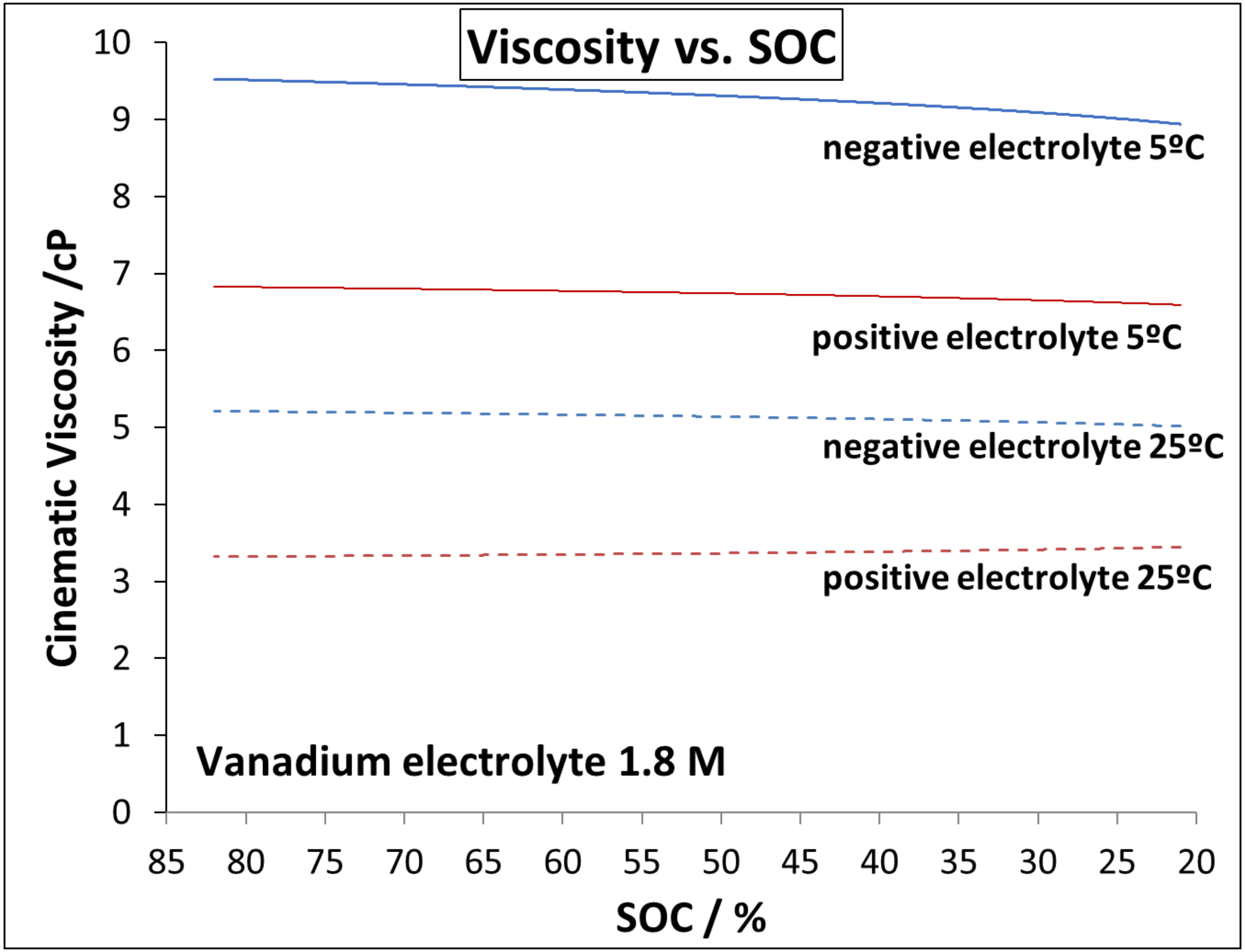
V species	5ºC	25ºC	40ºC	50ºC
V^{2+}	✓	✓	✓	✓
V^{3+}	✓	✓	✓	✓
V^{4+} (VO^{2+})	✓	✓	✓	✓
V^{5+} (VO_2^+)	✓	✓	✗	✗

0.9 M

V species	5ºC	25ºC	40ºC	50ºC
V^{2+}	✓	✓	✓	✓
V^{3+}	✓	✓	✓	✓
V^{4+} (VO^{2+})	✓	✓	✓	✓
V^{5+} (VO_2^+)	✓	✓	✓	✓

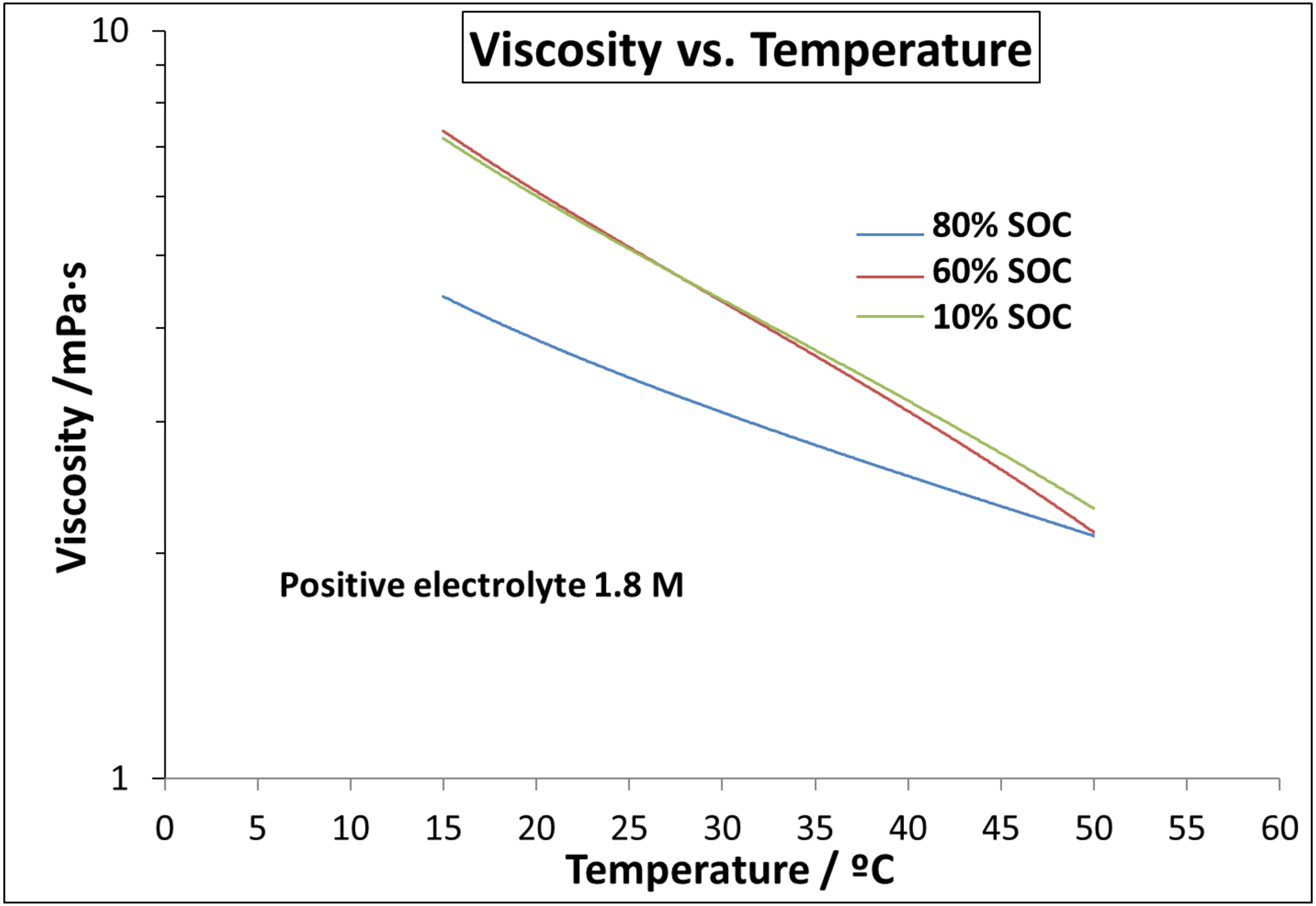


Results



Viscosity vs. SOC
Cinematic Viscosity /cP
10
9
8
7
6
5
4
3
2
1
0
negative electrolyte 5ºC
positive electrolyte 5ºC
negative electrolyte 25ºC
positive electrolyte 25ºC
Vanadium electrolyte 1.8 M
85 80 75 70 65 60 55 50 45 40 35 30 25 20
SOC / %

Results



Viscosity vs. Temperature
Viscosity /mPa·s
10
1
80% SOC
60% SOC
10% SOC
Positive electrolyte 1.8 M
0
5
10
15
20
25
30
35
40
45
50
55
60
Temperature / ºC

Conclusions & Outlook

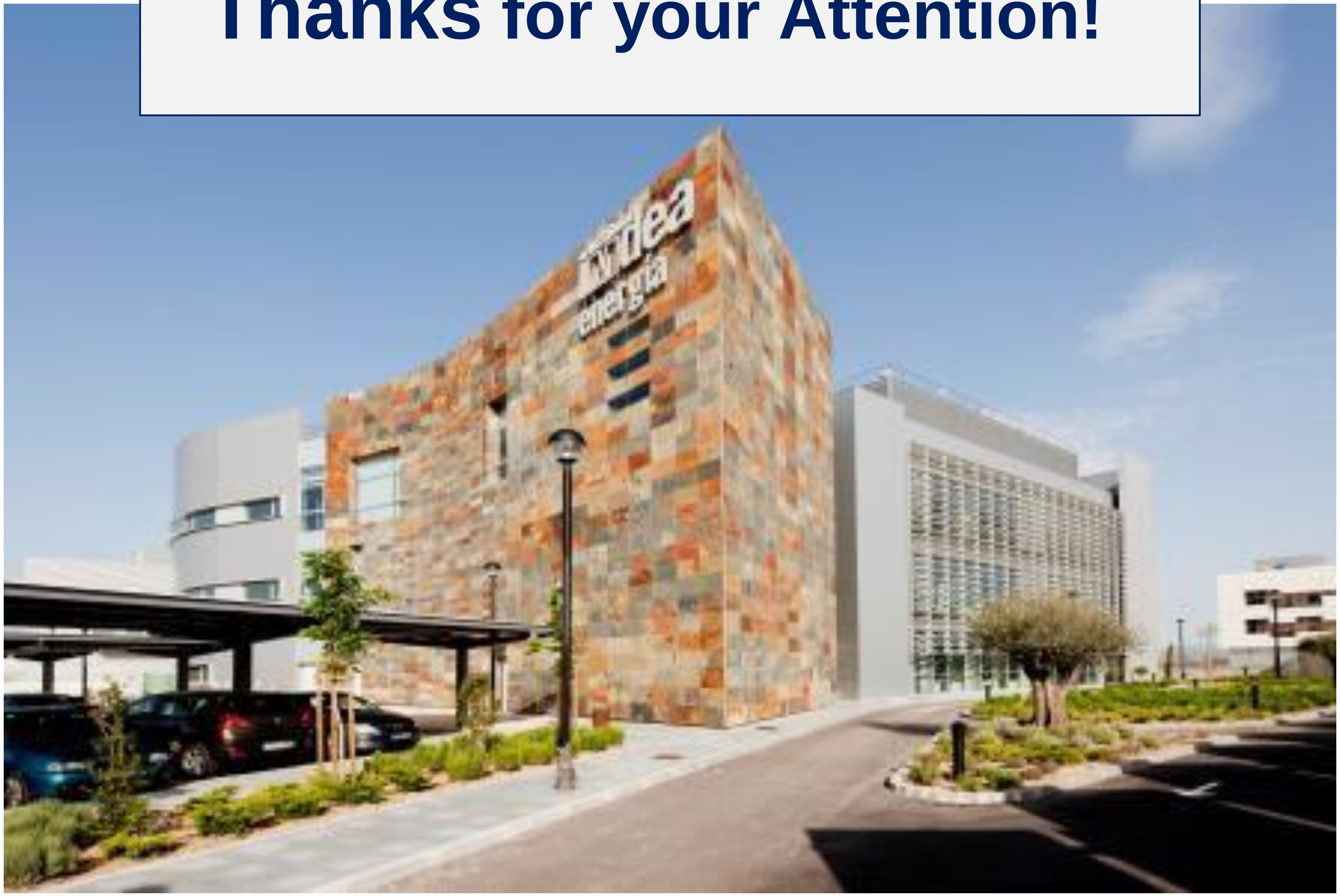
Conclusions:

- Stability tests at different temperatures show that the positive vanadium electrolyte precipitates above 40ºC
- Reducing vanadium concentration improves the stability
- Higher operational temperature improves the viscosity

Future Work:

- Improvement of energy density by introducing a redox mediating electrolyte and proof of concept in a laboratory scale set-up institute imdea energy

Thanks for your Attention!



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