VEGA - JTC 2021 call

VErtical Graphene for Aluminium-ion batteries

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Consortium

List of partners	Funding agency	Role in VEGA
Jožef Stefan Institute (JSI), Slovenia (Coordinator) **PI: Prof. Uroš Cvelbar**	Ministrstvo za izobraževanje, znanost in šport (MIZS)	• Coordination • Plasma synthesis of VGN • Designing VG-based cathodes for AIBs
Chalmers University of Technology (CUT), Sweden **PI: Dr. Jinhua Sun**	Swedish Research Council	• Electrochemical evaluation of hybrid VGN-electrodes for AIBs • Understanding the energy storage mechanism of VGN
University of Orléans (UO)/ Groupe de Recherches sur l'Energétique des Milieux Ionisés (GREMI UMR 7344), France **PI: Prof. Eva Kovacevic**	Agence nationale de la recherche (ANR)	• Analysis and simulation of VGN growth model • Designing graphene-based electrode assembly

Overview

VEGA's strategic lines with Graphene Flagship: Division 4: Energy, Composites and Production; Work package 12: Energy Storage

VEGA´s Identified *Scientific Questions*

- Alternatives to LIBs and identifying suitable multivalent metals for battery systems.
- Design and optimisation strategies of graphene as cathode material for Al^{3+} batteries.
- Establishing environmental friendly technique for graphene synthesis.
- Switching the morphology of graphene from horizontal to vertical on different substrates.
- Controlling the intersheet/interlayer spacing between two graphene layers.

Why AIBs: Low manufacturing cost, high stability and abundant availability of aluminium

Graphene as cathode: High conductivity, stability and layered structures allows a long-term intercalation reaction

Impact of vertical orientation: Fast ion diffusion and large electrode-electrolyte interaction area

Larger inter layer distance: Large number of intercalation and enhanced electrochemical performance

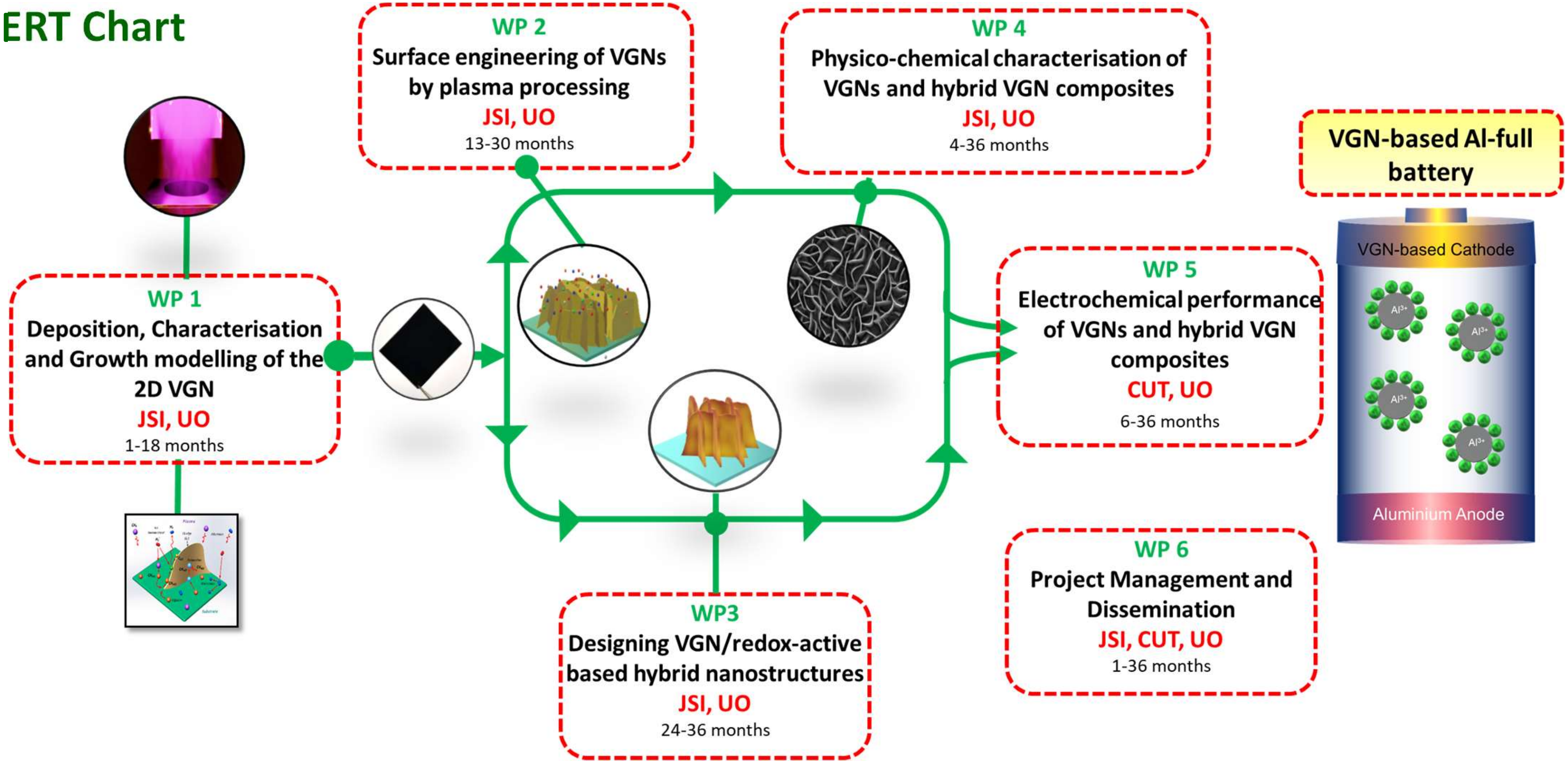
Objectives

VEGA goal: Plasma-enabled synthesis and engineering of Vertical Graphene for Aluminium ion batteries.

Scientific Objective	VEGA approach
Green approach for large-scale synthesis of vertical graphene	Demonstration of plasma enabled large-scale synthesis and processing of high-quality VGNs.
Graphene with interlayer distance between graphene layers more than 0.34nm	Adjusting plasma parameters during the initial deposition including temperature, gas mixtures, field of electric field to substrate etc.
Unravel several intercalation mechanisms in graphene as a cathode for AIBs.	Operando spectroscopic techniques for understanding the changes during electrochemical reactions.
Enhancing electrochemical performance by designing hybrid VGN-based composites as a cathode material for AIBs.	Designing VGN with metal sulphides or oxides to fabricate hybrid electrodes
Design a binder-free VGN-based cathode for advanced AIBs.	VGN structures embedded in polymer matrix to give flexibility.

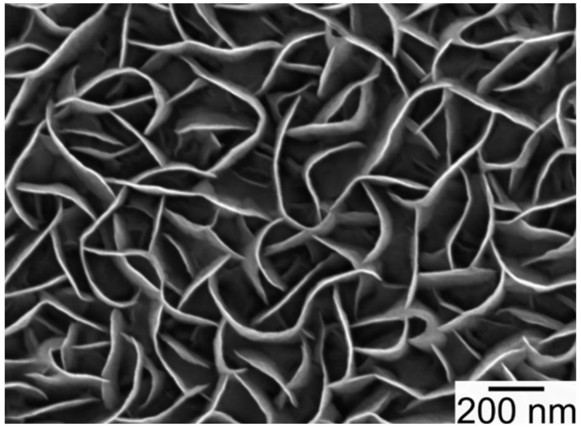
Work Plan

VEGA PERT Chart

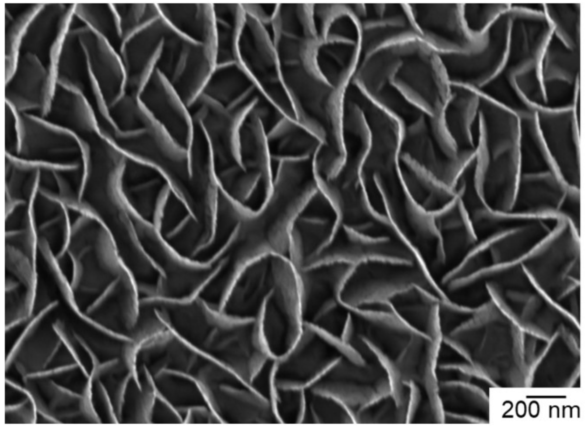


Initial Efforts

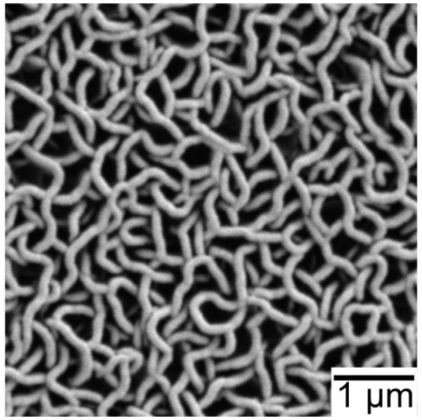
Plasma-deposited VG



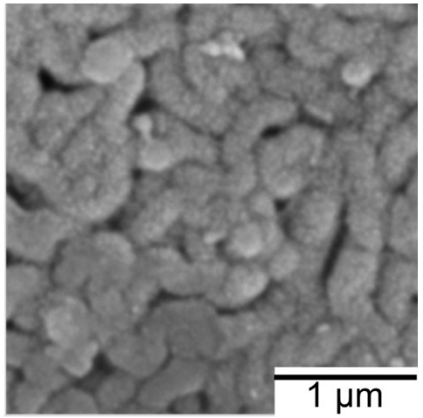
Plasma-assisted N-doped VG

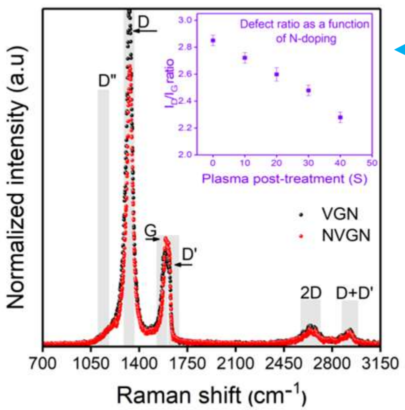


VG/ metal derivatives



VG in polymer matrix



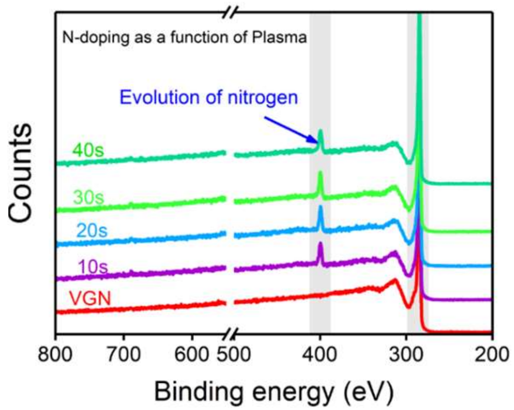


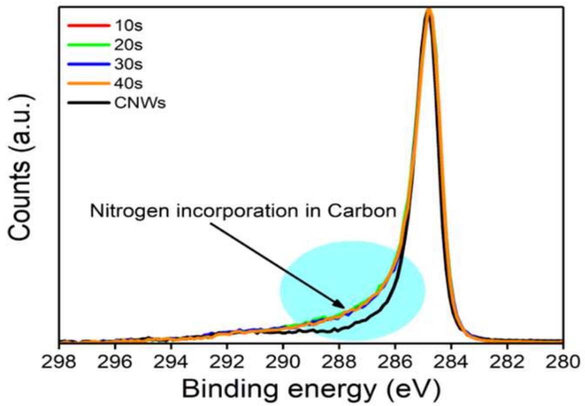
Raman spectra

Chemical changes in VG after plasma nitrogen incorporation

XPS analysis

N. M. Santhosh, et al.. Nano-Micro Lett. ***12****, 53 (2020).*





Expected Results

Key Performance Indicator	Target result
Deposition area and rate of the proof-of-concept plasma device	Area of deposition ~600 cm^2 per 1 hour and Height of deposition ~ 1µm/10 min
Interlayer spacing of graphene layers	Distance between 2 graphene layers in VGN increase to reach ~ 0.34 -0.5 nm
Surface engineered VGN	Achieve a high concentration of foreign atom with controlled bond configuration in the VGN lattice ~10%
Electrochemical performance	Achieve capacity of 400 mA h/g with long term cycling stability, 1000 cycles. Retain 80% initial capacity at a current density of 500 mA/g
Technology implementation	Implementing full-scale AIB using VGN-based cathodes and Al anodes and seek for the industrialization of the method and product.