

CONCEPT PAPER

for KIER International Cooperation Project

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Title	Designing 3D-framework as a dendrite-free electrode for solid-state lithium batteries (SSLBs)			
1. Needs	Li-ion batteries are considered the most advanced energy storage technology for powering electric transportation systems. To improve the energy density of Li-ion batteries, recent research efforts have been focused on employing Li metal anodes due to its light density (0.53 g/cm ³) and superior specific capacity (3,860 mAh/g vs. 372 mAh/g for commercial graphite anode). However, there are directly interrelated issues for Li metal anode: uncontrolled dendrite growth, unstable solid electrolyte interphase (SEI), and infinite volume change during charge/discharge process, all of which lead to accelerated cell energy fading and safety problems.			
2. Competition	Solid-state electrolytes (SSEs) are considered the key enabling strategy for solving these issues due to their unique safety features. Despite significant progress on SSE technologies, it is still difficult to control dendrite growth issues for a high level of success in SSLBs. Recently, the use of conductive nanostructured 3D-framework electrode has emerged as a promising strategy to control Li plating/stripping process and inhibit Li dendrite growth in Li metal batteries (LMBs). The unique morphology of 3D-framework electrodes is highly porous structures that can control the dendrite growth as well as facilitate ion and mass transportation. Therefore, it is essential to develop a new method to create the 3D-framework with controlled structure and property that can effectively control the dendrite growth.			
3. Approach	The uncontrolled Li dendrite growth during Li plating/stripping has limited practical application of high energy SSLBs. This project plan to solve this issue by employing nanostructured 3D-framework electrode that can control Li plating/stripping process and inhibit Li dendrite growth in SSLBs. Since the diffusion, distribution, nucleation and growth reactions of Li are highly dependent on the surface properties and architecture of the conductive framework, controlling the structures and properties of the 3D-framework are essential. This proposed work is aimed at designing and fabricating the novel conductive 3D-framework electrode with unique spatial structure, elucidating reaction mechanisms for metal plating/stripping during repeated battery cycling, and providing the technical solution for the dendrite-free electrode with high Coulombic efficiency, which is suitable for stable operation of high-energy SSLBs.			
4. Benefit	The synergetic point of the project lies in the joined expertise of KIER and foreign researcher to efficiently develop the 3D-framework electrodes for high-energy SSLBs. The foreign PI should be an expert of 3D nanostructured electrodes for LMBs. Based on their expertise, collaborative work by two PIs will enable to develop a new, advanced energy storage material for SSLBs with significantly improved energy density. An active collaboration that involves iterative process between the nanostructure design at foreign researcher and the large-scale demonstration of the batteries at KIER is a key factor to the success of this project.			
5. Deliverables	Key deliverable – Design and fabrication of the structure-controlled 3D-framework – Structural characterization of the 3D-framework. – Electrochemical performance evaluation of the graded 3D-framework and feasibility demonstration as a dendrite-free electrode in SSLBs with high energy density (> 250 Wh/kg) – At least 2 publications in peer-reviewed journals and/or patents			

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Title	Development of an intelligent reliable fuel electrode material using an ex-solution technique			
1. Needs	<ul style="list-style-type: none"> ● To develop solid oxide cells (SOCs) providing a high performance and hydrogen production as well as low degradation ● To design rational fuel electrode materials by understanding degradation phenomena on the electrode during SOC operation 			
2. Competition	<ul style="list-style-type: none"> ● To produce electricity or green hydrogen with high efficiency and durability ● To extend the materials design strategy toward the technology of protonic ceramic fuel cells (PCFC), CO₂ electrolysis, and co-electrolysis (steam & CO₂) 			
3. Approach	<ul style="list-style-type: none"> ● To examine the deterioration of Ni-based cermet fuel electrodes under various operation conditions including variable steam contents and impurities to figure out the electrode degradation ● To prepare fuel electrode materials using an ex-solution technique in which nano-sized active transition metal catalyst particles embedded in the electrode surface, enhancing the steam electrolysis and long-term stability ● The as-synthesized materials are applied to SOC electrodes and examined for the electrochemical performances and durability 			
4. Benefit	<ul style="list-style-type: none"> ● Securement of a highly efficient power generation and green hydrogen production technology ● Application of the materials technology to co-electrolysis, ammonia fueled fuel cells, and electrochemical cells, etc. 			
5. Deliverables	<ul style="list-style-type: none"> ● Key deliverable <ul style="list-style-type: none"> – Metal ex-solution particle population > 100/μm² – Electrical current density > -1 A/cm², degradation < 1.5%/kh – Two SCI papers (IF > 5) and a patent applied for 			