D. Energy Conversion and Storage Materials

Organizers: Ying Wu, Hongge Pan, Yunhui Huang, Jian Li

D-01 (Invited)
Research Progress of Carbon-based Tri-layer Composite Solid Oxide Fuel Cells
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Cost and reliability of solid oxide fuel cell (SOFC) system severely hinders its wide-spread commercialization. In this study, Low cost of tri-layer composite SOFC was designed and developed. High performance with uniformly distributed nano electrode was obtained via tape-casting and infiltration. And the technology was applied for the single cell of industrial size (10 cm × 10 cm), the high performance and well stability was verification.

D-02 (Invited)
Understanding the Performance Degradation of Solid Oxide Electrolysis Cells
San Ping Jiang
Curtin University

Renewable energy sources such as solar and wind power are important for the future energy supply, but requires suitable energy storage and regeneration technologies due to the nature of the intermittency in electricity generation. Solid oxide cell (SOC) is such a highly efficient device which can store the renewable electricity into chemical energy of fuels under solid oxide electrolysis cell (SOEC) operation mode and to regenerate the electricity from the stored fuels under solid oxide fuel cell (SOFC) operation mode. However, there are significant technological barriers for the development of SOCs, one of them is the significant performance degradation under the SOEC mode. This talk will reviews and update critically the durability and performance degradation issues of the SOECs and the emphasis is mainly on the physical, chemical and microstructural processes that cause the degradation and their dependence on the operation conditions and nature of the oxygen and hydrogen electrodes and electrolyte materials. The degradation due to the contaminants such as chromium, boron and silica from metallic interconnect, borosilicate glass sealants and/or raw materials will also be discussed. The recent development in the fundamental understanding of the sequence of the delamination processes at the oxygen electrode/YSZ electrolyte will be presented.

D-03 (Invited)
Metal Boranes for Multiple Energy Applications
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Metal boranes M(BxHy)n have been attracting increasing interest from the viewpoint of energy applications, especially in the context of solid-state hydrogen storage, superionic conductivity and CO2 conversion. Lower boranes such as metal tetrahydroborate M(BH4)n like LiBH4, Mg(BH4)2 and Ca(BH4)2, with hydrogen gravimetric density higher than 10 mass%, have been extensively investigated for high density hydrogen storage. Higher boranes such as metal dodecaborate M2(B12H12)n with a stable icosahedral cage structure, has been widely regarded as one of the main reasons resulting in the degraded re-hydrogenation. M2(B12H12)n, on the other hand, favors its potential application as superionic conductor. Recently, we found that the ionic conductivity of a bimetallic closo-borane LiNaB12H12 reaches 0.79 S/cm at 550 K above its order-disorder phase transition. This value is 10 times higher than those of its single counterpart of Li2B12H12 and Na2B12H12 at the same temperature. In addition, metal tetrahydroborate KBH4 was demonstrated to be capable of converting CO2 to methanol and methane in water-free conditions without using catalyst. In this presentation, we will overview the state-of-the-art of major achievements of metal boranes for hydrogen storage, superionic conductivity and CO2 conversion. Furthermore, we will discuss in detail the intrinsic mechanisms and future perspectives for multiple energy applications.

D-04 (Invited)
In-situ Neutron Powder Diffraction studies of phase equilibria in La-Mg-Ni alloys and their electrochemical performance as anodes of the metal hydride battery
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Ternary La-Mg-Ni hydrogen storage alloys attract significant interest as active anode materials of the Ni/MH batteries. Partial substitution of La by Mg in PuNi3-type alloys increases the electrochemical discharge capacity to 400-410 mAh g⁻¹, 25-30% superior as compared to the commercial AB5-type MH electrodes [1-5]. In present work we have studied phase equilibria in the as cast La₃₋ₓMgxNi₉ (x=1.0-1.2) alloys by applying in situ neutron powder diffraction in the temperature range from 300 K to 1273 K. Various transformations take place during the annealing of the alloys when temperature and holding time increase, leading to the variations of the phases content and transformations between the super-stacking intermetallics, having variable ratios (La+Mg)/Ni, 1:3, 2:7 and 5:19. Mg substitution for La and annealing of the alloys promote the formation of more homogeneous materials, with abundance of the target AB3 intermetallic depending on the magnesium content. The electrochemical properties are improved after annealing at 1223 K for 6 h. At 0.1 C, discharge rate of the pasted electrodes prepared from the annealed alloys show a discharge capacity of 340-350 mAh g⁻¹ (which increases to 400 mAh g⁻¹ for the pelleted electrodes containing carbonyl Ni), with 63 % of the capacity remaining at a discharge rate of 1.3 C. After 200 cycles with 100% depth of discharge, the annealed electrodes demonstrate very good cycle stability with a discharge capacity being at a level of 64 % of the initial capacity.

D-05
Effect of nickel/polypyrrole composite surface coating on electrochemical properties of La-Mg-Ni-based alloys
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La-Mg-Ni-based alloys are considered as a promising candidate owing to their high capacity and easy activation during the last decade. However, this kind of alloys suffers from poor high rate dischargeability and lower cycling stability. In our endeavor to improving the overall electrochemical properties, we succeed to deposit a nickel/polypyrrole composite layer at the alloy surface by an electroless co-deposition method. The sample with composite coating shows a sponge-like surface layer which provides rather large area which is beneficial to electrode reaction. The new surface layer contains metallic nickel and polypyrrole, and they have a synergetic effect during charge/discharge process. The polypyrrole and nickel in the composite coating fasten the charge and discharge process, respectively. The electrode with composite coating shows smaller charge transfer resistance and higher hydrogen diffusion coefficient, and consequently high rate dischargeability is greatly increased by 10.2% at a discharge current density of 1200 mA/g. As well as activation properties and charge retention rate are improved owing to the catalytic activity and the protective function of the composite coating.

D-06
Highly efficient bimetal synergetic catalysis of graphene supported palladium and nickel on hydrogen storage of magnesium hydride
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To improve the hydrogen storage performance of magnesium hydride, graphene supported Pd and Ni (PdNi/GN) was introduced to the magnesium-based materials. PdNi/GN catalysts were synthesized by a two-step chemical reduction method. Afterwards, the nanocomposites were prepared for the first time by hydriding combustion synthesis (HCS) and mechanical milling (MM). It is determined by X-ray diffraction (XRD) analysis that Pd/MWCNTs can significantly increase the hydrogenation degree of magnesium during the HCS process. The microstructures of the composites obtained by transmission electron microscope (TEM) and field emission scanning electronic microscopy (FESEM) analyses show that Pd and Ni nanoparticles are well supported on the surface of carbon nanotubes and the PdNi/GN are dispersed uniformly on the surface of MgH2 particles. Moreover, it is revealed that there is a synergistic effect of Ni and Pd on the hydrogen storage properties of the composites. The Mg95-(Pd3Ni3/GN4)5 shows the optimal hydriding/dehydriding properties, requiring only 100 s to reach its saturated hydrogen absorption capacity of 6.27 wt.% at 473K, and desorbing 6.86 wt.% hydrogen within 1200 s at 573 K. Additionally, the dehydrogenation activation energy of MgH2 in this system is decreased to 71.6 kJ/mol H2, much lower than that of as-received MgH2.

D-07
A coralline-like N-doped hierarchically porous carbon derived from Enteromorpha as host matrix for lithium-sulfur battery
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A novel N-doped coralline structured hierarchical porous carbon (NHPCs) with mostly micropores derived from enteromorpha was prepared as sulfur host for high performance Li-S batteries. The BET surface area of this “coralline” structure is as high as 2124 m2/g, which is beneficial to shorten Li+ migration path and accelerate the rate of electrochemical reaction. The cathode containing 40 wt.% sulfur exhibited an initial discharge capacity of
1555 mAh/g (93% of theoretical capacity) at a current density of 0.1C and a capacity loss of 0.05% per charge-discharge cycle after 500 cycle at a current density of 0.5C with a stable coulombic efficiency of 100% at a sulfur loading of 1 mg/cm2. The high-performance of this electrode in Li–S batteries can be attributed to the hierarchically porous carbon infrastructure and inherently abundant nitrogen-doping.

Fig. 1  SEM images of NHPC700G before (a and b) and after sulfur loading (c and d). Selected image for EDX mapping and elemental mapping of carbon, nitrogen and sulfur (e, f, g and h, respectively).

D-08
First principles study of the charge transport mechanisms in lithium superoxide
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A huge effort is underway to develop Li-air batteries for modern energy-storage applications. The understanding of the charge transport mechanisms in the reaction products could have profound implications for the enhancement of the battery performance. The primary discharge product has been identified to be lithium peroxide, Li2O2, the conductivity of which is under intensive experimental and theoretical investigation in recent years. However, the study of lithium superoxide, LiO2, which is presumed as an intermediate product, has been largely ignored until very recently when the synthesis of pure LiO2 was reported [Nature 2016, 529, 377-382]. Here, to unravel the charge transport mechanisms in LiO2, we perform first-principles calculations to predict the concentrations and mobilities of charge carriers and intrinsic defects. On the basis of hybrid functional approach our results indicate that crystalline LiO2 is an insulator, with bandgaps in excess of 3 eV. Formation of small electron and hole polarons is strongly preferred over the delocalized state, which is similar to those found in Li2O2. The electronic conductivity is mediated by both kinds of polarons, wherein the hole polarons exhibit a slightly higher mobility. Ionic contributions to the conductivity in LiO2, which are mainly comprised of the p-type oxygen dimer vacancies and n-type lithium vacancies, turn out to be non-negligible according to our calculation results. Finally, we discuss the charge transport properties in light of the recent experimental findings, which we hope will be helpful for further exploration and development in Li-air electrochemical cells.

D-09
Suppressing the Polysulfide Dissolution for High Performance Lithium Sulfur Battery
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Lithium-sulfur batteries are regarded as one of the most promising secondary battery system at
present due to their high theoretical specific capacity and theoretical specific energy. However, widespread practical applications for rechargeable lithium-sulfur batteries are plagued with many problems, such as low utilization rate, poor cycle life and rate performance, poor safety. To solve the above problems, conductivity of elemental sulfur should be improved and shuttle effect should be inhibited. In this talk, we proposed a new strategy to improve the performance of lithium sulfur battery by the suppression of the polysulfides dissolution, optimization of the composite materials with high conductivity, modification of the electrolyte. A long cycle life of 500 cycles could be achieved. In-situ XANES and UV/Vis spectroscopy by analysis of the electrolyte and in-operando XPS by investigation of electrodes confirmed that covalent bond can effectively reduce the production of long-chain polysulfide, which is confirmed by DFT calculations.

In-situ electrochemical study of lithium battery is regarded as one of most hot and challenge topics that the world is facing today. In this talk, the single battery was fabricated by rolled-up method, and will be applied to the study of the SEI formation and its properties. Through a combination of various characterization methods such as Auger Electron Spectroscopy (AES), Electrochemical Impedance Spectroscopy (EIS), and Transmission Electron Microscopy (TEM), the formation voltage, interface composition and depth profile, Li-ion intercalation and de-intercalation interface reaction, and properties of SEI layers will be explored, and the effect on the performance of lithium ion battery will be discussed as well.

D-10

Optimization and Investigation on Annealing Process and Nanometer Scale Piezoelectric Properties of (002) AlN Thin Films

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Currently, one of the most widely used thin film material in surface acoustic wave (SAW) device is (002) aluminum nitride (AlN) because of its fastest acoustic velocity along c-axis which can reach to 9650m/s. In order to improve the crystallographic orientation of (002) in AlN films, annealing was applied to give a temperature compensation to make the film recrystallized. In this study, the effects of different annealing processes on film texture, surface morphology, and piezoelectric properties of AlN thin films as well as the performance of AlN-based SAW devices were systematically investigated. The AlN films were directly deposited on SiO2/Si and Pt substrates in N2 atmosphere by DC magnetron sputtering using Al targets. The as-grown AlN thin films were annealed in N2 atmosphere for 30min with temperature ranging from 300oC to 600oC (with interval of 100oC) by means of in-situ and ex-situ, respectively. The crystal structure and piezoelectric properties of AlN thin films were characterized by X-ray diffraction (XRD), atomic force microscope (AFM), and piezoresponse force microscope (PFM). The SAW devices with 8 μm period (a=2 μm) interdigital electrodes using photolithography. The performance of SAW filter including center frequency and insertion loss were precisely measured by network analyzer. It is clearly manifested that the in-situ annealing is superior to ex-situ from the results of XRD and piezoelectric performance. There is a similar tendency of AlN thin films between crystallization and piezoelectricity: enhanced at first and receded in the end. We demonstrated that the high crystalline orientation and excellent grain distribution of (002) AlN thin films were achieved by in-situ annealing at 500oC, and high relative piezoelectric coefficient was implemented in corresponding devices.
An optimized percolative nanocomposite by building hierarchical interfaces with BaSrTiO3 nanocuboid dotted graphene sheets
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High-performance dielectric materials with high permittivity and suppressed dielectric loss are of interest for potential electrical applications. Ceramic/polymer composites show improved permittivity and low dielectric loss but the permittivity is usually limited to less than 100. The permittivity of conductive particles/polymer percolative composites can be dramatically improved by a small loading of conductive fillers, however, which is at the expense of a greatly increased dielectric loss. A dielectric composite that lies between the two kinds of composites that combine increased permittivity from a percolative composite with a suppressed dielectric loss from insulative composites is of interest. In this paper, we report an optimized percolative composite with hierarchical interfaces by dopamine modifying BaSrTiO3 (BST) nanocuboid dotted functionalized graphene sheets (FGS). Due to the hierarchical interfaces, the prevention of contact between FGS by BST nanocuboids and a tight adhesion of Dop@BST@FGS with the polymer matrix, the Dop@BST@FGS/P (VDF-HFP) nanocomposites exhibit a high permittivity of 170.4 and a suppressed dielectric loss of 0.114 at 1kHz. It is notable that the novel composite overcomes the problem of simultaneously realizing high permittivity and low dielectric loss in percolative nanocomposites. The findings of this research can provide a feasible approach to produce high-performance dielectric nanocomposite materials.

D-12 (Invited)
Nanowire Devices for Electrochemical Energy Storage
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Wuhan University of Technology

One-dimensional nanomaterials can offer large surface area, facile strain relaxation upon cycling and efficient electron transport pathway to achieve high electrochemical performance. Hence, nanowires have attracted increasing interest in energy related fields containing flexible and stretchable devices.

We designed the single nanowire electrochemical device for in situ probing the direct relationship between electrical transport, structure, and electrochemical properties of the single nanowire electrode to understand intrinsic reason of capacity fading. The results show that during the electrochemical reaction, conductivity of the nanowire electrode decreased, which limits the cycle life of the devices. Then, the prelithiation and Langmuir-Blodgett technique have been used to improve cycling properties of nanowire electrode. Recently, we have fabricated hierarchical MnMoO4/CoMoO4 heterostructured nanowires by combining "oriented attachment" and "self-assembly". We also developed the general synthesis of complex nanotubes by gradient electrospinning, including Li3V2(PO4)3, Na0.7Fe0.7Mn0.3O2 and Co3O4 mesoporous nanotubes, which exhibit ultrastable electrochemical performance when used in lithium-ion batteries, sodium-ion batteries and supercapacitors, respectively. We also established spiral-shaped three-dimensional micropseudocapacitors with the area of ≈1.67 mm2 and height of 1.7 μm, which deliver both ultrahigh energy density of 34.9 mWh cm-3 at the scan rate of 10 mV s-1 and high power density of 193.4 W cm-3 at the ultrahigh scan rate of 200 V s-1. Our work presented here can inspire new thought in constructing novel one-dimensional structures and accelerate the development of energy storage applications including flexible and stretchable devices.

D-13 Invited
The Study of Li-O2 Batteries Charging Process Based on DEMS Analysis
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Nonaqueous Li-O2 battery has received rapidly growing attention due to its high theoretical energy density. However, the fundamental understanding of cathode reaction is still limited, which hinder the potential application of Li-O2 battery. According to previous reports, the sluggish kinetic of solid state Li2O2 decomposition and side reaction caused by Li2O2 and/or intermediates cause the ever-increasing of charge profiles. To investigate the reaction taken place on different stage of charging process, we used Differential electrochemical mass spectrometry (DEMS) to identify charge product (O2) and byproducts (CO2, CO, H2). Combining with the electrochemical impedance spectrum and titration analysis, we proposed the possible reaction process of different stages. Furthermore, the influence of catalyst and redox mediator on byproducts formation has been investigated, which can offer insight into cathode reaction mechanism of Li-O2 battery.

D-14 (Invited)
Preparation and electrochemical characteristics of single-phase RE – Mg – Ni-based (RE = La, Pr, Nd, Sm) alloys with superlattice structure
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1. Induction
To mitigate the energy crisis and environmental impact of the fossil-fuel based economy, energy storage technology has been an important component of current energy strategies. Nickel metal hydride batteries (Ni/MH), as a promising energy storage technology for the integration of renewable resources, have been efficient power sources for a large range of applications due to the advantages of high energy density, environmental friendly and safety in use, etc., and have been available in many commercial applications, such as electronic tools cell phones, lighting fixtures, HEVs, EVs, and stationary energy storage wells. As negative electrode materials for the Ni/MH batteries, the AB5-type rare earth-based hydrogen storage alloys have been commercialized, but they suffer from limited discharge capacity in a range of 310 – 330 mAh g−1. In recent years, rare earth (RE) – Mg – Ni-based hydrogen storage alloys have attracted much attention as promising candidates to replace the AB5-type alloys owing to their remarkable discharge capacity and high-rate dischargeability. The ternary RE – Mg – Nix (2 < x < 4) alloys have layered AB3, A2B7, and A5B19 structures, where [AB5] and [A2B4] subunits are alternatively stacked along the c axis with different proportions [1]. However, the poor cycling stability restricts the RE – Mg – Ni-based hydrogen storage alloys to further extensive application [2]. To deeply study the capacity degradation mechanism and improve their cycling life, preparation of single-phase is basic and necessary, but this is of full of difficulty because of the similar composition and narrow temperature range between each superlattice phases and reports on the single-phase alloys are rare. Our group succeeded in preparing AB3-, A2B7-, and A5B19-type single-phase La – Mg – Ni superlattice alloys by powder sintering and induction melting methods followed by annealing treatment, and explored their formation and capacity degradation mechanism. Moreover, we also prepared AB3-, A2B7-, and A5B19-type single-phase superlattice RE – Mg – Ni (RE = Pr, Nd, Sm) alloys by the above methods and revealed the cycling stability improvement mechanism. We expect our findings can provides the basis and inspire new thoughts for improving the cycling performance of RE – Mg – Ni-based hydrogen
storage alloys for Ni/MH batteries.

2. Experimental

Single-phase RE – Mg – Ni (RE = La, Nd, Pr) alloys were prepared by powder sintering and induction melting methods followed by the annealing treatment in the study. The PuNi3-type single-phase RE0.67Mg0.33Ni3.0 (RE = La, Nd, Pr) alloys are obtained from annealing the as-cast alloys at 1123 K, 1298 K and 1293 K for 12 h, 24 h and 24 h, respectively. The Ce2Ni7-type single-phase La0.78Mg0.22Ni3.5 alloy are obtained from annealing the as-cast alloy at 1123 K for 12 h. The Sm0.80Mg0.20Ni3.5 alloy with the Gd2Co7-type single-phase was prepared by powder sintering the SmNi, MgNi2 and Ni precursors at 1223 K for 96 h. The Pr5Co19-type single-phase La0.84Mg0.16Ni3.80 and Pr0.84Mg0.16Ni3.80 alloys were prepared by powder sintering method at 1173 K for 115 h and 1223 K for 96 h, respectively, in which the precursors for the La0.84Mg0.16Ni3.80 alloy were LaMgNi4 and LaNi5 alloys while PrMgNi4 and PrNi5 alloys for the Pr0.84Mg0.16Ni3.80 alloy.

3. Results and Discussion

3.1 AB3-type single-phase RE – Mg – Ni (RE = La, Nd, Pr) alloys

The PuNi3-type single-phase RE0.67Mg0.33Ni3.0 (RE = La, Nd, Pr) alloys were prepared via the induction melting followed by an annealing treatment [3,4]. We found that the La0.67Mg0.33Ni3.0 alloy exhibits a maximum discharge capacity (Cmax) of 401 mAh g$^{-1}$ and a high rate dischargeability (HRD) of 39.0% at 1500 mA g$^{-1}$. But its capacity retention is as low as 76.3% at the 100th cycle due to its unstable structure during hydrogen absorption/adsorption cycles. In comparison, PuNi3-type single-phase Nd0.67Mg0.33Ni3.0 and Pr0.67Mg0.33Ni3.0 alloys exhibit improved overall electrochemical properties, which the HRD1500 of the double alloys significantly increased to 56.7% and 58.7%, and the cycling stability improved to 79% and 76% at the 300th cycle, respectively. The increased cycling stabilities of the Nd0.67Mg0.33Ni3.0 and Pr0.67Mg0.33Ni3.0 alloys are mainly attributed to the decreased lattice strain due to the matched volume changes of [A2B4] and [AB5] subunits during hydrogen absorption-desorption, therefore, the PuNi3-type single-phase Nd0.67Mg0.33Ni3.0 and Pr0.67Mg0.33Ni3.0 alloys show less pulverization and oxidation, and better cycling stability.

3.2 A2B7-type single-phase RE – Mg – Ni (RE = La, Sm) alloys

The Ce2Ni7-type single-phase La0.78Mg0.22Ni3.5 alloy was prepared by zoning annealing treatment of the induction melting alloy [5]. The single-phase alloy shows superior discharge capacity, close to 394 mAh g$^{-1}$, and the high electrochemical cycling stability, which can achieve 413 cycles as its discharge capacity reduces to 60% of the maximum value. We found that the capacity attenuation of the single-phase alloy is mainly due to the loss of active material at the alloy surface caused by oxidization of La and Mg, which the oxidization of La occurs prior to that of Mg, and the pulverization of the alloy is not severe with 100 charge/discharge cycles. To further improve the cycling stability of A2B7-type alloy, a Gd2Co7-type single-phase Sm0.80Mg0.20Ni3.5 alloy was firstly prepared by powder sintering SmNi, MgNi2 and Ni precursors [6]. It is found the Gd2Co7-type single-phase alloy exhibits high structural stability and excellent gas-solid hydrogen storage properties. Neither disproportionation nor amorphization occurs after 100 hydrogen absorption-desorption cycles and the capacity retention rate of the alloy at the 100th cycle reaches to 99.3% as a result. And the maximum hydrogen capacity of the Gd2Co7-type single-phase alloy reaches to 1.881 wt.% under 10 MPa H2 at 298 K and it only takes 3.4 min to achieve a maximum hydrogen content of 1.436 wt.% (1.05 H/M) at the 20th cycle and keeps this hydrogen absorption rate until to the 100th cycle. Besides, it is found that the hydrogen absorption/desorption of the Sm0.80Mg0.20Ni3.5 alloy undergoes two equilibrium stages, relating to transformation of H2 between H-solid solution phase and hydride phase with a lower rate and higher enthalpy change at the lower concentration H2 stage, and the direct conversion between H2 and the hydride phase with a higher rate and lower enthalpy change at the higher concentration H2 stage. The two step mode lowers the inner-molecular strain and mismatch in
subunit volumes of the alloy in hydrogen absorption/desorption, caused from the transformation of H2 at the lower concentration of H2 stage, thus leading to good structural stability and excellent cycling stability.

3.3 A5B19-type single-phase RE − Mg − Ni (RE = La, Pr) alloys

The La0.84Mg0.16Ni3.80 [7] and Pr0.84Mg0.16Ni3.80 alloys with only Pr5Co19-type phase were firstly prepared by our group by powder sintering REMgNi4 and RENi5 (RE = La, Pr) precursor powders in a temperature range of 600 – 900 °C, and then annealed at 900 °C for 4 and 4.5 days, respectively. It is found that the Pr5Co19-type single-phase alloys possess good discharge capacity, superior high rate dischargeability and cycling stability. The maximum discharge capacities of the alloys are 338 and 334 mAh g⁻¹, and their high rate dischargeabilities at the 1500 mA g⁻¹ reach to 51.5% and 53.4%, respectively. A5B19-type Pr4MgNi19 alloy is more prominent in the cycling stability, which its cycling number reaches to 190 cycles as the discharge capacity reduces to the 70% maximum value, 70 cycles longer than that of the La4MgNi19 alloy, which is outstanding for negative material of high power Ni/MH battery.

3.4 Formation mechanism of single-phase RE − Mg − Ni alloys

RE − Mg − Ni alloys with superlattice structures were formed by the peritectic reaction during the step wise sintering process. The REMgNi4 precursor with low melting point firstly turns into a RE (Mg)-rich phase (Liquid 1), while the RENi5 precursor with a melting point remains in a solid state. Based on the La − Ni binary diagram and peritectic reaction theory, RENi5 solid phase reacts with Liquid 1 and forms (RE,Mg)Ni3 phase. As the temperature further increases, the (RE,Mg)Ni3 phase starts to liquidize to form Liquid 2, which reacts with the remaining RENi5 phase to form (RE,Mg)2Ni7 phase. In the last stage, as the temperature continues to rise, the (RE,Mg)2Ni7 phase turns into another liquid phase (Liquid 3), and the (RE,Mg)5Ni19 phase is formed by the peritectic reaction between RENi5 phase and Liquid 3.

3.5 Discharge degradation mechanism of single-phase RE − Mg − Ni alloys

Degradation study shows that the inter-molecular strains in the alloys are the main reason that leads to the fast capacity degradation of RE − Mg − Ni alloys [9]. The strains are caused by the difference in the expansion/contraction properties between [RENi5] and [REMgNi4] subunits during charge/discharge which is mainly observed in the H-dissolved solid solution instead of hydride. The improved cycling stability of new type RE − Mg − Ni alloys are attributed to the relieved strain between [RENi5] and [REMgNi4] subunits, thus the RE − Mg − Ni alloys exhibiting superior structural stability and then achieving less pulverization and oxidation, and better cycling stability.

4. Conclusion

The single-phase RE − Mg − Ni alloys with superlattice structure are formed by the peritectic reaction. During the preparation processes, the precursor’s ratio, the composition of the as-cast alloy, sintering conditions, and annealing conditions are the key issues. The single-phase alloys possessed good overall electrochemical properties, especially the cycling stability. While the strain in the alloys resulted from the difference in the expansion/contraction properties between [RENi5] and [REMgNi4] subunits during charge/discharge still leads to the capacity degradation. There two ways to relieved the inner strain, one is adjusting [RENi5]/[REMgNi4] subunit ratio of the alloy, and the other is regulating the constitution of the RE. We expect our study can inspire new ideas on improving the cycling performance of the RE − Mg − Ni-based alloys.

D-15
Preparation of 3D Graphene Network-based Composites and Their Applications in Energy Storage and Conversion
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The unique properties and promising applications of graphene have been intensively studied in the past decades. However, several challenges still remain to utilize graphene in practical applications, such as the aggregation of graphene sheets, the controlled preparation of high-quality graphene and the controlled fabrication of hierarchical-structured graphene composites. In this work, we will present our recent work on the preparation of 3D graphene networks and their composite materials as well as the application in energy storage and conversion. We developed a novel synthetic method for large-scale and high-quality 3D graphene networks based on a chemical vapor deposition process, which provides an effective way to solve one of the most important challenges currently for the utilization of graphene in practical applications, i.e. aggregation. Based on this result, we also developed the preparation methods for a variety of novel graphene composites with hierarchical structures, including the composites of graphene with metal oxides, sulfides, hydroxides, noble metals, carbon nanotubes and metal-organic frameworks. Those resultant composite materials have shown promising applications in energy storage and conversion, such as Li-ion batteries and supercapacitors, and also in electrochemical sensors. Moreover, by using metal-organic frameworks as precursors, novel composite materials composing of porous metal oxides (e.g. Fe2O3 and ZnO) and graphene were successfully prepared. Importantly, the obtained MoO3/graphene composites exhibited promising application in flexible all-solid-state supercapacitors.

D-16 (Invited)
The synthesis of Mg-based nanostructures for advanced hydrogen storage
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Developing uniform and stable nanostructures is an effective approach to improve the potential application of magnesium hydride. Here, we report the hydrogenation induced self-assembly of MgH2 on graphene with homogenous distribution. High loading of uniform and stable nanostructured MgH2 was controllably realized by the bottom-up assembly strategy coupled with the high surface area of graphene. The well-defined structural features, including good distribution, uniform particle size (a controllable particle size ~5 nm for monodisperse MgH2), and high thermal stability, endow the as-synthesized MgH2 nanoparticles advanced hydrogen storage performance. For example, a reversible storage capacity of up to 5.35 wt.% H2, with no degradation after 100 complete cycles at 200 °C, was observed for Mg anchored on graphene. Furthermore, the Mg-Ni alloy nanofibers were fabricated successfully via deposition of Mg vapor on the bamboo-like Ni nanofibers. The synthesized Mg-Ni nanofibers could absorb/desorb H2 with fast kinetics at 200 °C, and the activation energy of hydrogenation and dehydrogenation were reduced to 18.64 kJ/mol and 30.82 kJ/mol, respectively. Our results demonstrate a new route for fabrication of nanostructured Mg-based hydrogen storage alloys.

D-17 (Invited)
Structure and electrochemical performance of double perovskite anode materials
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University of Science and Technology of Beijing

A novel double perovskite Sr2FeMo2/3Mg1/3O6 was prepared and characterized as anode material for SOFCs. It shows excellent structural stability in both oxidizing and reducing conditions, suitable thermal expansion coefficient (16.9(2)×10^{-6} K^{-1}), high electrical conductivity, stable redox cycling performance as well as fast oxygen surface exchange kinetics. The structure study shows that the doping Mg actually takes the Fe-site, leading to the co-occupancy of Fe on both B and B' sites. The first-principles computation reveals that the
presence of FeB-O-FeB’ bonds decreases the formation energy of oxygen vacancies, which is beneficial to oxygen ion diffusion and oxygen surface exchange kinetics. In a electrolyte (300 μm) supported single cell, the Sr2FeMo2/3Mg1/3O6 anode demonstrates excellent cell performance with maximum power density of 637, 866 and 1044 mW cm-2 at 800, 850 and 900 °C, respectively. The designed Sr2FeMo2/3Mg1/3O6-δ is an attractive anode candidate for SOFCs.

D-18 (Invited)
Catalytically enhanced magnesium-based hydrogen storage materials
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Mg-based hydrogen storage material has been regarded as one of the most promising solid state hydrogen storage materials due to its large theoretical hydrogen capacity, abundant resource and low cost. However, Mg-based material usually suffers from high thermodynamic stability and sluggish hydrogenation/dehydrogenation kinetics. Adding suitable catalyst has been widely accepted as effective approach to enhance the hydrogen sorption performance. In our recent studies, different carbonaceous materials supported nano metal catalysts were added to Mg-based hydride by the process of hydriding combustion synthesis and mechanical milling (HCS+MM). It is found that the hydrogen storage properties of magnesium hydride can be enhanced greatly by the catalysis of carbon supported nano metal catalysts. The hydrogenation/ dehydrogenation temperature is decreased largely and the kinetics gets improved greatly by catalyst addition. In particular, the as-prepared sample shows ultrafast hydrogenation kinetics at a low temperature of 373 K, reaching saturated hydrogen capacity of more than 6 wt.% within 100 s. More than 6 wt.% hydrogen can be released within 1800 s at 523 K. The dehydriding activation energy has been decreased to about 70.0 kJ/mol. The prominent hydrogen storage properties of Mg-based materials are related to the highly dispersive nano hybrid catalyst.

D-19
Design and research on electrochemical performance of inexpensive sodium-ion batteries electrode
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Recently, ambient-temperature sodium-ion batteries (as a substitute of lithium-ion batteries) have raised much attention for grid-level applications considering the sustainability advantages of NIBs. Significant progresses have been made for NIB cathodes by adapting the knowledge learned on LIBs. Hence there is a strong current interest in research high-performance electrode for NIBs. We will discuss a SnS2-RGO composite with excellent electrochemical performance as the anode of sodium-ion batteries. The SnS2-RGO anode delivered a high charge (desodiation) specific capacity of 630 mAh g-1 at 0.2 A g-1, and more impressively, 544 mAh g-1 after a ten-fold increase in current density to 2 A g-1. We also presents the Sb2S3-rGO composite as a high capacity Na host; delivering a desodiation specific capacity of 600 mAh g-1 at 100 mA g-1 and good cyclability for 70 cycles

D-20 (Invited)
Bamboo Shoot Shell Derived Hierarchical Porous Carbon for the Application of High Performance
Lithium-Sulfur batteries
Xianyou Wang
Xiangtan University

Lithium-sulfur (Li-S) batteries are believed to be one of the most promising candidates for next-generation high-energy-density rechargeable batteries, however the short cycle life, poor efficiency and low utilization of sulfur have become the technical bottleneck to restrict Li-S battery development. Herein, we use naturally abundant bamboo shoot shell as carbon source and deliberately design a bio-inspired bamboo shoot shell derived carbon with the hierarchical porous structure like lotus root as a polysulfide reservoir for Li-S, which has shown a significant enhancement to the electrochemical performance of Li-S batteries. Especially, it has been found that the BC/S-3, which is prepared at a 5:1 weight ratio of KOH to bamboo shoot shell derived carbon, has the highest sulfur content of 73 wt%. Besides, it also shows the best electrochemical performance, e.g., a high initial capacity of 1245 mAh/g, a low cycle capacity decay of 0.69% per cycle for 50th cycles at 0.2 C, a high capacity retention of 652 mAh/g after 100th cycles at 0.5 C and an excellent coulombic efficiency (~94%).

D-21 (Invited)
Microstructure and Interface Engineering of FePt/C Nanocatalysts for High Electro-Oxidation Activity and Durability

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A methodology by coupling a microfluidic-batch process modified by in-situ carbon-black mixing with successive annealing and de-alloying was developed for engineering microstructure and interfaces of FePt/C nanocomposites. Ultra-small FePt nanocrystals rich of vertexes/edges/sides and with gradually increased Pt contents from inner to outer can be constructed at certain Fe/Pt atomic ratios (2/1 or 1.1/1) via this methodology, which can be directly grown on carbon-black for enhanced nanocrystal-carbon interface interaction by introducing an in-situ carbon-black mixing process. FePt(Fe1-xPtx)Oy(OH)z/C nanocomposites with FePt alloy cores and Pt-doping hydroxyl iron oxide shells can be further formed after annealing. After controlled de-alloying Fe in annealed nanocomposites with an optimized Fe/Pt ratio of 2/1, the nanocomposites exhibit excellent electrochemical catalytic performance, preserving an activity of 4330 mA/mg-Pt (32 times of the commercial Pt/C), enhanced durability and tolerance to CO poisoning, using methanol oxidation as models.

D-22 (Invited)
Synthesis and Hydrogen Storage of Advanced Mg-based Composite

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The discovery of new hydrogen storage materials has greatly driven the entire hydrogen storage technology forward in the past decades. Magnesium hydride, which has a high hydrogen capacity and low cost, has been considered as one of the most promising candidates for hydrogen storage. Unfortunately, extensive efforts are still
needed to improve its hydrogen storage performance, since MgH2 suffers from high operation temperature, poor dehydrogenation kinetic, and unsatisfactory thermal management. In this paper, a series of micro/nano additive-enhanced MgH2 composites were successfully synthesised and systemically investigated in improving the hydrogenation/de-hydrogenation performance of MgH2.

**D-23 Invited**

**Synergistic catalytic effects of multiple Ti hydride phases on the hydrogen storage properties of Mg-based nanocomposite at moderate temperatures**

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In order to improve the hydrogen sorption kinetics of Mg at room temperature, the Mg-TiH1.971-TiH1.5 nanocomposite is successfully prepared by hydrogen plasma-metal reaction (HPMR) method and hydrogenation/dehydrogenation at 673 K. The Mg nanoparticles are hexagonal in shape with the size in the range of 50-190 nm. The spherical Ti hydrides nanoparticles of about 13 nm are uniformly dispersed on the surface of Mg nanoparticles. During hydrogenation/dehydrogenation cycle, the Ti hydrides nanoparticles restrain the growth of Mg nanoparticles. The Mg-Ti hydrides nanocomposite quickly absorbs 4.3 wt % H2 in 10 min at room temperature and reaches a saturation value of 5.0 wt % in 60 min. The apparent activation energies for hydrogen absorption and desorption are 12.5 and 46.2 kJ mol⁻¹, respectively. The improved kinetics and reduced activation energy are explained in terms of the nanostructure of Mg and the synergic catalytic effect of Ti hydrides nanoparticles.

**D-24**

**Metal–Organic Frameworks Derived Porous Core/Shell Structured ZnO/ZnCo2O4/C Hybrids as Anodes for High-Performance Lithium-Ion Battery**

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Metal–organic frameworks (MOFs) built up with metal ions/clusters and organic ligands have attracted a great deal attention in energy storage for their exceptional tunable porosities, good structural robustness and flexibility. In this work, porous core/shell ZnO/ZnCo2O4/C nanospheres, composed of ZnCo2O4 as the shell and ZnO as the core, are for the first time fabricated by using core/shell ZnCo-MOF precursors as reactant templates. When evaluated as anode materials for lithium-ion batteries (LIBs), the as-synthesized porous ZnO/ZnCo2O4/C anodes exhibit a large reversible capacity, excellent rate capability, and superior cycling stability. It can retain a capacity of 669 mA h g⁻¹ after 250 cycles at a current density of 0.5 A g⁻¹ and deliver 715 mA h g⁻¹ at a high rate of 1.6 A g⁻¹. It is firmly believed that the excellent lithium-storage performance is mainly attributed to their unique core/shell structure with oxide nanocrystals of about 15 nm, which are dispersed uniformly among the three-dimensional hierarchical nanostructures. The advantages of the ZnO/ZnCo2O4/C electrode can be described as follows: the core/shell structure can effectively relieve the strain caused by the volume change and the homogeneous carbon layer can largely enhance the electrical conductivity and avoid the aggregation of oxide nanoparticles, while the nanoparticles can effectively shorten the transport pathways of lithium ions and electrons. This strategy may shed light on designing new MOF-based hybrid electrodes for energy storage and conversion devices.
The Application of Phenom Desktop SEM in Energy Materials
Jack Zhang
Phenom China

Tailoring thermodynamics and kinetics for hydrogen storage in metal borohydride ammoniates
Yongfeng Liu, You Li, Yanjing Yang, Ming xia Gao, Hongge Pan
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The development of high-capacity hydrogen storage materials with favorable thermodynamics and kinetics is still of significant importance for the practical applications of hydrogen fuel cell technologies. Recently, as a new family of solid-state hydrogen storage materials, magnesium borohydride ammoniates attracted great interest due to their high hydrogen capacities and relatively low dehydrogenation temperatures. However, the practical utilization of these compounds for hydrogen storage is hindered by their unfavorable exothermic dehydrogenation thermodynamics. Here, we demonstrate several successful attempts to tailor the dehydrogenation thermodynamics and kinetics of magnesium borohydride ammoniates through reducing particle size, elemental substitution and forming composites. In particular, the onset temperature for hydrogen release from the nanoconfined Mg(BH4)26NH3 is dramatically decreased to approximate 40 oC, and more encouragingly, hydrogen desorption is endothermic in nature. The relationship between pore size and dehydrogenation behavior is established, and the critical pore size for the endothermic dehydrogenation of the nanoconfined Mg(BH4)26NH3 is found to be less than 4 nm. The nanoconfinement effect of carbon scaffolds is believed to be the primary reason for the change in the dehydrogenation pathway caused by incorporating Mg(BH4)26NH3 into microporous activated carbon.

Polydopamine-derived nitrogen-doped carbon tubes for high-performance electrochemical energy storage
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Objectives:Polydopamine (PDA)-derived carbon has the structure and electrical conductivity similar to N-doped multi-layered graphene, so it has been widely used to improve the electrochemical performances of many high-capacity lithium-ion-battery anode materials such as SnO2-based anode material by buffering the volume change of these high-capacity materials, and enhancing the electron conductivity of the composite electrodes.

Methods:One-dimensional PDA-derived N-doped carbon tubes (denoted as N-CTs) were fabricated by pyrolyzing the PDA coating on the surface of electrospun silica-nanofiber template, and subsequent post-etching process. Meanwhile, the N-CTs were creatively used to improve the electrochemical performance of SnO2-based composite electrode materials by encapsulating SnO2-loaded porous carbon (SnO2@PC) in them, and thus a novel fiber-in-tube hierarchical nanostructure of SnO2@porous carbon in N-CTs (denoted as SnO2@PC/N-CTs) was fabricated. The electrochemical performances of the as-prepared N-CTs and SnO2@PC/N-CTs were studied as anode materials for lithium-ion batteries (LIBs).

Results:The N-CTs anode shows high specific capacity, excellent rate capability and robust durability. Interestingly, the capacity gradually increased from 587 to 1103 mA h g-1 upon the 500th cycle at 500 mA g-1. The SnO2@PC/N-CTs anode exhibits a high reversible capacity of 1045 mA h g1 after 300 cycles as well as a high-rate cycling stability after 1000 cycles.
Conclusions: The N-CTs anodes show high specific capacity, excellent rate capability, robust durability, and an interesting phenomenon of self-improvement in capacity. As the carbon protective shells for SnO2-based electrode materials, the N-CTs not only facilitate electron and ion transport to the internal active materials, but also act as a barrier to confine the volume expansion of SnO2 for preserving the integrity of the overall electrode. Therefore, the as-obtained SnO2@PC/N-CTs electrode exhibits high reversible capacity, good rate capability, and excellent long-term cycling stability. Our work presents a promising approach to improve other high-capacity metal oxides materials, and is also beneficial for the future utilization of N-CTs in the field of high-performance electrochemical energy storage.

D-28 (Invited)
PEM fuel cell applications in unmanned aerial vehicles
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Unmanned Aerial Vehicles (UAVs) have received fast development and deployment in recent years because they can play important roles in many areas such as anti-terrorism, fire-fighting, utility checking, agriculture and forestry, weather forecasting, land surveying, and aerial videoing. As the main propelling power, electrical motors, in comparison with the internal combustion engines (ICEs), possess advantages in easier operation, higher reliability, higher flight attitude, and longer lifetime. However, due to the low energy densities of batteries used in conventional electrical UAVs, their continuous flight time is seriously limited, preventing them from larger scale applications.

Wuhan Troowin Power System has development fuel cell powered UAVs that overcome the bottleneck of the short continuous flight distance encountered by conventional. For example, the fuel cell powered rotary wing UAVs have achieved 273 minutes of continuous flight. This new world record is about 4 times longer than Li-Ion battery powered UAVs, and thus significantly improve the usability of electrical UAVs.

This presentation will introduce the developmental process and the major specifications of Troowin’s fuel cell powered rotary wing and fixed wing UAVs.

D-29 (Invited)
Metal Organic Frameworks (MOFs) Derived Porous Materials as Electrodes for Lithium Secondary Batteries
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The increasing demand for higher energy density storage devices steers scientific researches on high capacity electrode materials. Metal-organic frameworks (MOFs) or coordination polymers have drawn much attention for their applications as electrodes for energy storage applications. MOFs consisting of organic ligands and metal ions, can transform into carbon materials and metal species with proper methods. Carbon materials derived from MOFs by simply carbonization of organic ligand and removal of metal species have shown good electrochemical performance in lithium-sulfur batteries and lithium-selenium battery applications. MOFs derived tailor metal oxides or metal oxide/carbon nanomaterials with unique nanostructures exhibit outstanding electrochemical performance when used as LIBs anodes.

In the present work, nitrogen-doped carbon sponges (NCS) composed of hierarchically micropores carbon layers, are derived from metal organic framework (MOF) via carbonization at high temperature under Ar and NH3 flow.
Se is impregnated into 0.4–0.55 nm micropores by melting-diffusion and infiltration method. The confinement of Se within small sized micropores of NCS efficiently avoids Se loss, mesopores between carbon layers absorb sufficient electrolyte, as well as serve as cushion space for the large volume change during delithiation-lithiation processes. When acted as cathode materials for Li-Se batteries, the NCS/Se-50 composite with 50 wt.% Se exhibits excellent cycling stability, superior rate capability and high coulombic efficiency. The unique large surface rod-like MOF derived N-doped carbon sponges with hierarchical pores could be potential candidates in the related energy-storage systems. Nitrogen-doped carbon (NDC) spheres with abundant 22 nm mesopores and 0.5 nm micropores are obtained by directly carbonization of nitrogen contained MOF nanocrystals. Large S8 and small S2-4 molecules are successfully infiltrated into 22 nm mesopores and 0.5 nm micropores, respectively. The effect of sulfur immobilization in mesopores and micropores on the electrochemical performance of lithium-sulfur (Li-S) battery based on NDC-sulfur hybrid cathodes is investigated. The NDC/S2-4 hybrid exhibits excellent cycling performance, high coulombic efficiency and good rate capability as cathode for Li-S batteries. The confinement of smaller S2-4 molecules in the micropores of N-doped carbon efficiently avoids the loss of active sulfur and formation of soluble high-order Li polysulfides. The porous carbon can buffer the volume expansion and contraction changes, promising a stable structure for cathode. Furthermore, N doping in MOF-derived carbon not only facilitates the fast charge transfer, but also is helpful to build a stronger interaction between carbon and sulfur, strengthening immobilization ability of S2-4 in micropores. This unique synthetic strategy and N-doped porous carbon derived from MOF nanocrystals could be applied in other high energy storage devices.

A sandwich-like structure with reduced graphene oxide (RGO) wrapped MOF-derived ZnCo2O4-ZnO-C polyhedrons on nickel foam as an anode for high performance lithium ion batteries (LIBs), is synthesized via a simply growing MOFs on Ni foam, and wrapping of graphene oxide nanosheets on MOFs, then annealing under N2 atmosphere. When tested as anode for LIBs, the unique RGO/ZnCo2O4-ZnO-C/Ni sandwich-structured LIBs anodes exhibit superior coulombic efficiency, excellent cycling stability and rate capability. The in situ formed carbon layers outside the ZnCo2O4-ZnO act as not only conductive substrate but also buffer layer for volume changes. The open pores in ZnCo2O4-ZnO-C polyhedrons provide sufficient electrolyte as well as serve as cushion space to further alleviate volume changes. The RGO nanosheets act as a flexible protector to firmly fix polyhedrons on the Ni foam, as well as conductive substrate to wire up all the polyhedrons. The interconnected carbon layers and two high conductive substrates (RGO and Ni foam) together form an unhindered highway for charge transfer during discharge/charge processes, promising good electrochemical performance.

### D-30 (Invited)

**Research and development of proton exchange membrane fuel cell**

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Owing to the virtue of high efficiency, no pollutant emission, low operating temperature, PEMFCs have drawn massive attention recently. However, the cost and durability still remain the threshold to the commercialization of PEMFC [1]. To reduce the cost and improve the durability both while, DICP DNL 301 has devoted much effort in the key component, key material, and systematic research. Aimed at increasing the activity and stability of state-of-the-art Pt/C electrocatalysts, Pd@Pt core-shell catalysts were synthesized by chemical reduction methods. The addition of Pd into the catalysts not only reduce the using amount of Pt, but also improve the activity and durability of catalysts. Nafion membrane, which is the most commercially available PEM, is often attacked by free radical resulting in high degradation rate. The free radical scavengers CeO2 existed comprise membranes
were prepared. The result showed increased durability of the comprise membrane due to the mitigate the free radical attack [2]. Gas diffusion layer (GDL) becomes hydrophilic in the long-time operation, effecting the mass transport of the cell. Polyvinylpyrrolidone (PVP) aqueous solution was used to prepare MPL slurry. The prepared GDL has increased stability for the better dispersibility of PTFE in PVP aqueous solution [3]. With the aim of design an oriented ultrathin catalyst layer, highly ordered TiO2 nanotubes (TNTs) array was taken as the catalyst support. The Ni@Pt-TNTs electrode synthesized via Ni replacement exhibited good electrochemical durability. The ordered electrode based on TNTs was tested in a single cell for the first time. The maximum power density reached 557 mW cm-2 with the prepared TNTs as the anode of a fuel cell. To decrease the corrosion of metallic bipolar plate in fuel cell, the CrN/Cr multilayer was coated onto 316L stainless steel. The modified bipolar plates has prominent corrosion resistance and good electrochemical stability. To analyses the dynamic response of PEMFC, through inserting several potential sensors between cathode, anode gas diffusion layer and flow field, the cathode in-plane potential distributions of single fuel cell within a stack were studied. The result showed the potential of gas inlet is higher than other regions in the condition of a high current density. In the system level, the new generation PEMFC system with 50kW was developed.

D-31
Nanostructured materials for high performance energy storage in Li-ion batteries
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Recently, abundant metal oxide materials and alloy materials have attracted wide interest for their promise in delivering a high specific capacity at low cost in Li-ion battery. A myriad of nanostructures, particularly nanocomposites of active materials and carbon materials, have been developed to improve the conversion reaction/alloy reaction reversibility and hence the cycle stability and rate performance. However, development of electrodes of long cycling stability and high rate performance remains a significant challenge. And it is lack of structure design in controlling the composite material’s porosity and packing density, which are critical to batteries’ energy density. In this work, we briefly review our recent work on nanostructured materials with enhanced performance in Li-ion battery. Our work provides an ideal structure design for conversion anodes or alloy anodes of large volume change.

D-32 (Invited)
A new method for few-layer graphene preparation via plasma assisted ball milling
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Few-layer graphene (FLG) was prepared via plasma assisted ball milling with expandable graphite as raw and WC,
BN, ZnO, Fe₂O₃, GeO₂ as ball-milling media respectively. The structure and morphology of the FLG was characterized by X-ray diffraction, Raman spectrum, scanning electron microscopy, transmission electron microscopy. The result showed that 6-layer FLG nanosheets were successfully prepared by plasma assisted ball milling for 8h with WC as ball-milling medium. In addition, the Mohs hardness and relative permittivity of ball-milling media contributed huge influence on the number of layers of FLG. The number of layers decreased as the Mohs hardness of ball-milling media increased. Moreover, when the relative permittivity of ball-milling media came closed to 8, the prepared FLG showed the highest quality and the number of layers were all less than 7.

D-33 (Invited)

**Ball milling: a pragmatic method to produce the nanomaterials of energy storage**

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Nanomaterials and nanotechnology are playing more and more important roles in advancing the electrochemical energy storage and conversion technologies such as lithium ion batteries, supercapacitors and fuel cells, offering great promise to address the rapidly growing environmental concerns and the increasing global demand for energy. In this presentation, I will demonstrate that various nanostructured electrode materials can be prepared by the ball milling method, such as MoO₃, FeTiO₃, MoS₂ and Fe₂O₃–SnO₂–C nanomaterials, which exhibit an improved electrochemical performance. Also, the ball milling method can synthesize much larger quantities of nanostructured materials, which may meet a major challenge for the future industrial applications in the energy storage.

D-34 (Invited)

**Application of Spray Technique to the Preparation of Materials for Energy and Environment**

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Spray is a dynamic collection of drops dispersed in gas. The process of forming a spray is known as atomization. There are thousands of applications in which sprays allow material to be used most efficiently. As a well-developed industrial method, spray drying technique has been extensively utilized in fabrication of powders or particles of a variety of materials. Herein, we report on the application of this facial technique to the preparation of materials for energy and environmental applications.

D-35

**High Frequency SAW Device Based on ZnO/Diamond stacked layer structure**

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As the rapid development of communication system, currently there is an increasing number of requirements on ZnO based high frequency surface acoustic wave (SAW) devices. In view of this condition, ZnO thin films were used to stacked with diamond to construct the stacked layer device in this work. ZnO thin films were prepared by RF magnetron sputtering on diamond substrate using ZnO ceramic target. The effect of different temperature annealing processes on crystalline orientation of ZnO thin film were studied and optimized. The surface
morphology and crystalline orientation of ZnO were characterized by atomic force microscope (AFM), x-ray diffraction (XRD), respectively. UV lithography was used for the fabrication of inter-digital transducer (IDT), and the frequency response of the devices was analyzed by microwave vector network analyzer. In conclusion, we developed a two port SAW filter with ZnO/Diamond stacked layer structure and a high frequency response (GHz) and a low insertion loss were achieved.

D-36 (Invited)
Fabrication of manganese dioxide nanosheets by using simple mechanical exfoliation method for flexible supercapacitor device application
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As a kind of energy storage devices with high power density, high efficiency, long life expectancy and environmental friendliness, supercapacitors have received considerable research attention for the past two decades. In addition, for the development of wearable devices, the functional unit of flexible energy storage devices has been given more and more attention nowadays. In this work, we use a simple method, which is mechanical exfoliation of bulk manganese dioxide (MnO2) crystal in water together with the surfactant, to produce high quality MnO2 nanosheets. In addition, the as-prepared MnO2 nanosheets were synthesized as a kind of functional ink and coated on the polyethylene glycol terephthalate (PET) with silver layer as the flexible supercapacitor device. The x-ray diffraction (XRD) profiles confirm that the as-prepared material is MnO2. The field emission scan electron microscope (FESEM) demonstrates that the MnO2 crystal owns more thin layers structure and it can be sure that the MnO2 nanosheet has been achieved after mechanical exfoliation. The as-prepared flexible supercapacitor with the uniformly nanocomposite has outstanding conductivity and superior electrochemical performance. The electrochemical test is setup in the potassium hydroxide (KOH) solution of 6 M. All of the electrochemical analysis apply three electrode analysis method by the electrochemical work station. The measurements of cyclic voltammetry(CV) exhibits that the supercapacitor has a large current and the huge spacer between charge and discharge process means that the supercapacitor has perfect capacitive property. The curve of galvanostatic charge and discharge is closed symmetry and the process of discharge has a platform which was caused with the faradaic pseudocapacitance react. At current density of 0.1A/m2, the supercapacitor shows specific capacitance of 415 F/m2. These results suggest that the obtained MnO2 nanosheets are the better candidate for supercapacitor applications.

D-37
A coralline N-doped hierarchically porous carbon derived from Enteromorpha as host matrix for lithium-sulfur battery
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Given that Changing the waste material into things of value and easy processes, this work features a promising approach to prepare sulfur/carbon composites for high-performance Li–S batteries.

Synthesis
Enteromorpha was procured from Qingdao coastal district, Shandong province in east China. Enteromorpha was first thoroughly washed and cleaned with ultra-purified (UP) water to remove impurities, dried under sunlight for several days and then grounded into powder. The NHPCs samples were obtained by hydrothermal co-carbonization of enteromorpha and glucose mixture. For that the grounded enteromorpha powder was mixed with glucose solution under continuous stirring for 18 h, the suspension was then transferred in stainless steel Teflon-lined autoclave and heated at 180 °C for 24 h in the oven. After that the autoclave was allowed to cool at room temperature followed by filtration, washing and finally drying at 110 °C for 12 h under vacuum. The hydrothermally carbonized carbons were further chemically activated by employing potassium hydroxide as activating agent at different temperatures for 1 h. The carbon to KOH ratio was 1:4. The products were denoted as NHPC700G and NHPC800G where 700 and 800 is referring to the activation temperatures, respectively. Another sample of carbon was also prepared without the addition of glucose and is named as NHPC700.

Synthesis of carbon/sulfur composite
The S/NHPC700G composites were prepared by a melt-diffusion strategy. The NHPC700G was well-mixed with sulfur in a weight ratio of 1:3. The mixture was then sealed in a stainless steel vessel and heated at 155 °C for 12 h followed by heating at 250 °C for 90 min under N2 atmosphere for surface cleaning. The other composites S/NHPC800G and S/NHPC700 were also obtained by the same method.

Results
The electrochemical properties of NHPCs/S composite were studied by cyclic voltammetry (CV) technique at the potential sweep rate of 0.05 mVs-1. A single reduction peak at ~1.6 V corresponding to the formation of sulfur to polysulfides, and single oxidation peak at ~2.35 was observed in the CV of S/NHPC700G composite. This behavior is different from the two-plateau discharge and charge of typical cyclo-S8 and corresponds to the microporous carbon. It is assumed that microporous carbon contains only smaller sulfur allotropes (S2-4) due to the space constrains, thus it only forms lower order polysulfides and higher order polysulfides do not observe during the redox reaction. The CV results are consistent with the BET results and confirm the extremely high percentage of micropores in the NHPCs. The areas and positions of CV peaks remain almost unaltered after second cycle, entailing cycling stability and reaction reversibility of the NHPCs/S composite cathode.

The cathode containing 40.0% (by weight, wt%) sulfur exhibited an initial discharge capacity of 1555 mAh g-1 (92.8% of theoretical capacity) at a current density of 0.1 C and a capacity loss of 0.05% per charge-discharge cycle after 500 cycle at a current density of 0.5 C with a stable coulombic efficiency of 100%.

Conclusion
A novel N-doped coralline-like structured hierarchical porous carbon (NCHPC) with mostly micropores have been successfully fabricated using enteromorpha a marine waste as low cost, green carbon source by simple hydrothermal carbonization followed by KOH activation method. The obtained NHPCs were utilized as a conductive matrix for Li–S batteries and demonstrated excellent electrochemical performance. The NHPC prepared at 700oC with BET surface area (1416 m2.g-1) and pore volume (0.68 cm3.g-1) exhibited excellent structural stability and maintained 100% columbic efficiencies under various cycling rates. The excellent performance is attributed to the inherent N-doping and special coralline-like structure that not only restrains soluble polysulfides within the micropores but also enables stable and uninterrupted pathway for fast electronic/ionic transportation. These results show that enteromorpha has great potential to be utilized as a bio-source for obtaining carbon. The special structural and textural characteristics of NHPCs are promising to be
used as conductive matrix in Li-S batteries and also anticipated to be employed in photocatalysis and supercapacitors.

**D-38**

**A Controllable Synthesis of Large-scale MoS2 Monolayers and Its Application to MoS2/p-Si Solar Cells**

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Recently two-dimensional (2-D) materials, such as graphene, boron nitride, and transition metal dichalcogenides, have drawn great attentions for the unique electronic and optical attributes. Compared with graphene, molybdenum disulfide (MoS2) monolayers possess high carrier mobility as well as sizable bandgaps around 1-2 eV which change from indirect to direct in single layers. In addition, MoS2 monolayers show strong peaks in the visible range associated with van Hove singularities in the density of states, which is benefit to enhance the light absorption and light electron-hole creation. Thus excellent optical and electrical properties of MoS2 monolayers provide potential applications in the field of electronics and optoelectronics. The chemical vapor deposition (CVD) methods, such as decomposition of thiomolybdates, and sulfurization of Mo films or molybdenum compounds have been developed to fabricate MoS2 monolayers. However, a two-source CVD method always results in triangular islands and random orientation of the MoS2 domains. In this paper, MoS2 monolayers were uniformly fabricated by sulfurizing the Mo foils in sulfur vapor at 600 °C. Scanning electron microscope, transmission electron microscope and Raman measurements were carried out to analyze the structure characteristics of MoS2 with different thickness, indicatable of a controllable synthesis of MoS2 monolayers in large-scale area. By optimizing structural characteristics and interface passivation, the built-in potential and external quantum efficiency were simultaneously improved in MoS2/p-Si solar cells. An initial efficiency of 5% was achieved for MoS2/p-Si solar cells, which may guide further efforts arising the structure engineering of MoS2 monolayers for high efficient 2-D solar cells.

**D-39**

**A Polypyrrole-Nanofiber-Supported Ruthenium nanoparticle Composite as an Efficient Cathode Material for Li-O2 Batteries**

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Objective: It is reported that ruthenium (Ru) nanoparticles can promote both the ORR and the OER as a bifunctional catalyst and thus demonstrate exceptional round-trip efficiency, specific capacity, cycling stability, etc., making Ru a promising material to serve as the cathode catalyst in Li-O2 batteries. Therefore, hybridizations of Ru nanoparticles with nanostructured matrix were expected to introduce excellent electrocatalytic performance. However, the electrochemical behaviors of the Ru-containing cathodes demonstrate that they have relatively low
specific capacity with high ORR and OER overpotentials. To achieve better electrochemical properties, we have designed a polypyrrole-nanofiber-supported ruthenium (PPy-Ru) composite catalyst as a cathode material for Li-O2 batteries.

Methods: PPy nanofibers were obtained via the polymerization reaction route using distilled Py (pyrrole). PPy-Ru composite catalyst with a three-dimensional (3D) network structure were prepared by decorating Ru nanoparticles onto the PPy nanofibers employing NaBH4 as reducing agent.

Results: The polypyrrrole (PPy) nanofibers have been prepared by polymerization reaction method, on which the Ruthenium (Ru) particles were reduced to form a composite material. X-ray diffraction, Raman spectroscopy, thermogravimetric analysis, and electron microscopy were applied to determine the structures, compositions, and morphologies of the samples. The potential application of the catalyst cathodes for Li-O2 batteries was also investigated. Compared with the PPy cathode, the composite cathodes display notable enhancements in the catalytic performances. These are resulting from the synergistic benefit of the PPy nanofibers with three-dimensional (3D) structure and the Ru nanoparticles on them. The PPy nanofibers not only raise the electrical conductivity of the composite cathode, but also provide enough area for tri-phase reaction and volume change buffer in the discharge and charge processes. The Ru nanoparticles with intrinsically high catalytic activity could promote the oxygen evolution reaction (OER) and oxygen reduction reaction (ORR), dramatically improving the electrocatalytic performances of the Ru-PPy composite as the cathode for the Li-O2 batteries.

Conclusion: 3D PPy webs decorated by Ru nanoparticles were synthesized and present favorable catalytic activity towards both the ORR and the OER. The Ru/PPy cathode with optimized weight percentage deliver significantly improved discharge/charge capacities with high round-trip efficiency. With a fixed capacity, the Li-O2 cell containing this composite cathode could be continuously discharged and charged without obvious terminal voltage variation. This excellent electrocatalytic performance benefits from the synergistic effects of the well-dispersed Ru nanoparticles with superior catalytic activity and the high porosity and conductivity of the PPy. All these results suggest that the Ru/PPy composite is promising for use as a cathode catalyst material for advanced Li-O2 batteries.

D-40

Novel Au inlaid Zn2SnO4/SnO2 hollow rounded cubes for dye-sensitized solar cells with enhanced photoelectric conversion performance

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During past few years, Dye-sensitized solar cells (DSSCs) based on TiO2 underwent their bottleneck period for their efficiency and photobleaching. The investigation and requirement of novel materials for DSSCs have been a new trend. In this work, we developed a facile strategy for the fabrication of uniform Au inlaid Zn2SnO4/SnO2 hollow rounded cubes with an adjustable Au loading content using ZnSn(OH)6 as the precursor, chloroauric acid as the Au source and ascorbic acid as the reducing agent. The micro/nanostructure and chemical compositions of Zn2SnO4/SnO2 and Au inlaid Zn2SnO4/SnO2 samples were characterized using XRD, SEM, TEM, EDS and N2 adsorption and desorption techniques. The photovoltaic performance was evaluated by using DRS, PL, J–V, IPCE and EIS techniques. The Au inlaid Zn2SnO4/SnO2 hollow rounded cubes show enhanced light absorption ability and reduced recombination rate of photogenerated electron–hole pairs compared with pure Zn2SnO4/SnO2. The hollow rounded cube structured Au–Zn2SnO4/SnO2 sample displays a high surface area and high dye adsorption ability. As photoanodes for DSSCs, the Au–Zn2SnO4/SnO2 hollow rounded cubes demonstrate a greatly enhanced Jsc and an improved power conversion efficiency of up to 2.04%, almost 73% higher compared to the
photovoltaic conversion efficiency of pure Zn2SnO4/SnO2 based DSSCs. The greatly improved power conversion efficiency of DSSCs based on the Au inlaid Zn2SnO4/SnO2 photoanode can be attributed to the following three factors. Firstly, the localized surface plasmon resonance of Au nanoparticles plays a crucial role in the enhancement of visible light absorption. Secondly, the potential barrier on the Zn2SnO4/SnO2 surface caused by Au nanoparticles can suppress electron–hole recombination, diminish the loss of electrons during the transfer process and improve the photocurrent density. Thirdly, the enhanced photovoltaic performance can also be attributed to the unique structural characteristics of hollow rounded 

**D-41**
**Study on the structure activity relationship between crystal structure and electrochemical properties of electrode materials for lithium ion batteries**
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The modified methods of electrode materials for lithium ion batteries include three kinds of element doping, surface coating and nanoelectrode. Based on the crystal structure of electrode materials, we put forward some original and innovative ideas for the three kinds of modification methods of electrode materials for lithium ion batteries. Specifically, we discuss the effect of element doping on Li/Ni disorder and electrochemical performance of electrode materials. Secondly, we choose some lithium ion conductor materials and use some in situ coating methods to improve the properties of electrode materials. Thirdly, nanoelectrode material is focused on the effects of different crystal face on electrochemical performance.

**Poster**

**D-P01**
**Thermal performance enhancement of erythritol/carbon foam composites via surface modification of carbon foam**
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Erythritol (C4H10O4) is an important phase change material (PCM) for thermal energy storage. Erythritol has high latent heat of ~ 350 J/g and is not poisonous and corrosive. However, erythritol has the same problem as the other organic PCMs, that is, low thermal conductivity, which decrease the heat transfer rate of thermal energy storage system.

Carbon foam has high thermal conductivity and low bulk density as well as good chemical inertness, and has been used to prepare phase change composites in many studies. Carbon foam is able to improve the heat transfer rate of thermal energy storage system, reduce the system weight, and enhance the systems operational stability. However, few work focus on how the interface compatibility of the interfaces between carbon foam and phase change materials affects the microstructures and thermal performances of phase change composites.

In the present work, the thermal performances of the erythritol/carbon foam composites, including thermal diffusivity, thermal capacity, thermal conductivity and latent heat, were investigated before and after carbon foam surface modification using hydrogen peroxide as a surface treatment agent. It is found that there were oxygen functional groups C=O and C-OH on the carbon surface formed after the surface modification, which enhances the wetting ability of the liquid erythritol to carbon foam surface and improves the erythritol content in the
erythritol/carbon foam composites. The latent heat of the erythritol/carbon foam composite before and after surface modification increased from 202.0 to 217.2 J/g, increasing by 7.52%. The thermal conductivity of the erythritol/carbon foam composite before and after surface modification also sharply increased from 40.35 to 51.05 W/(mK), increasing by 31.50%. At the same time, the supercooling degree of erythritol had a large reduction from 97 to 54 ℃. Additionally, the carbon foam, whose surfaces were modified by this simple and effective method, is also able to form dense composites with other polar PCMs, which provides an extendable way to enhance the thermal performances of the composites composed of carbon foams and PCMs.

D-P02

α-Fe2O3 thin film modified by surface plasmon resonance of Au nanoparticles coupled with surface passivation by atom layer deposition of Al2O3 for photoelectrocatalytic water splitting

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Objective: The short lifetime of photogenerated charge carriers of hematite (α-Fe2O3) thin films strongly hindered the photoelectrocatalytic (PEC) performances.

Methods: α-Fe2O3 thin films with surface nanowire were synthesized by electrodeposition and post annealing method for photoelectrocatalytic (PEC) water splitting. The Au nanoparticles (NPs) and Al2O3 shell by atom layer deposition were further introduced to modify the photoelectrodes. Different constructions were made with different deposition orders of Au and Al2O3 on Fe2O3 films.

Results: The thickness of the α-Fe2O3 films can be precisely controlled by adjusting the duration of the electrodeposition. Among the different configurations, the Fe2O3-Au-Al2O3 construction shows the best PEC performance with 1.78 times enhancement by localized surface plasmon resonance (LSPR) of NPs in conjunction with surface passivation of Al2O3 shells.

Conclusion: The enhanced PEC performance of the Fe2O3-Au-Al2O3 construction could be attributed to the Al2O3 intensified LSPR, effective surface passivation by Al2O3 surface coating, and the rapid charge carriers transfer due to the Schottky Junctions at the interface of metal and semiconductor.

D-P03

Fabrication and characterization of bilayer ferroelectric thin films based on (1-x) (Ba0.7Ca0.3TiO3) - x[Ba(Zr0.2Ti0.8)O3]

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Objective: The nanogenerators (NGs) as an emerging energy convertor have attracted much attention in recent years since they can convert tiny mechanical energy in the environment such as low frequency movement, airflowing and heart beating into electrical energy. Piezoelectric NGs have been implemented in animals’ bodies to harvest energy. As an emerging lead-free piezoelectric material, Ba(Zr0.2Ti0.8)O3- (Ba0.7Ca0.3)TiO3 (BZT-BCT) has a piezoelectric coefficient (~620 pC/N) that can be compared with the conventional PZT family (200 ~ 710pC/N). And it has been reported that NG has been successfully developed based on BZT-BCT nanostructure. However, BZT-BCT thin film exhibits low piezoelectric effect because of the clamping effect from the substrate. Recently, multilayers thin films or superlattices have displayed enhanced piezoelectric properties. Such ferroelastic interactions in a ferroelectric bilayer lead to a giant piezoelectric response in tetragonal (T) PbZr0.3Ti0.7O3 film deposited on a rhombohedral (R) PbZr0.7Ti0.3O3 film.
Method: In this work, bilayer ferroelectric lead-free thin films of 0.6(Ba0.7Ca0.3TiO3) - 0.4[Ba(Zr0.2Ti0.8)O3] / 0.4(Ba0.7Ca0.3TiO3) - 0.6[Ba(Zr0.2Ti0.8)O3] were deposited on Pt/Ti/SiO2/Si substrates by RF magnetron sputtering using ceramic targets of 0.6(Ba0.7Ca0.3TiO3) - 0.4[Ba(Zr0.2Ti0.8)O3] and 0.4(Ba0.7Ca0.3TiO3) - 0.6[Ba(Zr0.2Ti0.8)O3]. The microstructures of the prepared films are characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Piezoresponse force microscopy (PFM) is used to analyze the ferroelastic-domain arrangement.

Results: We demonstrate that a bilayered heterostructure, comprised of a 0.4(Ba0.7Ca0.3TiO3) - 0.6[Ba(Zr0.2Ti0.8)O3] film deposited on a 0.6(Ba0.7Ca0.3TiO3) - 0.4[Ba(Zr0.2Ti0.8)O3] film, has been deposited on electrode-buffered Si substrates. The insertion of the underlayer leads to a nanoscale ferroelastic domain arrangement that is easily susceptible to external electric fields, which greatly improves the quality of the films and enhances the piezoelectric properties.

Conclusion: We demonstrate that a bilayered heterostructure, comprised of a 0.4(Ba0.7Ca0.3TiO3) - 0.6[Ba(Zr0.2Ti0.8)O3] film deposited on a 0.6(Ba0.7Ca0.3TiO3) - 0.4[Ba(Zr0.2Ti0.8)O3] film, on electrode-buffered Si substrates leads to a nanoscale ferroelastic domain arrangement that is easily susceptible to external electric fields. Ferroelectric domains of the bilayered films move under the application of an external electric field leading to the enhancement in piezoelectric coefficient of 100 pm · V-1, larger than what is normally observed in constrained single-layered (1-x)(Ba0.7Ca0.3TiO3) -x[Ba(Zr0.2Ti0.8)O3] thin films. Such ferroelastic-domain motion is very attractive for the applications of nanogenerators.

D-P04
Effects of element migration on the stability of La0.6Sr0.4Co0.2Fe0.8O3-δ cathode under intermediate temperature solid oxide fuel cell operation conditions
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The effects of element migration on the stability of La0.6Sr0.4Co0.2Fe0.8O3-δ (LSCF) cathodes are investigated at 750 °C and different current densities. The electrochemical results show that performance activation in the initial stage accompanied with the performance degradation in the high temperature environment is the characteristic of cathodic current polarization. High current density causes serious performance degradation with short-term activation process. Line profiles of XPS show that cathodic current polarization at 200 mA cm-2 for 120 h leads to Sr segregation from the bulk to the top surface, which is responsible for the performance degradation of LSCF cathodes. Nevertheless, cathodic current polarization drives Co diffusing from the bulk to the near surface beneath the Sr-enriched layer of LSCF cathodes. Long time treatment at high current density results in continuous performance degradation, mainly related with the increase of ohmic resistance, which is originated from element migration to the surface.

D-P05
Preparation and properties of molecularly imprinted polymers for use as SPE of sulfadimidine in milk
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In this work, molecularly imprinted polymers (MIPs) and non-imprinted polymers (NIPs) have been prepared and evaluated for the development of solid phase extraction (SPE) method for the analysis of sulfadimidine (SM2) in milk samples. It is a high selective pretreatment method for the analysis of SM2 based on MIPs with high adsorption capacity and suitable particle size using SM2 as the template. The MIPs/SM2 were characterised by scanning electron microscopy (SEM) and fourier transform-infrared spectroscopy (FT-IR). Furthermore, the performance of the MIPs/SM2 as SPE material was investigated in detail. The properties involving adsorption dynamics and selective recognition capacity were evaluated. The MIPs/SM2 exhibited good site accessibility in which it only took 20 min to achieve adsorption equilibrium and high selectivity for the template SM2. This pre-treatment methodology for extracting SM2 was simple and cleaner extractions. Three local milk samples were analysed by HPLC – MISPE, and SM2 was detected in only two samples, while the SM2 contents were lower than national limits. Average recoveries of the SM2 was 87.5%. It was used for the purification and enrichment of SM2 from milk successfully.

D-P06
High efficient Co3O4 Nanoparticles-Decorated Mesoporous Beta Composite as a synergistic Catalyst for Oxygen Reduction
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Electrocatalyst for oxygen reduction reaction (ORR) is vital for a variety of renewable energy applications and energy-intensive industries. The design and synthesis of highly active ORR catalysts with strong durability at low cost is extremely desirable but remains challenging. A precious-metal-free cathode catalyst, Co3O4 nanoparticle/mesoporous Beta zeolite (Co3O4/m-beta) strongly coupled hybrid, has been successfully synthesized by a steam-assisted crystallization (SAC) and hydrothermal approach as an efficient electrochemical catalysis of the oxygen reduction reaction (ORR) for the first time. The m-Beta zeolite provides functional groups to nucleate and anchor nanocrystals. The active CoOOH species, that is, Co3+/Co2+ redox couple and Brønsted acid sites on the mesoporous ZSM-5 matrix facilitate an approximate 4e- process for the catalysis of the ORR comparable to commercial 20 wt% Pt/C. The high electrochemical catalytic performance is due to the synergetic catalytic effects between the Co3O4 redox couple and Bronsted acid sites on the mesoporous Beta matrix. More importantly, excellent durability and tolerance to methanol make this hybrid material a promising candidate for highly efficient ORR in fuel cells and metal-air batteries.

D-P07
Highly efficient bimetal synergetic catalysis of graphene supported palladium and nickel on hydrogen storage of magnesium hydride
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To improve the hydrogen storage performance of magnesium hydride, graphene supported Pd and Ni (PdNi/GN) was introduced to the magnesium-based materials. PdNi/GN catalysts were synthesized by a two-step chemical reduction method. Afterwards, the nanocomposites were prepared for the first time by hydriding combustion synthesis (HCS) and mechanical milling (MM). It is determined by X-ray diffraction (XRD) analysis that Pd/MWCNTs can significantly increase the hydrogenation degree of magnesium during the HCS process. The microstructures of the composites obtained by transmission electron microscope (TEM) and field emission scanning electronic microscopy (FESEM) analyses show that Pd and Ni nanoparticles are well supported on the surface of carbon nanotubes and the PdNi/GN are dispersed uniformly on the surface of MgH2 particles. Moreover, it is revealed that there is a synergistic effect of Ni and Pd on the hydrogen storage properties of the composites. The Mg95-(Pd3Ni3/GN4)5 shows the optimal hydriding/dehydriding properties, requiring only 100 s to reach its saturated hydrogen absorption capacity of 6.27 wt.% at 473K, and desorbing 6.86 wt.% hydrogen within 1200 s at 573 K. Additionally, the dehydrogenation activation energy of MgH2 in this system is decreased to 71.6 kJ/mol H2, much lower than that of as-received MgH2.

D-P08
Synthesis of monolonic structure gallium oxide film on sapphire substrate by magnetron sputtering
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Beta-Ga2O3 films have been deposited on singlecrystalline sapphire (0001) substrate by RF Magnetron Sputtering technique in the temperature range 300 – 500 oC. The microstructure of the beta-Ga2O3 films were investigated in detail using X-ray diffractometer (XRD), scanning electron microscope (SEM). The results showed that the film prepared at 500 oC has the best crystallinity with a clear out-of-plane orientation of beta-Ga2O3 (-201)|| Al2O3 (0001). The average transmittance of the films in the visible wavelength range exceeded 90% and the optical band gap of the films varied from 4.68 to 4.94 eV which were measured by a UV - vis - NIR spectrophotometer. Then the capacitors based on beta-Ga2O3 films were manufactured and using Al as electrode materials. The capacitance characteristics of the capacitor were investigated in detail.

D-P09
Adipic acid imbedded into silica matrix: an experimental study for shape-stabilized phase change material
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A novel shape-stabilized phase change material was prepared by incorporating adipic acid into silica scaffold. Magnesium adipinicum was served as precursor of adipic acid in this study. Thermal energy capacity and thermal reliability of adipic acid/silica composite phase change material was investigated using differential scanning calorimeter, thermal stability was evaluated using thermogravimetric analysis, chemical structure was characterized using Fourier transform infrared spectroscopy, and crystal structure was carried on using powder
X-ray diffraction analysis. The as-prepared composite material present promoted thermal stability and reliability comparing to that of pure phase change materials. Besides, the spillover of corresponding phase change material was prevented, thus the corrosion was mitigated due to the coverture of silica. It is envisioned that the final shape-stabilized phase change material have great potential in actual application for thermal energy storage.

D-P10
Thermoelectric performance of Cu2Se thin films prepared by the method of electrochemical deposition
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Copper selenide thermoelectric thin films are deposited on indium tin oxide substrates using electrochemical deposition process with an acidic aqueous solution of Cu2SO4, SeO2 and H2SO4. The growth process and the effect of the deposition potential on the microstructure of the Cu2Se thin films are studied. The growth mechanism for the Cu2Se thin films prepared by electrochemical deposition method is investigated. The chemical composition and surface morphology of the thin films are analyzed by X-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The electrical conductivity of the thin films is measured by the four probe method. The results indicate that the deposition potential plays significant roles in the composition and surface morphologies of the films. With the deposition potential enhances, both the grain size and the roughness of the films increase gradually. The phase composition of the films varies with Cu content. The electrical conductivity of the films increases as the increase of the deposition potential.

D-P11
Improved microstructural evolution of intrinsic nanocrystalline silicon and solar cell performance
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Hydrogenated nanocrystalline silicon (nc-Si:H) is a promising material for the bottom cell in amorphous silicon (a-Si:H) based multi-junction solar cells. To obtain high efficiency nc-Si:H cells, both the material quality and device structure need to be optimized. In this study, nc-Si:H thin-film n-i-p solar cells were constructed on flexible stainless steel substrates by plasma-enhanced chemical vapor deposition. Influence of the n-type seed-layer on the microstructural evolution of the subsequent intrinsic nc-Si:H absorbers and the resultant performance of nc-Si:H solar cells was investigated. It was found that a highly-crystallized n-layer helps to reduce the incubation layer thickness at the n/i interface. A multi-step gradient hydrogen dilution technique has been adopted to control the microstructure of the intrinsic layer in nc-Si:H solar cell. The experimental results demonstrated that the efficiency can be much improved when there’s a higher crystallinity at n/i interface. By combining above methods, an efficiency of 8.29% (Voc=0.49 V, Jsc=24.9 mA/cm2, FF=68%) has been achieved for nc-Si:H single-junction solar cells. Then, the optimized nc-Si:H solar cell was used as a bottom component in a-Si:H/nc-Si:H tandem solar cell. The influence of the thicknesses of bottom cells and top cells were investigated to achieve good current matching. An efficiency of 11.14% has been obtained for tandem solar cell with Voc of 1.32V, Jsc of
12.98 mA/cm² and fill factor of 65%. Combining the improved nc-Si:H intrinsic layer and optimized n/i interface, the performance of nc-Si:H single-junction and a-Si:H/nc-Si:H tandem cells has been significantly improved.

D-P12
A damage mechanics based method for fatigue life prediction of the metal graded materials
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The metal graded material is a kind of functional graded materials (FGM) which is composed of two or more metal materials with the rational distribution and uniform transition. Due to the special mechanical properties of metal graded material, it can meet the requirement that different location has different mechanical property. So the metal graded material has a wide application in various fields, especially in the aerospace field. However, because of its special inhomogeneity, the usual fatigue life prediction method of uniform materials is not well adapted to this new material. Therefore, a new method to predict the fatigue life of metal graded material is presented, which is based on the theory of continuum damage mechanics. In this paper, a model of the cantilever beam is established, which is made of the TC4-TC11 graded material as an example. Firstly, according to the principle of thermodynamics, the damage evolution equation of metal graded materials is derived. Secondly, the damage evolution parameters for TC4-TC11 metal graded materials are calibrated according to the experimental data. Finally, the model of beam is established and the stress analysis and life prediction are carried out. The simulation results show that this method is feasible.

D-P13
Nitrogen-doped Electrocatalytically Active Pd/MWCNTs Nanohybrids for Oxygen Reduction Reaction
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A novel nitrogen-doped Palladium/Multiwalled Carbon Nanotubes (Pd/MWCNTs) nanocatalyst with enhanced catalytic activity for oxygen reduction reaction (ORR) is prepared via in situ method using polyaniline as nitrogen source. Electrocatalytic behavior towards ORR of the Pd/MWCNTs as well as commercial Pd/C catalyst was investigated in O2 saturated KOH alkaline solution. Cyclic voltammograms showed a substantial reduction process on both samples, while the onset potential for ORR on the as-prepared nitrogen-doped Pd/MWCNTs catalyst was almost 50 mV more positive than commercial Pd/C, indicating an increased ORR activity. Linear sweep voltammograms showed that the mass transport limited current for Pd/MWCNTs (5.10 mA cm⁻² at 1600 rpm) was higher than commercial Pd/C (4.59 mA cm⁻² at 1600 rpm). After 200 cycles cyclic voltammetry scanning, the mass transport limited current density at 1600 rpm of Pd/MWCNTs catalyst reduced to 3.57 mA cm⁻² while commercial Pd/C dropped to 2.04 mA cm⁻², showing a better stability on this Pd/MWCNTs catalyst.

D-P14
A Facile Synthesis of MoS2/Reduced Graphene Oxide@Polyaniline for High-Performance Supercapacitors
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This account reports a facile and effective preparation route of molybdenum disulfide/reduced graphene oxide@polyaniline (MoS2/RGO@PANI) composite through a two-step synthetic method. The rational combination of two components allowed a uniform dispersion of polyaniline (PANI) on the surface of molybdenum disulfide/reduced graphene oxide (MoS2/RGO). The synergistic effect induced by the combined components resulted in outstanding energy storage performance in terms of high specific capacitance (1224 F g⁻¹ at 1 A g⁻¹), good rate capability (721 F g⁻¹ at 20 A g⁻¹) and cycling stability (82.5% retention after 3000 cycles). The symmetric supercapacitor made of MoS2/RGO@PANI displayed interesting characteristics, such as a high specific capacitance of 160 F g⁻¹ at 1 A g⁻¹, a maximum energy density of 22.3 Wh kg⁻¹ and power density of 5.08 kW kg⁻¹.

D-P15
High-performance asymmetric supercapacitors based on cobalt chloride carbonate hydroxide nanowire arrays and activated carbon
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Cobalt chloride carbonate hydroxide nanowire arrays (CCCH NWAs) with an average length of 8 μm grown on Ni foam was successfully fabricated via a simple hydrothermal process. Electrochemical tests show a specific capacitance as high as 1737 F/g at 2.5 mA/cm², and an good cycling stability demonstrated by a 87.3% capacitance retention after 2000 cycles at a current of 7.5 mA/cm². An asymmetric supercapacitor was also successfully assembled with CCCH NWAs and activated carbon (AC) applied as positive and negative electrode, respectively. The asymmetric supercapacitor exhibited a maximum energy density of 29.1 Wh/kg at power density of 100 W/kg in the wide voltage region of 0-1.6 V, as well as a good electrochemical stability. The impressive results presented here may pave the way for promising applications in cheap, easy preparation and high energy density storage systems.

D-P16
The relationship of processing parameters and GH4169 alloy surface topography of selective laser melted
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Selective laser melting (SLM) technology based on powder bed has been used to manufacture GH4169 samples. In the present work, taking Ni-based powders of GH4169 as experiment material, the good technological parameters of SLM were determined by analyzing the effect of the laser electric current, the scan speed ,the laser pulse width, the laser light frequency, the push powder thickness, the scan interval and the scanning way on Single-layer single-channel scanning, single-layer multi-channel scanning and multi-level multi-channel scanning. The effects of process parameters on the powder formability was analyzed. The cross-sections morphology and density of the block specimen prepared under the different SLM process parameter were studied. The optimal process parameters were the scanning speed of 150 mm/min, the laser pulse width of 5.0 ms, the push powder thickness of 0.15 mm, the scanning current of 140 A, the laser light frequency of 12Hz and the scan interval of
Despite recent progress in lithium-sulfur batteries (LSB), the chemically immobilizing mechanism for sulfur species hasn’t been understood totally. For the first time, we report on insight into the immobilizing nature for soluble lithium polysulfides (LPS) based on metal-organic frameworks (MOFs) derived porous TiO2-S cathodes for LSB. The LSB based on hierarchically porous TiO2-S cathode displays greatly enhanced rate capability with superior specific capacity and coulombic efficiency. Electrochemical impedance spectroscopy for fresh and cycled cells indicates that the charge transfer kinetics of the TiO2-S cathode can be obviously enhanced, and the diffusion coefficient of Li-ions greatly increases due to the Ti-S chemical bonding during charge/discharge process, almost 17 times higher than that of fresh TiO2-S hybrid cathode. The charge resistance and diffusion coefficient can be comparable to that of previously reported carbon/sulfur cathode. It is revealed that dissolution of lithium polysulfides, deposition of Li2S/Li2S2 and shuttle effect can be greatly mitigated due to the chemical immobilization effect from Ti-S chemical bonding. Furthermore, the porous structures of MOFs-derived TiO2 effectively alleviate the volume change, shortens the diffusion path of Li+. The present work provides a hint to design rational cathodes for high performance LSB.

We present a facile hot injection and hydrothermal method to synthesize Cu2ZnSnS4 (CZTS) nanoparticles sensitized metal-organic frameworks (MOFs)-derived mesoporous TiO2. The MOFs-derived TiO2 inherits the large specific surface area and abundantly porous structures of the MOFs structure, which is of great benefit to effectively enhance the dye loading capacity, prolong the incident light traveling length by enhancing the multiple interparticle light-scattering processes, and therefore improve the light absorption capacity. The sensitization of CZTS nanoparticles effectively enlarges the photoresponse range of TiO2 to the visible light region and facilitates photoinduced carrier transport. The formed heterostructure between CZTS nanoparticles and MOFs-derived TiO2 with matched band gap structure effectively suppresses the recombination rates of photogenerated electron/hole pairs and prolongs the lifespan of the carriers. Photoanodes based upon CZTS/MOFs-derived TiO2 photoanodes can achieve the maximal photocurrent of 17.27 mA cm-2 and photoelectric conversion performance of 8.10%, nearly 1.93 and 2.21 times higher than those of TiO2-based photoanode. The related mechanism and model are investigated. The strikingly improved photoelectric properties are ascribed to a synergistic action between the MOFs-derived TiO2 and the sensitization of CZTS nanoparticles.
Hierarchically Layered MoS2/Mn3O4 Hybrid Architectures for Electrochemical Supercapacitors with Enhanced Performance
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Supercapacitors are widely used nowadays in power equipment, digital telecommunication systems and electronic products as an important class of energy storage devices, due to their high power density and efficiency, fast recharge capability and long cycle life. We for the first time report a novel kind of supercapacitor using hierarchical MoS2/Mn3O4 hybrid architectures as electrodes based on layered MoS2 and Mn3O4 nanoparticles via a simple and low-cost hydrothermal and chemical precipitation route. The Mn3O4 nanoparticles are homogeneously incorporated into thin layers of MoS2 hierarchical architectures. The cycle stability of MoS2/Mn3O4 nanostructure is greatly improved, still reserves a capacity of 119.3 F g$^{-1}$ after 2000 cycles at a current density of 1.0 A g$^{-1}$, about 69.3% reservation of the initial capacitance. While MoS2 layered nanostructured electrode only shows a capacitance of 47.2 F g$^{-1}$. It should be noted that the capacitance of MoS2@Mn3O4 nanostructures is more than two times higher than that of MoS2 electrode. The good performance is due to the synergistic effect between the layered MoS2 and Mn3O4 nanoparticles. The layered hybrid displays a larger specific surface to provide enough active sites for the redox reaction and shorten the distance of charge transfer for ions and electrons. While Mn3O4 acts as a holder to enhance the stability of the MoS2 framework and provides additional capacity. The Mn3O4 nanoparticles can serve as a holder and prevent MoS2 nanosheets from restacking. Moreover, the MoS2 sheets act as substracts to improve to the conductivity of Mn3O4. The layered MoS2/Mn3O4 hybrid inspires a new way of designing high-performance electrochemical supercapacitors.

D-P20
CdS Quantum Dots Sensitized Mesoporous BiVO4 Heterostructures for Solar Cells with Enhanced Photo-Electrical Conversion Efficiency
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CdS quantum dots sensitized olive-shaped mesoporous BiVO4 for solar cells with enhanced photo-electrical conversion efficiency was prepared by solvothermal chemical reaction and successive ionic layer adsorption and chemical reaction (SILAR) techniques. An improved photo-electrical conversion efficiency of up to 1.29 % is achieved for quantum dot sensitized solar cell (QDSCs) based on CdS/BiVO4 heterostructure photoanodes, about two times larger than that of QDSCs based on pure BiVO4 photoanodes (0.62 %). Coupling CdS with BiVO4 can further expand the light response range of BiVO4 from visible to near infrared region, and thus enlarge the light harvesting region, which can be confirmed by the UV-vis diffuse reflectance measurements. A uniquely matched energy band structure for CdS/BiVO4 heterostructure can be conducive to efficiently separate photogenerated charge carriers, which reduces the probability of recombination between light-induced electrons and holes, resulting in greatly enhanced photoelectric conversion efficiency. Electrochemical impedance spectroscopy measurements suggest that coupling m-BiVO4 with CdS QDs can effectively improve the charge transfer behavior. Furthermore, the formation of CdS/BiVO4 heterostructure can effectively prolong the charge carriers’ lifetime. The large specific surface area and properly mesoporous structure of CdS/BiVO4 heterostructure can effectively adsorb more sensitizer and create more reaction center on the contact interface between the electrolyte and photoanode.
D-P21
Highly crystalline Ti-doped SnO2 hollow-structured photocatalyst with enhanced photocatalytic activity for degradation of organic dyes
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Nanoscale semiconductors have received extensive attention as potential effective photocatalysts due to their unique effects. Among the various semiconductors, SnO2 can cover a spectral bandwidth different from that of TiO2. We developed a facile infiltration route for synthesizing hollow-structured SnO2 with an adjustable Ti doping content using SiO2 as hard templates. Ti-doped SnO2 with a doping content of 20 mol% displays the highest photocatalytic activity, with 92% MB photocatalytically decomposed under UV light irradiation, with 54% MB photocatalytically decomposed under visible light irradiation. Homogeneous doping of Ti into the lattice of SnO2 prevents the recombination of electron–hole pairs and expands the range of usable excitation light to the visible-light region. In addition, the highly crystalline state, large surface area, and large pore size of Ti-doped SnO2 also contribute to the improved photocatalytic activity of the Ti-doped SnO2 samples.

D-P22
Highly ordered mesoporous spinel ZnCo2O4 as a high-performance anode material for lithium-ion batteries
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Highly ordered mesoporous spinel ZnCo2O4 (HOM-ZnCo2O4) with controlled morphology, high surface area and narrow pore size distribution is prepared through a facile infiltration route with molecular sieve SBA-15 as templates for the first time. At the same time, nanostructured porous spherical spinel ZnCo2O4 (NPS-ZnCo2O4) framework is also synthesized using silicon spheres as templates. HOM-ZnCo2O4 is revealed to have a highly ordered mesoporous structure with a pore diameter of ~ 4 nm and a high surface area of 112.0 m2 g-1, while NPS-ZnCo2O4 is a framework containing 3D connected pores with a diameter of ~ 100 nm and surface area of 88.4 m2 g-1. As the anode material, HOM-ZnCo2O4 displays a high reversible specific capacity up to 1623 mA h g-1, ~300 mA h g-1 larger than NPS-ZnCo2O4 (1286 mA h g-1), at a current density of 2.0 A g-1. When applying a high current density of 8.0 A g-1, the capacity of HOM-ZnCo2O4 still remains at a high level of 1470 mA h g-1, but NPS-ZnCo2O4 undergoes a severe degradation to 751 mA h g-1. The large specific surface area contributes much to the better rate performance of the former because it provides a larger cross section for Li+ flux. Also, the small pore size may be more in favor of maintaining the structural stability of porous spinel material than the large one. Aside from its nanostructured characteristics, an inner atomic synergistic effect within the cubic lattices may account for the superior electrochemical performance of HOM-ZnCo2O4. HOM-ZnCo2O4 that exhibits high capacities and well stability is a kind of competitive anode materials and highly-ordered mesoporous structure is superior in electrode design.

D-P23
A novel one-step situ synthesis of 3D Nickel-Antimony thin film for advanced sodium-ion anode batteries
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3D Nickel-Antimony (NiSb) thin film alloy with high sodium storage capacities has been fabricated via the one-step situ solvothermal synthesis successfully, which developed the advantages of low-cost, simplification and high production sufficiently. To form the special NiSb thin-film structure, the self-supported porous Ni foam was served as the templet. Meanwhile, it also can be used as a binder-free conductive network to improve the electronic conductivity. Thus, the 3D NiSb thin film alloy exhibited excellent electrochemical properties for sodium-ion anode material. The specific capacity was maintained at around 420 mAh g⁻¹ after 100 cycles at 100 mA g⁻¹. And, when the current density increased at 100, 200 and 400 mA g⁻¹, reversible capacities of 643.8, 520.5 and 378.6 mAh g⁻¹ can be obtained, respectively. Importantly, when the current density was reduced back to 100 mAh g⁻¹, the capacity can recover to 475.7 mAh g⁻¹. The outstanding cycling performance and rate capability can be attributed to the unique porous and 3D-binder-free structure which contributed to the electronic transmission and Na⁺ transformation as well as alleviation of the volume changes.

D-P24

Effect of citric acid dosage and sintered temperature on the composition, morphology and electrochemical properties of lithium vanadium oxide prepared by a sol–gel method
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A lithium vanadium oxide cathode material was synthesized via sol-gel processing using citric acid as the chelating agent. Different dosage of citric acid and sintered temperature were introduced to investigate their effects on the products composition, morphology and electrochemical properties. Results show that the V2O3 yield was inhibited and the crystallization of grain was accelerated with the increasing dosage of citric acid. Furthermore, V2O3 was oxidized to LiV3O8 and Li0.3V2O5 with the increase of sintered temperature. The single thermal battery shows a high initial capacity of 312.2 mAh/g at a current density of 100 mA/cm² (the terminated voltage is 0.2 V), and the preparing condition of its active material was: the sample was sintered at 450 °C; the molar ratio of total metal ions to citric acid was 1:2.

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Internal friction behaviors of Ni-Mn-In magnetic shape memory alloy with two-step structural transformation
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Shape memory alloys (SMAs) undergo reversible diffusionless solid-to-solid transformations between two distinct phases in response to changes in external fields, such as temperature, applied stress or magnetic field, in which the atoms orderly rearrange to create internal interfaces moving through crystals. As for the Heusler-type Ni-Mn-Z (Z=In, Sn, Sb) magnetic shape memory alloys (MSMAs), they are different from traditional, thermally activated SMAs because of a strong magnetoelastic coupling during the magnetic field induced martensitic transformation from ferromagnetic austenite to paramagnetic / antiferromagnetic martensite. The unique structural transformation leads to their multi-functionalities, such as large magnetic-field-induced strain, inverse magnetocaloric effect, giant magnetoresistance effect and high magnetothermal conductivity, extending many practical applications in
high-performance actuators, and environment-friendly magnetic refrigerator, magnetically controlled damper, etc. More recently, another emerging use for the MSMAs is in energy harvesting, that is, capturing energy from waste, environmental, or mechanical sources and converting it into a usable form, such as mechanical vibration energy at low frequencies during walking, because of a significant magnetization change in the MSMAs as a response to changes of external fields. All these applications are associated with the creation and motion of the internal interfaces, which can be characterized by the internal friction (IF) behaviors. As we all known, a knowledge of the IF behaviors is crucial for a deeper understanding of the physical mechanisms behind the multifunctional properties of the MSMAs. The physical properties in the application of his energy conversion, such as electromagnetic energy, thermal energy, mechanical energy, are all closely related to the behavior of IF behaviors. So it is of great practical significance to study IF behavior to the energy conversion of shape memory memory alloys.

In recent years, much effort has been put to extend the study of the IF behaviors in Ni-Mn-Ga alloys by means of dynamic mechanical analysis (DMA). Researchers found that the IF behaviors exhibit strong dependences on transformation temperatures, stress amplitude, frequency and temperature rate. Early studies have proven that the IF behavior is a powerful tool that to detect the existence of transformation phenomena and throwing new light on their structural mechanisms.

Compared with the well-studied Ni-Mn-Ga alloys, the study of the IF behaviors in Ni-Mn-In alloys is rare because of their inherent brittleness. Fortunately, in our previous work, a good ductility of 6.6% was achieved in dual phase (\( \beta \)-Ni51.8Mn31.4In16.8 and \( \gamma \)-Ni62.4Mn32.5In5.1) Ni52Mn32In16 alloy prepared by directional solidification. More recently, we reported that a high isothermal IF over a large temperature range is obtained in the dual-phase Ni-Mn-In alloy. In this work, the low-frequency IF behaviors of the directionally solidified Ni52Mn32In16 alloy are systemically investigated to determine their dependences on external fields including the frequency and the heating/cooling rate. The effect of the second phase (\( \gamma \)) on the IF was qualitatively discussed.

Polycrystalline ingots of Ni52Mn32In16 alloys were prepared using Ni (99.995% purity), Mn (99.98% purity) and In (99.99% purity) as raw materials by arc-melting under an argon atmosphere. They were melted four times in order to make the compositional homogenous, followed by sucking into the water cooled copper crucible, and ultimately formation rods with the diameter 7 mm and length 55 mm. By directional solidification method, these rods were grown in Al2O3 crucibles at a temperature gradient of 500°C/cm and a growth rate of 100 \( \mu \)m /s. Then they were annealed at 1173K for 24 h, the IF behavior was investigated by DMA. All characteristic transformation temperatures were taken from the peak values measured by DSC at a rate of 3°C/min for both heating and cooling.

In this work, we found the two-step structural transformation, rather than the single stage structural transformation of other shape memory alloys. According to the experimental results, the MT peak is an asymmetric shoulder rather than those sharp peaks for other shape memory alloys and the IMT peak has the maximum IF value. Furthermore, the well-known pre-martensitic behavior in Ni2MnGa-type MSMAs is not observed in the dual-phase Ni-Mn-In samples. As the cooling / heating rate increases, the height of the IMT peak increases and its position is shifted to higher temperatures. In comparison with the IMT peak, the MT peak is independent on the cooling/heating rate. The starting temperatures of the MT and represent a weak dependence on , while the IMT peak is strongly dependent, i.e. the starting point of the IMT peak is remarkably shifted to lower temperatures as the frequency increases. Meanwhile, the heights of both the MT and IMT peak rapidly decrease with increasing the frequency. This work also throws new light on their structural transformation mechanisms.

**Reversible hydrogen sorption properties of Sodium Borohydride - Graphene based composites**
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Hydrogen energy is clean and inexhaustible, thus it is regarded as one of the most promising energy resources for the future world. As hydrogen storage has become the bottleneck toward the upcoming “hydrogen economy.” Solid state hydrogen storage method has advantages in hydrogen storage density, efficiency of energy utilization and safety of operation, which is considered as a prospective on-board energy resource. Among various solid state hydrogen materials, metal borohydrides have been widely studied for their high hydrogen storage capacity. However, the use of metal borohydrides for hydrogen storage is challenging because of both kinetic and thermodynamic limitations which result from the strong covalent and ionic bonds involved in the metal borohydrides. Therefore, the hydrogen storage properties of metal borohydrides need to be improved.

Methods:
The starting materials were used as received without further purification. NaBH₄ (~98%), graphene, NiCl₂ were purchased from Strem Chemicals Inc., Nanjing XFNANO Materials Tech Co., Ltd., China, and Aladdin Reagent Database, Inc., respectively. The sample storage and handling were performed in a Lab 2000 glove box (Etelux Interargas system Co., Ltd.) filled with purified argon. Ni-graphene composite was prepared by dissolving NaBH₄ into aqueous solution of NiCl₂, followed by the addition of graphene at room temperature. The resulting solution was ultrasonically treated for 1 h and then dried under vacuum at 40 °C for 5 h after centrifugation. The intermediate product was named as Ni@Graphene, after ball milled with NaBH₄, we got a new nanocomposite, NaBH₄/Ni@Graphene. Hydriding/dehydriding properties of samples were measured by a Sievert type apparatus manufactured by Shanghai Institute of Microsystem and Information Technology. The PCT measurements were performed at different temperatures in the hydrogen pressure range of 0.001-4.6 MPa. Temperature programmed-dehydrogenation (TPD) measurements were performed starting from vacuum at a heating rate of 3 °C min⁻¹. The desorbed hydrogen was determined by volumetric methods. Dehydriding behaviors of samples were examined by synchronous thermal analyses (Thermogravimetry/Differential scanning calorimetry, TG/DSC, Netzsch, STA 449 F3 Jupiter). The heating rate was set at 3, 5 and 10 K min⁻¹, with the temperature rising from 26 to 500 °C under 1 bar flowing argon atmosphere. The samples at different states were characterized by X-ray diffraction (XRD Rigaku D/MAX-2500, VL/PCX, Cu Ka radiation). Fourier transform infrared spectroscopy (FTIR) was also used as an analysis and test method.

Results:
According to XRD patterns, these hydrogen storage composites were only physical mixing instead of chemical reaction in the high-energy ball-milling process. The FTIR spectra further corroborated this statement. The rehydrogenation of the NaBH₄/Ni@Graphene was measured by PCT at a constant temperature of 460 °C. For comparison, PCT of Ni@Graphene was also performed at the same temperature. Hydrogen desorption tests of samples were carried out at the rate of 3K / min from 20 °C to 460 °C, and then kept more than 10 hours at 460 °C, the final hydrogen desorption amount was 4.3 wt%. It was observed that a significant hydrogen release process began at about 437 °C, the hydrogen desorption amount increased rapidly with the increasing temperature. After a 15-hour hydrogen release, the hydrogen desorption curve tended to be flattened, indicating that the hydrogen desorption reaction completed under this temperature. The pure NaBH₄ can barely release hydrogen before 500 °C, only reaches 2 wt% at 550 °C. Hence, adding graphene, to some extent, improved the hydrogen desorption property of NaBH₄, using Ni@Graphene prepared by solution method significantly increased the...
hydrogen desorption performance. Hydrogen absorption capacity of 1.2 wt% was obtained in NaBH4/Ni@Graphene in a period of 7 hours at 430 °C and 3MP hydrogen pressure. The hydrogen absorption rate was stable, and hydrogen absorption process could continue as time goes on. The XRD results and FTIR profiles proved the regeneration of NaBH4, indicating the improvement of rehydrogenation properties through the addition of Ni@Graphene. Owing to the addition of Ni@graphene and ball milling process, NaBH4 particles were well dispersed and the surface area was increased, thus the hydrogen sorption properties were improved. Further studies are undergoing to study the mechanisms of reversible hydrogen storage in NaBH4.

Conclusion:
In comparison with NaBH4, NaBH4-Ni@Graphene composite showed better dehydrogenation and rehydrogenation properties. Graphene played a very important role during dehydrogenation and rehydrogenation process.

**Eutectic mixture of stearic acid-acetanilide as phase change material**
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The binary mixtures of stearic acid (SA)-acetanilide (AA) as phase change material was investigated by differential scanning calorimetry (DSC) and X-ray powder diffraction (XRD). The solid-liquid phase diagrams of systems were established, and eutectic compositions of binary mixtures and corresponding thermal properties were verified: SA-AA, $x_{SA}=0.919$ ($x_{SA}$ is the molar fraction of SA). The melting temperature and latent heat of fusion of eutectic mixture are 67.54 °C and 206.47 J g$^{-1}$ for SA-AA system respectively. A modeling approach on the bases of thermodynamics was employed to predict solid-liquid equilibria of the studied mixtures and their latent heats of fusion. The simulated results are in good agreement with experimental results. As novel phase change material (PCM), the studied eutectic mixture has attractive thermal properties and great utility for solar heat applications.

**Supercapacitor performance of bamboo-based activated carbon**
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Bamboo-based carbon was prepared successfully by a simple heat treatment with or without KOH or CO2 activation in protective atmosphere conditions, and characterized for possible energy storage applications. Different activation methods (KOH, CO2, both KOH and CO2) could influence the electrochemical capacitance of Bamboo charcoal dramatically. And the morphology and pore features of the activated carbons were characterized by nitrogen adsorption-desorption test and scanning electron microscopy. The results showed that under the activation with both KOH and CO2 of the prepared sample provides a specific surface area of 950 m$^2$/g and a carbon yield of 65%. Meanwhile, the highest specific capacitance is 109 F g$^{-1}$ at current density of 0.5 A g$^{-1}$ in 6 M KOH electrolyte. And the specific capacitance retention is also more than 90% of the original capacitance after 10000 cycles. Bamboocharcoal, a kind of renewable natural resource, with microporous structure, high specific surface area and good adsorption capacity, can provide a new research direction in the field of high-performance supercapacitor.

**Superstructure and physical properties of skutterudite-related phase CoGe1.5Se1.5**
In addition to the ideal skutterudite structure (space group Im-3), another group of ternary compounds with skutterudite-related crystal structure, MT1.5Ch1.5 (M = Co, Rh or Ir, T = Ge or Sn and Ch = S, Se or Te) has attracted much attention since their large variety of compositions, complex crystal structure and interesting thermoelectric properties. While, the superstructure of this kind of compounds is still under discussion and the influence of chemical composition on electronic properties of CoGe1.5Se1.5 needs more studies. In this work, CoGe1.5Se1.5 skutterudite-related phase with a homogeneity range was synthesized by solid state reaction. The phase, crystal structure, thermal stability and electronic properties were studied. XRD indicates that CoGe1.5Se1.5 crystallizes in a modification of the skutterudite CoAs3 type structure with space group R-3 (a = b = 11.751(1) Å, c = 14.36(1) Å). HRTEM-SAED shows more information about the superstructure to confirm the trigonal space group R-3. The lattice parameter of CoGe1.5Se1.5 skutterudite-related phase was found to be dependent on the concentration of Ge and Se. CoGe1.5Se1.5 decomposed between 1073 K and 1173 K under argon atmosphere investigated by in-situ XRD, suggesting a good thermal stability of this phase. CoGe1.49Se1.42, CoGe1.43Se1.34 and CoGe1.50Se1.15 dense bulk samples were obtained by hot-press technique. The chemical composition detected by FESEM/EDS suggests the existence of voids at Ge and Se crystallographic sites. The electrical resistivity of the compounds decreases with increasing temperature, acting as a semiconductor. The chemical composition has a big influence on the value of electrical resistivity.

**Molecularly imprinted polymers / graphene oxide modified glassy carbon electrode for selective detection of sulfanilamide**

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A novel sensitive electrochemical sensor was developed by precipitation-polymerization to synthesize molecularly imprinted polymers/graphene oxide (GO@MIPs) in the presence of sulfanilamide (SNM) as template molecules. GO@MIPs were used as electrode sensing material to dispensing onto a glassy carbon electrode (GCE) in chitosan aqueous solution. The performance of the imprinted and non-imprinted materials was evaluated by square wave voltammetry (SWV) and chronoamperometry. Using the GO@MIPs as electrode sensing material, the electrode showed a high selectivity and sensitivity toward SNM in aqueous solutions. There was two linear relationship between the peak currents intensity in SWV measurement and SNM concentrations in the range 10 -100 ng/mL and 400-1000 ng/mL. The results were accurate (with recoveries higher than 90%), precise (with standard deviations less than 5%) and the detection limit was 10 ng/mL. The new sensor is selective, simple to construct and easy to operate. The MIPs sensor was successfully applied to quantify SNM in milk samples.

**Aluminum alloy anode materials for Li-ion batteries**

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The pure Al is expected to be an active material for a negative electrode in Li-ion battery, with the larger theoretical capacity of 2235 mAh/g than that of graphite (372mAh/g). In this paper, Arc melting Al7Cu2Fe and Al73Cu5Fe22 were treated by mechanical balling milling to reduce particle sizes for a suitable size. The 2032-type coin cells with the active materials and lithium metal were assembled. Two kinds of materials' structures, mechanism of lithium intercalation and electrochemical performances were studied by XRD, SEM, TEM, and galvanostatic charge/discharge test. At the same time, the influence of heat treatment to the alloy materials was also studied. The results show that the content of aluminum and the heat treatment process had huge impact on the cycle performance of Aluminum alloys.

Preparation and thermal characterization of oxalic acid dihydrate/bentonite composite as form-stable phase change materials for thermal energy storage

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Phase change materials (PCMs) are the effective substances for thermal energy storage. Oxalic acid dihydrate (OAD) which has very high initial phase transition enthalpy is a promising PCM. However, the melting point of OAD is 101 °C higher than the boiling point of water. Serious leakage is caused by a large amount of water steam when heated to melt. Then there are large degradations of thermophysical properties over time which hinder further application. In this paper, shape-stabilized composite phase change materials composed of oxalic acid dihydrate (OAD) and bentonite were prepared by a facile blending method to overcome the problem of leakage. Various characterization techniques were carried out to characterize their structural and thermal properties, including: thermal analyses (TGA and DSC), Fourier transform infrared spectroscopy (FT-IR), and field emission scanning electron microscopy (FE-SEM). The FT-IR results indicated the interactions between OAD and bentonite, such as the capillary force and the hydrogen bonding, resulting in the confined crystallization process. As a result, the OAD that was confined was amorphous. The TGA analysis and SEM results showed that sample has the best coating effect when the amount of bentonite is 17.7%. The DSC analysis demonstrated that a decrease in the OAD content was accompanied by a continuous decrease in the melting point and phase change enthalpy of the composites.

The assessment of lead environmental footprint in lead-acid battery based on LCA

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Lead-acid battery (LAB), one kind of chemical battery, is widely used in the world, but the serious pollution in the process of LAB production and disposal of waste LAB is the concerning environmental issue. Therefore, the assessment of the lead environmental footprint (LEF) of lead in LAB was carried out based on the LCA theory and China’s status.
In the research, the life cycle of lead in LAB included the raw materials extraction and processing, manufacture, transportation, use, end-of-life and regeneration. And 14 kinds of environmental impact categories were chosen,
including global warming, ozone depletion, respiratory effect, ionizing radiation, tropospheric ozone formation, acidification, eutrophication-land, eutrophication-water, abiotic depletion-mineral/fossil fuels, toxicity-environment, toxicity-human health(cancer), toxicity-human health (non-cancer), water scarcity, and land use. According to the LAB industry characteristics in China, 1t electrolytic lead was chosen as function unit for materials extraction and regeneration processing and 1 KV Ah was chosen as function unit for the processes of manufacture, transportation, use, and end-of-life. Then the LEF accounting model was built with Ecoinvent database and the survey data from the key companies of LAB production and secondary lead production in China. The normalized results indicated that the raw materials extraction and processing were two largest contributories to the LEF, and the environmental impacts of primary lead was significantly higher than the secondary lead; during the processes of the primary and secondary lead, the most serious environmental problems were caused by the smelting of the lead and transportation of waste battery respectively. Therefore, on the basis of the results, there are several practical measures should be taken to reduce the LEF of LAB, such as building an effective LAB recycling system, enlarging the market share of the legal secondary lead, and avoiding the long-distance transportation of the waste battery. The results can be used in the LAB’s enterprises to accelerate their green development.

**New Sn-Cu/C composite anode materials with high cyclic stability for Lithium ion battery**
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In this work, Sn-Cu/C composite anode material with high cyclic stability was obtained through the modification and structure design of Sn-Cu alloy. The Sn-Cu alloy was modified by non-crystallization. And a “core-shell” structure was found to control the volume change. The results showed that the weakening of the crystallization improved the cyclic stability of the Sn-Cu alloy anode material. And after “core-shell” structure design, the Sn-Cu/C composite showed high cyclic stability of 200 cycles. The “core-shell” structure controlled the volume change within the structure and left room for the volume expansion of Sn-Cu alloy. Non-crystallization and “core-shell” structure designs are proved to be useful ways in improving the cyclic stability of Sn-Cu alloy anode materials.

**Activated porous carbon wrapped sulfur sub-microparticles as cathode materials for Lithium sulfur battery**
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The lithium-sulfur battery hold a high theoretical capacity and specific energy, which is 45 times larger than that of today’s lithium-ion batteries. Yet low sulfur loading capacity and large particle size of the cathode greatly offset its advantage in high energy density. Herein, we introduce a liquid phase deposition method to fabricate sulfur sub-microparticles wrapping by activated porous carbon materials. Compared with common sublimed sulfur cathode, the composites cathode comprised by sulfur sub-microparticles and porous carbon shows an enhanced initial discharge capacity of 1093 mAh/g enhanced from 840.7mAh/g at C/10. The reversible specific capacity after 100 cycles increases from 383 mAh/g to 504 mAh/g. This method has some advantages such as simple
process, convenient operation and low cost. It is an available method for industrial manufacturing of lithium/sulfur batteries.