FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Low temperature carbonization of cellulose nanocrystals for high performance carbon anode of sodium-ion batteries	Hongli Zhu, Fei Shen, Wei Luo, Shuze Zhu, Minhua Zhao, Bharath Natarajan, Jiaqi Dai, Lihui Zhou, Xiulei Jie, Reza S. Yassarf, Teng Li, Liangbing Hu	Nano Energy 2017, 33, 37–44.	A unique mesoporous and percolated carbon was achieved by directly carbonizing CNC derived from trees. The mesoporous carbon immersed with short-range ordered carbon lattice and percolated carbon nanofibers has the ideal structure and conductivity for SIB anode with outstanding performance including high capacity, excellent rate, and good cycling stability.
Direct Observation of Dual-Filament Switching Behaviors in Ta2O5-Based Memristors	Chia-Fu Chang, Jui-Yuan Chen, Chun-Wei Huang, Chung-Hua Chiu, Ting-Yi Lin, Ping-Hung Yeh, and Wen-Wei Wu	Small 13.15 (2017).	Ag/Ta2O5/Pt RRAM devices have low power consumption and high stability. By measuring electrical properries of FIB sample in atmosphere and vacuum, role of humidity and affects the Ag+ concentration was shown.EDS and EELS results indicated that the filament composed of the oxygen vacancies and Ag atoms forms the dual filament
In-situ TEM Observation of Multilevel Storage Behavior in Low Power FeRAM Device,	Chung-Hua Chiu, Chun-Wei Huang, Ying-Hui Hsieh, Jui-Yuan Chen, Chia-Fu Chang, Ying-Hao Chu and Wen-Wei Wu,	Nano Energy 34 (2017): 103-110.	Ferroeelctric RAM are the most mature candidates for data storage device, however their scabilitiy is limited. This study proposed that mixed multiphase multiferroelectrics BFO are god candidate to tackle this problem.
Stability of a Bifunctional Cu-Based Core@ Zeolite Shell Catalyst for Dimethyl Ether Synthesis Under Redox Conditions Studied by Environmental Transmission Electron Microscopy and In Situ X-Ray Ptychography	Baier S, Damsgaard CD, Klumpp M, Reinhardt J, Sheppard T, Balogh Z, Kasama T, Benzi F, Wagner JB, Schwieger W, Schroer CG, Grunwaldt JD.	Microscopy and Microanalysis (2017): 1-12.	Complementary use of in situ TEM and ptychography provided valueable insight into core-shell characteristics of nanomaterials.
Preparation and Phase Transition of FeOOH Nanorods: Strain Effects on Catalytic Water Oxidation	Gisang Park, Yong-Il Kim, Young Heon Kim, Mira Park, Kyu Yeon Jang, Hyunjoon Song,and Ki Min Nam	Nanoscale 9.14 (2017): 4751-4758.	Evolution of β-FeOOH to Fe2O3 nanorods was investigated via in situ TEM and verified with ex-situ results. Additionally, catalytic prorpercies were correlated to strctural changes.
Gas Phase Synthesis of Multifunctional Fe-Based Nanocubes	Jerome Vernieres, Stephan Steinhauer, Junlei Zhao, Audrey Chapelle, Philippe Menini, Nicolas Dufour, Rosa E. Diaz, Kai Nordlund, Flyura Djurabekova, Panagiotis Grammatikopoulos, and Mukhles Sowwan*	Advanced Functional Materials 27.11 (2017).	Sensing properties of Fe-based nanostrcutures was investigate inside an ETEM through structural and morphological changes.
In situ investigation of ordering phase transformations in FePt magnetic nanoparticles	James E. Wittig, James Bentley, Lawrence F. Allard	Ultramicroscopy 176 (2017): 218-232.	HAADF imaging mode was used to investigate structural evolution of FePt nanoparticles at temperature up to 700C. Expliting magnetic properties and structure of L10-ordered single-domain FePt is importand for technological purposes.
Evolution of Microstructural Disorder in Annealed Bismuth Telluride Nanowires	Kristopher J. Erickson, Steven J. Limmer, W. Graham Yelton, Caitlin Rochford, Michael P. Siegal, and Douglas L. Medlina,	ECS Journal of Solid State Science and Technology 6.3 (2017): N3117-N3124.	Chips were used as support. No in situ tests and results were conducted during this study.
Atomic Scale Dynamics of Contact Formation in the Cross-Section of InGaAs Nanowire Channels	Renjie Chen, Katherine L. Jungjohann, William M Mook, John Nogan, and Shadi A. Dayeh	Nano Letters 2017, 17 (4), 2189–2196.	Time-sequenced HRTEM images revealed solid-state amorphization step and formation of NixIn0.53Ga0.47As. It regrew into a single crystalline Ni2In0.53Ga0.47As phase at temperatures above 375 °C by additional incorporation of Ni adatoms from the contact reservoir.
An experimental system combined with a micromachine and double-tilt TEM holder	Takaaki Satoa, Eita Tochigi, Teruyasu Mizoguchi, Yuichi Ikuhara, Hiroyuki Fujita	Microelectronic Engineering 164 (2016): 43-47.	A custom-made MEMS device was fabricated to add mechanical capabiliaites by which one can investigate nanomechanical properties of different materiasl and structures.
Formation and Dynamics of Electron-Irradiation-Induced Defects in Hexagonal Boron Nitride at Elevated Temperatures.	Pham T, Gibb AL, Li Z, Gilbert SM, Song C, Louie SG, Zettl A	Nano Letters 2016, 16 (11), 7142–7147.	Study of stability and behavior of various defect in graphene sheets at RT-1000C temperature revealed a feasible and accurate way to control the shapes of h-BN defects, vacancies, edges, and nanopores at the atomic level. This will extend the range of applicatiosn and capabilities of this material.
Memristors with diffusive dynamics as synaptic emulators for neuromorphic computing	Wang Z, Joshi S, Savel'ev SE, Jiang H, Midya R, Lin P, Hu M, Ge N, Strachan JP, Li Z, Wu Q, Barnell M, Li G, Xin H, Williams R, Xia Q Yang JJ	Nature Materials 2016, 16 (1), 101–108.	A new class of memristor were demonstrated as synaptic emulators that function primarily on the basis of diffusion (rather than drift) dynamics. The microscopic nature of both the threshold switching and relaxation of the diffusive memristor is revealed for the first time by in situ HRTEM and explained by nanoparticle dynamics simulation.
Opposite effects of Cu and Pt atoms on graphene edges	Emi Kano, Ayako Hashimoto and Masaki Takeguchi	Applied Physics Express 2017, 10 (2), 025104.	Interaction between Pt or Cu atoms with the edge structure of graphene was observed and studied to determine the effect of different confirguration with the metal atoms. With atomic resolution imaging, evolution of defect as a function of time was also shown.
In situ observation of the thermal stability of black phosphorus	Shenghuang Lin, Yanyong Li, Wei Lu, Ying San Chui, Lukas Rogée, Qiaoliang Bao and Shu Ping Lau	2D Materials 2017, 4 (2), 025001.	Decomposition and submilation temeprature of 2D-BP were tested and verified using in situ heating. Obtaining atomically thinned BP falkes was confirmed via difraction patterns and HRTEM imaging.
External-field-induced crystal structure and domain texture in (1−x)Na0.5Bi0.5TiO3–xK0.5Bi0.5TiO3 piezoceramics	M. Otonicara, , J. Parkb, M. Logarb, G. Estevesc, J.L. Jonesc, B. Jancara	Acta Materialia 2017, 127, 319–331.	Morphotropic phase boundary in NBT-KBT bulk materials were studied by preparing thin cross sections. Samples were prepared via both mechanical polishing and FIB. Using diffraction patterns and dark-field imaging existence of different phases were detected and confitmed.
Probing electron beam effects with chemoresistive nanosensors during in situ environmental transmission electron microscopy	S. Steinhauer, Z. Wang, Z. Zhou, J. Krainer, A. Köck, K. Nordlund, F. Djurabekova, P. Grammatikopoulos, and M. Sowwan	Applied Physics Letters 2017, 110 (9), 094103.	Electrothermal chips were used to grow in situ nanowires and measure resistance change due to O absorption in an ETEM. Pre-patterned Cu was used to grown CuO nanowires, while SnO2 nanowires were used as-grown. This research has applications in nanosensors and can be utilized to liquid microscopy studies.
Evidencing the structural conversion of hydrothermally synthesized titanate nanorods by in situ electron microscopy	Linfeng Fei, Wei Lu, Yongming Hu, Guanyin Gao, Zehui Yong, Tieyu Sun, Naigen Zhou, Haoshuang Gu and Yu Wang	J. Mater. Chem. A 2017, 5 (8), 3786–3791.	Composition and structure conversion of hydrothermally synthesized titanate nanorods at high temperature were monitored using diffration patterns, HRTEM imaging and EELS analysis.
The impact of carbon coating on the synthesis and properties of α″-$Fe_{16}N_2$ powders	C.A. Bridges, O. Rios, L.F. Allard, H.M. Meyer, III, A. Huq, Y. Jiang, J.-P. Wangd, M.P. Brady	Phys. Chem. Chem. Phys., v18, pp13010, 2016	High temperature in situ TEM was used to study thermal stability of α″-$Fe_{16}N_2$. It was shown that that the carbon coating is effective at reducing the level of sintering of Fe nanoparticles during the reduction stage prior to ammonolysis. Loss of ordering in the nitrogen sublattice of carbon composite $Fe_{16}N_2$ powders in the range of 168 °C to 200 °C was observed.
Direct observation of Li diffusion in Li-doped ZnO nanowires	Guohua Li, Lei Yu, Bethany M Hudak, Yao-Jen Chang, Hyeonjun Baek, Abhishek Sundararajan, Douglas R Strachan, Gyu-Chul Yi and Beth S Gution	Mater. Res. Express, v3, pp054001, 2016	Li-doped ZnO nanowires were used to study Li diffusion upon in situ heating, where a continuous increase of low atomic mass regions within a single NW was observed between 200 °C and 600 °C. Using EELS and photoluminescence measurements a kick-out mechanism was introduced to explain the migration and conversion of the interstitial Li (Lii) to Zn-site substitutional Li (LiZn).
Atomic Resolution in Situ Imaging of a Double-Bilayer Multistep Growth Mode in Gallium Nitride Nanowires	A. D. Gamalski, J. Tersoff, and E. A. Stach	Nano Lett., v16, pp2283, 2016	Dynamics of catalytic GaN wire growth from liquid Au− Ga was studied at 800-900C inside an ETEM. Through lattice-resolved imaging they suggested that NW growth by multiple steps is due to the low mobility of double bilayer steps.

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
In situ TEM studies of micron-sized all-solid-state fluoride ion batteries: Preparation, prospects, and challenges	Mohammed Hammad Fawey, Venkata Sai Kiran Chakravadhanula, Munnangi Anji Reddy, Carine Rongeat, Torsten Scherer, Horst Hahn, Maximilian Fichtner and Christian Kübel	Microsc. Res. Tech., v79, pp615, 2016	Sample preparation of all-solid-state fluoride ion batteries using FIB has been discussed extensively, where redeposition, resistivity, porosity of the electrodes/electrolyte and leakage current are addressed. Through HRTEM imaging and diffraction patterns both anode and cathode sides were studied.
On the role of the gas environment, electron-dose-rate, and sample on the image resolution in transmission electron microscopy	Martin Ek, Sebastian P. F. Jespersen, Christian D. Damsgaard, Stig Helveg	*Adv Struct Chem Imag,* v2, 2017	They investigate resolution degradation as a function of time, which was resulted from interaction between sample-gas-beam, as well as the charge-buildup over the viewing are of the sample. They also showed that for in situ experiment using ETEM, low beam dosage should be used in order to maintain resolution.
Real-Time Observation of Reconstruction Dynamics on TiO2(001) Surface under Oxygen via an Environmental Transmission Electron Microscope	Wentao Yuan, Yong Wang, Hengbo Li, Hanglong Wu, Ze Zhang, Annabella Selloni, and Chenghua Sun	*Nano Lett.,* v16, pp132, 2016	Using an ETEM, stress-induced reconstruction dynamics of anatase TiO2 was studied under oxygen atmosphere. At 500 C, the surface structure initially formed metastable patterns and then transformed to meta stable patterns. High resolution imaging and simulation studies enabled researchers to better depict the fundamental mechanisms.
Mass transport phenomena in copper nanowires at high current density	Yu-Ting Huang, Chun-Wei Huang , Jui-Yuan Chen , Yi-Hsin Ting , Shao-Liang Cheng , Chien-Neng Liao , and Wen-Wei Wu	*Nano Res.,* pp1, 2016	Electro- and thermo-migration processes, induced by direct current sweep, were investigated in Cu nanowires using in situ TEM techniques. High current density of 10^6 A/cm2 and temperatures up to 400 C were applied to the sample to observe and characterize the migration processes.
Robust mesoporous silica compacts: multi-scale characterization of microstructural changes related to physical–mechanical Properties	Harsh Maheshwari, John D. Roehling, Bryce A. Turner, Jamal Abdinor, Tien B. Tran-Roehling, Milind D. Deo, Michael H. Bart, Subhash H. Risbud Klaus van Benthem	*J Mater Sci,* v51, pp4470, 2016	Direct observation of mesopore closure in silica powders at temperature up to 1150C was carried out using TEM. It was determined that collapsing of pores started arouns 1000C and at 1150C they completely collapsed.
Sublimation of Ag nanocrystals and their wetting behaviors with graphene and carbon nanotubes	Ruixue Lian, Han Yu, Longbing He, Lei Zhang, Yilong Zhou, Xinyang Bu, Tao Xu, Litao Sun	*Carbon,* v101, pp368, 2016	Authors investigated the sublimation and wetting behaviors of Ag nanocrystals on graphene/CNTs with in situ heating HRTEM. The observed faster sublimating at lower temperatures than theoretical predictions. The wetting angle was quantified as a function of particle size.
Nickel/Platinum Dual Silicide Axial Nanowire Heterostructures with Excellent Photosensor Applications	Wu YT, Huang CW, Chiu CH, Chang CF, Chen JY, Lin TY, Huang YT, Lu KC2, Yeh PH, Wu WW	*Nano Lett.,* v16, pp1086, 2016	Formation of Si-Ni and Si-Pt binary and ternary phases at high temperatures were studied where Si nanowire was secured between two pads of Ni and Pt. Diffusion of Pt and Ni resulted in formation of binary phases which was shown with STEM imaging and EDS analysis.
In Situ Observation on Dislocation-controlled Sublimation of Mg Nanoparticles	Yu Q, Mao MM, Li QJ, Fu XQ, Tian H, Li JX, Mao SX,3, Zhang Z	*Nano Lett.,* v16, pp1156, 2016	Sublimation mechanism of MgO-Mg core-shell nanoparticles was investigated by systematic defect characterization with a focus on role of dislocations. A liquid-like motion of solid-gas interface was observed which was correlated to the remarkable change in sublimation rate.
Visualisation of single atom dynamics in water gas shift reaction for hydrogen generation	Gai, Pratibha L., et al.	*Catal. Sci. Technol.,* v6, pp2214	In Situ observation of water gas shift reaction using an ETEM revealed formation of cluster gold nanoparticles from single atom dynamics.
Rapid synthesis of hybrids and hollow PdO nanostructures by controlled in situ dissolution of a ZnO nanorod template: insights into the formation mechanism and thermal stability	Subhajit Kundu and N. Ravishankar	*Nanoscale,* v8, pp1462, 2016	ZnO nanorods were used as template to grow PdO nanotubes, upon subsequent dissolution of ZnO. Thermal stability of the final product was studied using the Fusion system, where above 300C thinning of the shell and diameter initiated. Upon heating to 700C, significant degradation was observed and SAED reveled reduction of PdO to Pd.
Interactions between C and Cu atoms in single layer graphene: direct observation and modelling	Emi Kano, Ayako Hashimoto, Tomoaki Kaneko, Nobuo Tajima, Takahisa Ohno and Masaki Takeguchi	*Nanoscale,* v8, pp529, 2016	Interaction between Cu single atoms with carbon atoms of a sheet of graphene at 150C and 300C was studied. Through DFT calculations energy barriers for defect formation and c-c bond rotation were calculated and effect of e-beam irradiation was investigated as well.
Surface Segregation of Fe in Pt–Fe Alloy Nanoparticles: Its Precedence and Effect on the Ordered-Phase Evolution during Thermal Annealing	Sagar Prabhudev, Matthieu Bugnet, Guo-Zhen Zhu, Christina Bock, and Gianluigi A. Botton	*Chem. Cat. Chem.,* v7, pp3655 – 3664, 2015	Disorder to order transformation as well as phase segregation in Pt-Fe alloy nanoparticles were studied. In situ TEM imaging, EDS and EELS analysis provided a comprehensive understanding of the involved mechanism. Combined with ex situ studies, it was found out that phase segregation of Fe precedes the ordering process.
Thermal Stability of Core–Shell Nanoparticles: A Combined in Situ Study by XPS and TEM	Cecile S. Bonifacio, Sophie Carenco, Cheng Hao Wu, Stephen D. House, Hendrik Bluhm, and Judith C. Yang	*Chem. Mater.,* v27, pp6960, 2015	In situ TEM and in situ XPS were performed to investigate structural reconfiguration of core-shell Ni-Co nanoparticles at temperatures of up to 600C. In addition to images and spectra, EDS analysis confirmed stepwise process of surface oxide removal and metal segregation.
Unraveling the Origin of Structural Disorder in High Temperature Transition Al2O3: Structure of θ-Al2O3	Libor Kovarik, Mark Bowden, Dachuan Shi, Nancy M. Washton, Amity Andersen, Jian Zhi Hu, Jaekyoung Lee, János Szanyi, Ja-Hun Kwak, and Charles H. F. Peden	*Chem. Mater.,* v27, pp7042, 2015	Morphology and structure of θ-Al2O3 was investigate at temperatures of up to 1100C in a combined series of imaging, spectroscopy and quantum calculation techniques. The structure was described as a disordered intergrowth of two crystallographic variants at the unit cell level.
Intermetallic GaPd2 Nanoparticles on SiO2 for Low-Pressure CO2 Hydrogenation to Methanol: Catalytic Performance and In Situ Characterization	Elisabetta M. Fiordaliso, Irek Sharafutdinov, Hudson W. P. Carvalho, Jan-D. Grunwaldt, Thomas W. Hansen, Ib Chorkendorff, Jakob B. Wagner, and Christian D. Damsgaard	*ACS Catal.,* v5, pp5827, 2015	CO2 hydrogenation capabilities of GaPd2/SiO2 was tested inside an ETEM. Ex situ study of the same location revealed that in situ ETEM results represent similar catalytic behavior.
Applying compressive sensing to TEM video: a substantial frame rate increase on any camera	Andrew Stevens, Libor Kovarik, Patricia Abellan, Xin Yuan, Lawrence Carin and Nigel D. Browning	*Adv. Struct. Chem. Imag.,* v1, 2015	Compressive-sensing (CS) was used to increase the frame rate of conventional cameras via low-cost hardware modifications. The conventional 0.1ms rate of current cameras is not capable of capturing data from fast reactions, and fast cameras are expensive, hence such approaches are of interest in the in situ research field.
Crystallization Pathway for Metastable Hexagonal Close-Packed Gold in Germanium Nanowire Catalysts	Ann F. Marshall, Shruti V. Thombare, and Paul C. McIntyre	*Cryst. Growth Des.,* v15, pp3734, 2015	Followup to an ex situ study, researcher investigate presence of rare hcp-Au morphology at room temperature. This study was only feasible via fast quenching rates of Fusion systems. Additionally, temperature accuracy and imaging capabilities of the Fusion system enabled them to further investigate their initial hypothesis.
Electrospray formation and combustion characteristics of iodine-containing Al/CuO nanothermite microparticles	Haiyang Wang, Jeffery B. DeLisio, Guoqiang Jian, Wenbo Zhou, Michael R. Zachariah	*Combust. Flame,* v162, pp2823, 2015	The effect of iodine content in Al/CuO nanothermite microparticles was studied using in situ capabilities of Fusion SEM. Particularly, the fast heating rates and high temperature range were of importance in this in situ study. This was confirmed via imaging the release of iodine (<500C) prior to the thermal reaction (~800C)

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Nucleation of fcc Ta when Heating Thin Films	Janish, Matthew T., William M. Mook, and C. Barry Carter	*Scr. Mater.,* v96, pp21, 2015	Thin tantalum films have been studied during in situ heating in a transmission electron microscope. Diffraction patterns from the as-deposited films were typical of amorphous materials. Crystalline grains were observed to form when the specimen was annealed in situ at 450 °C. Particular attention was addressed to the formation and growth of grains with the face-centered cubic (fcc) crystal structure. These observations are discussed in relation to prior work on the formation of fcc Ta by deformation and during thin film deposition.
Thermal Stability of Core-shell Nanoparticles: A Combined in situ Study by XPS and TEM	Cecile S. Bonifacio, Sophie Carenco, Cheng Hao Wu, Stephen D. House, Hendrik Bluhm, and Judith C. Yang	*Chem. Mater.,* v27, pp 6960, 2015	In situ techniques of transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS) were used to investigate the thermal stability of Ni–Co core–shell nanoparticles (NPs). The morphological, structural, and chemical changes involved in the core–shell reconfiguration were studied during in situ annealing through simultaneous imaging and acquisition of elemental maps in the TEM, and acquisition of O 1s, Ni 3p, and Co 3p XP spectra.
Inelastic Electron Irradiation Damage in Hexagonal Boron Nitride	Cretu, Ovidiu, Yung-Chang Lin, and Kazutomo Suenaga.	*Micron,* v72, pp21, 2015	It's a study of the inelastic effects caused by electron irradiation in monolayer hexagonal boron nitride (h-BN). The data was obtained through in situ experiments performed inside a low-voltage aberration-corrected transmission electron microscope (TEM). By using various specialized sample holders, we study defect formation and evolution with sub-nanometer resolution over a wide range of temperatures, between −196 and 1200 °C, highlighting significant differences in the geometry of the structures that form.
Intermetallic $GaPd_2$ Nanoparticles on SiO_2 for Low-Pressure CO_2 Hydrogenation to Methanol: Catalytic Performance and In Situ Characterization	Elisabetta M. Fiordaliso, Irek Sharafutdinov, Hudson W. P. Carvalho, Jan-D. Grunwaldt, Thomas W. Hansen, Ib Chorkendorff, Jakob B. Wagner, and Christian D. Damsgaard	*ACS Catal.,* v5, pp5827, 2015	A combination of complementary in situ and ex situ techniques are used to investigate the GaPd2/SiO2 catalyst. In situ X-ray diffraction and in situ extended X-ray absorption fine structure spectroscopy show that the GaPd2 intermetallic phase is formed upon activation of the catalyst via reduction and remains stable during CO2 hydrogenation.
Towards Atomic Level Understanding of Transition Alumina Phases and Their Phase Transformations	L. Kovarik, M. Bowden, D. Shi, A. Anderson, Jianzhi Hu, J. Szanyi, J. H. Kwak and C.H.F. Peden	*Microsc. Microanal.,* v21, 2015	The study addresses the structural nature of δ-Al2O3 and θ-Al2O3 and the mode of their phase transformations using combination of in situ and ex situ imaging and spectroscopy techniques.
Chemical Homogeneity in Entropy-Stabilized Complex Metal Oxides	Ali Moballegh, Christina M. Rost, Jon-Paul Maria and Elizabeth C. Dickey	*Microsc. Microanal.,* v21 , pp1349, 2015	In this work, five binary metal oxides, MgO, CaO, NiO, CuO, and ZnO, were chosen considering favored coordination, iconic radii, and diversity in crystal structures. An equimolar mixture of the constituent metaloxide powders were mixed and pressed into ceramic pellets. The pellets were subsequently annealed in an air until equilibrium was achieved and then quenched to the room temperature.
Crystallization Pathway for Metastable Hexagonal Close-Packed Gold in Germanium Nanowire Catalysts	Marshall, Ann F., Shruti V. Thombare, and Paul C. McIntyre	*Cryst. Growth Des.,* v15, pp3734, 2015	The study finds that the mechanism of formation of hexagonal-close-packed (hcp) Au nanocatalysts following Ge nanowire growth is (1) formation of the metastable hcp beta alloy phase under nonequilibrium conditions of Ge supersaturation and undercooling and (2) out-diffusion of Ge from the solidified alloy phase, while maintaining its hcp crystal structure.
Unraveling the Origin of Structural Disorder in High Temperature Transition Al_2O_3: Structure of θ-Al_2O_3	Libor Kovarik, Mark Bowden, Dachuan Shi, Nancy M. Washton, Amity Andersen, Jian Zhi Hu, Jaekyoung Lee, János Szanyi, Ja-Hun Kwak, and Charles H. F. Peden	*Chem. Mater.,* v27, pp 7042, 2015	In this work, we investigate structure and disorder in high-temperature-treated transition Al2O3 and provide a structural description for θ-Al2O3 by using a suite of complementary imaging, spectroscopy, and quantum calculation techniques. Contrary to current understanding, our high-resolution imaging shows that θ-Al2O3 is a disordered composite phase of at least two different end-members. By correlating imaging and spectroscopy results with density functional theory (DFT) calculations, we propose a model that describes θ-Al2O3 as a disordered intergrowth of two crystallographic variants at the unit-cell level.
Electrospray Formation and Combustion Characteristics of Iodine-containing Al/CuO Nanothermite Microparticles	Haiyang Wang, Jeffery B. DeLisio, Guoqiang Jian, Wenbo Zhoub, Michael R. Zachariah	*Combust. Flame,* v162, pp2823, 2015	This paper employs an electrospray assembly approach to create Al/CuO nanothermite microparticles containing molecular iodine ranging from 5 wt.% to 50 wt.%, and evaluates their combustion properties and potential use as sporicidal agents. The reactivity was evaluated using a constant-volume combustion cell, which showed that, with increasing iodine content, the Al/CuO/I2 reaction rate is decreased by several orders of magnitude, while the burning time increased.
Atomic Visualization of the Phase Transition in Highly Strained BiFeO 3 Thin Films with Excellent Pyroelectric Response	Chung-Hua Chiu, Wen-I Liang, Chun-Wei Huang, Jui-Yuan Chen, Yun-Ya Liu, Jiang-Yu Li, Cheng-Lun Hsin, Ying-Hao Chu, Wen-Wei Wu	*Nano Energy,* v17, pp72, 2015	In this study, an excellent pyroelectric response is associated with reversible phase transitions in mixed-phase BFO films using thermal stimuli. Using an in situ high-resolution transmission electron microscope (HRTEM), we observed that phase transition between rhombohedral-like (R-like) and tetragonal-like (T-like) BFO involved the migration of the phase boundary, which is a prerequisite for the growth of the T-like phase and requires an intermediate phase.
Surface Segregation of Fe in Pt–Fe Alloy Nanoparticles: Its Precedence and Effect on the Ordered Phase Evolution during Thermal Annealing	Sagar Prabhudev, Matthieu Bugnet, Guo-Zhen Zhu, Christina Bock, and Gianluigi A Botton	*Chem. Cat. Chem.,* v7, pp3655, 2015	Coupling electron microscopy techniques with in situ heating ability allows to study phase transformations on the single-nanoparticle level.The study exploits this setup to study disorder-to-order transformation of Pt–Fe alloy nanoparticles, a material that is of great interest to fuel-cell electrocatalysis and ultrahigh density information storage.
Effect of Metal–support Interactions in Ni/Al 2 O 3 Catalysts with Low Metal Loading for Methane Dry Reforming	Jessica L. Ewbank, Libor Kovarik, Fatoumata Z. Dialloa, Carsten Sievers	*Appl. Catal. A,* v494, pp57, 2015	Nickel catalysts prepared by a variety of different methods are commonly used for reforming reactions such as methane dry reforming. Two preparation methods, controlled adsorption and dry impregnation, are implemented to explore the effect of preparation method on the formation of active sites on alumina supported nickel catalysts. By varying only the preparation method, comparison of catalysts that differ primarily in metal–support interactions, strong metal–support interaction (controlled adsorption) and weak metal–support interactions (dry impregnation), are obtained.
Nanoscale Size Effects in Crystallization of Metallic Glass Nanorods	Sungwoo Sohn, Yeonwoong Jung, Yujun Xie, Chinedum Osuji, Jan Schroers & Judy J. Cha	*Nat. Commun.,* v6, 2015	The paper investigates crystallization of metallic glass-forming liquids by in situ heating metallic glass nanorods inside a transmission electron microscope. It unveils that the crystallization kinetics is affected by the nanorod diameter.
Palladium-platinum Core-shell Icosahedra with Substantially Enhanced Activity and Durability Towards Oxygen Reduction	Xue Wang, Sang-Il Choi, Luke T. Roling, Ming Luo, Cheng Ma, Lei Zhang, Miaofang Chi, Jingyue Liu, Zhaoxiong Xie, Jeffrey A. Herron, Manos Mavrikakis & Younan Xia	*Nat. Commun.,* v6, 2015	Conformal deposition of platinum as ultrathin shells on facet-controlled palladium nanocrystals offers a great opportunity to enhance the catalytic performance while reducing its loading. Here the study reports such a system based on palladium icosahedra. Owing to lateral confinement imposed by twin boundaries and thus vertical relaxation only, the platinum overlayers evolve into a corrugated structure under compressive strain.
Preparation and properties of PLGA nanofiber membranes reinforced with cellulose nanocrystals	Yunfei Mo Rui Guo, Jianghui Liu, Yong Lan, Yi Zhang and Wei Xue	*Biointerfaces,* v132, pp177, 2015	The objective of this study was to improve their utility by introducing cellulose nanocrystals (CNCs) into PLGA nanofiber membranes. PLGA and PLGA/CNC composite nanofiber membranes were prepared via electrospinning, and the morphology and thermodynamic and mechanical properties of these nanofiber membranes were characterized by scanning electron microscopy (SEM).

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Quantitative analysis for in situ sintering of 3% yttria-stablized zirconia in the transmission electron microscope	Hasti Majidia, Troy B. Hollandb and Klaus van Benthema	*Ultramicroscopy,* v152, pp35, 2015	Authors studied 3% yttria-stablized zirconia particle-agglomerate systems to elucidate different stages of sintering up to 1140 °C by monitoring both pores and particles inside the TEM. They demonstrate the first densification curves generated from sequentially acquired TEM images. A MATLAB-based image processing tool was developed to calculate the projected area of the agglomerate with and without internal pores during in situ sintering.
Consolidation of Partially Stabilized ZrO2 in the Presence of a Noncontacting Electric Field	Hasti Majidia and Klaus van Benthema	*Phys. Rev. Lett.,* v114, pp195503, 2015	Authors investigated electric field–assisted sintering techniques to demonstrate accelerated densification of partially stabilized ZrO2 at lower temperatures than the conventional sintering methods. It is shown that under isothermal condition at 900 °C, an electric field strength of 500 V/cm shows a sudden threefold enhancement in the shrinkage of the agglomerates. It was concluded that the applied electrostatic potential lowers the activation energy for point defect formation within the space charge zone and therefore promotes consolidation.
Electronic Transport of Recrystallized Freestanding Graphene Nanoribbons	Qi, Zhengqing John, Colin Daniels, Sung Ju Hong, Yung Woo Park, Vincent Meunier, Marija Drndić and A. T. Charlie Johnson	*ACS Nano,* v9, pp3510, 2015	An investigation into atomic recrystallization and electronic transport in graphene nanoribbon devices using experimental and theoretical methods. The research addresses the need for a complete understanding of graphene devices' electronic and structural enhancements as enabled by current annealing.
Effect of Metal–Support Interactions in Ni/Al2O3 Catalysts with Low Metal Loading for Methane Dry Reforming	Ewbank, Jessica L., Libor Kovarik, Fatoumata Z. Diallo and Carsten Sievers	*Appl. Catal.,* v494, pp57, 2015	An investigation into the effects of controlled adsorption and dry impregnation on the formation of alumina nickel catalysts when used as preparation methods.
Observing Gas-Catalyst Dynamics at Atomic Resolution and Single-Atom Sensitivity	Helveg, S., C.F. Kisielowski, J.R. Jinschek, P. Specht, G. Yuan and H. Frei	*Micron,* v68, pp176, 2015	A report on utilizing innovative tools and methods to study surface structures and dynamics in order to improve the understanding of structure-sensitive catalytic functions. The benefits of the state-of-the art technology and methodology is demonstrated with exit wave reconstructions of TEM images of a nanocrystalline Co□O□ catalyst material acquired in situ during exposure to either a reducing or oxidizing gas environment.
Inelastic Electron Irradiation Damage in Hexagonal Boron Nitride	Cretu, Ovidiu, Yung-Chang Lin and Kazutomo Suenaga	*Micron,* v72, pp21, 2015	An investigation into the elastic effects caused by electron irradiation monolayer hexagonal boron nitride (h-BN). The researchers discovered that charging and thermal effects cause electron damage, which can be prevented by strengthening the h-BN samples with a layer of graphene.
Low Voltage Transmission Electron Microscopy of Graphene	Bachmatiuk, Alicja, Jiong Zhao, Sandeep Madhukar Gorantla, Ignacio Guillermo Gonzalez Martinez, Jerzy Wiedermann, Changgu Lee and Mark Hermann Rummeli, et al.	*Small,* v11, pp515, 2015	An introduction to graphene focusing on relevant TEM technical aspects, specimen preparation techniques and TEM and STEM approaches.
Environmental TEM Study of the Dynamic Nanoscaled Morphology of NiO/YSZ During Reduction	Simonsena, Søren Bredmose, Karsten Agersteda, Karin Vels Hansena, Torben Jacobsena, Jakob Birkedal Wagnerb, Thomas Willum Hansenb and Luise Theil Kuhna	*Appl. Catal. A,* v489, pp147, 2015	The examination of NiO's reduction both in pure form and in a NiO/yttria-stablized zirconia composite in hydrogen relevant for solid oxide electrochemical cells. This was achieved by comparing results from environmental transmission electron microscopy with those from thermogravimetric analysis.
Thermal Stability of Gold Nanoparticles Embedded within Metal Oxide Frameworks Fabricated by Hybrid Modifications onto Sacrificial Textile Templates	Padbury, Richard Paul, Jonathan C. Halbur, Peter J. Krommenhoek, Joseph B. Tracey and Jess S. Jur	*Langmuir,* v31, pp1135, 2015	The demonstration of gold nanoparticles' entrapment after being embedded in a hybrid organic-inorganic matrix.
In Situ TEM Investigation of Reduction-Oxidation Reactions during Densification of Iron Oxide Nanoparticles	Bonifacio, Cecile S., Gautom K. Das, Ian M. Kennedy and Klaus van Benthem	*Microsc. Microanal.,* v20, pp1558, 2014	The identification of a preferred phase of Fe□O□ for sintering during in situ study. The researchers also discovered evidence for reduction-oxidation reaction mechanisms during sintering.
Beam Damage During Energy-Dispersive X-ray Spectroscopy of FePt Nanoparticles	Bentley, J., J.E. Wittig and J.R. McBride	*Microsc. Microanal.,* v20, pp610, 2014	The demonstration of gold nanoparticles' entrapment after being embedded in a hybrid organic-inorganic matrix.
Nucleation of Graphene and Its Conversion to Single-Walled Carbon Nanotubes	Picher, Mattheiu, Pin Ann Lin, Jose L. Gomez-Ballesteros, Perla B. Balbuena and Renu Sharma	*Nanoletters,* v14, pp6104, 2014	The investigation into reliable as-synthesized nanoparticle composition measurement and the possibility of revealing composition gradients within a nanoparticle.
Catalyst Faceting During Graphene Layer Crystallization in the Course of Carbon Nanofiber Growth	Maurice, Jean-Luc, Didier Pribat, Z. He, G. Patriarche and Costel Sorin Cojocaru	*Carbon,* v79.11, pp93, 2014	The study of graphene layers' growth at the surface of crystalline catalyst particles. The researchers observed the development of catalyst facets as it occurred simultaneously with graphene planes' replacement of atomic catalyst layers.
Understanding Catalyst Behavior During In Situ Heating Through Simultaneous Secondary and Transmitted Electron Imaging	Howe, Jane Y., Lawrence F. Allard, Wilbur C. Bigelow, Hendrix Demers and Steven H. Overbury	*Nanoscale Res. Lett.,* v9, pp614, 2014	The observation of Au leached with Au/iron oxide catalyst when heated to temperatures up to 700 °C.
Nucleation of fcc Ta when Heating Thin Films	Janish, Matthew T., William M. Mook and C. Barry Carter	*Scr. Mater.,* v94, pp16, 2015	The study and imaging of crystalline grains' formation and growth on thin tantalum film after it was annealed in situ. The researchers paid special attention to the grains with face-centered cubic structures.
Visualized Effect of Oxidation on Magnetic Recording Fidelity in Pseudo-Single-Domain Magnetite Particles	Almeida, Trevor P., Takeshi Kasama, Adrian R. Muxworthy, Wyn Williams, Lesleis Nagy, Thomas W. Hansen, Rafal E. Dunin-Borkowski, et al.	*Nat. Commun.,* v5, pp5154, 2014	The examination of the chemical remanent magnetization (CRM) processes of PSD Fe3O4 grains in situ using environmental TEM and off-axis electron holography.
Decomposition of Amorphous Si2C by Thermal Annealing	Gustus, René, Wolfgang Gruber, Lienhard Wegewitz, Udo Geckle, Robby Prang, Christian Kübel, Wolfgang Maus-Friedrichs, et al.	*Thin Solid Films,* v552, pp232, 2014	The observation of amorphous Si2C films' crystallization after being deposited from RF magnetron co-sputtering on Si wafer substrates. The crystallization is a result of annealing at 1200° C at 2 hours. After 20 hours, the polycrystalline silicon vanishes from the film. Its dematerialization is demonstrated through in situ and ex situ TEM measurements, suggesting a possible decomposition model.
Direct Observation of Pt-Terminating Carbyne on Graphene	Kano, Emi, Masaki Takeguchi, Jun-ichi Fujita and Ayako Hashimoto	*Carbon,* v80, pp382, 2014	The formation and observation of carbynes using Pt atoms on graphene with in situ TEM.
Phase Transition, Domains Walls and Defects Dynamics of LaAlO3 via In Situ Heating in the Transmission Electron Microscope	Mao, Qingyun, Megan Holtz, Darrell G. Schlom and David A. Muller	*Microsc. Microanal.,* v20, pp1556, 2014	The effects of heating bulk LAO single crystals in situ at high temperatures, including phase transition with diffraction as well as twin boundaries and defect motion.
In Situ High Temperature Atomic Resolution Transmission Electron Microscopy of 2D Nanomaterials	Gibb, Ashley L., Nasim Alem, Jian-Hao Chen, Jim Ciston and Alex Zettl	*Microsc. Microanal.,* 20, 1770, 2014	The observation of vacancy formation, migration, coalescence and healing in a suspended h-BN sample after heating to 973 K.
Real-time Imaging and Elemental Mapping of AgAu Nanoparticle Transformations	Lewis, E., T. Slater, E. Prestat, A. Macedo, P. O'Brien, P. Camargo and S. Haigh	*Nanoscale,* v6, pp13598, 2014	The study of the growth and coalescence of Kirkendall voids during the electron beam-driven oxidation of AgAu core-shell nanoparticles.

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Observing Thermomagnetic Stability of Non-Ideal Magnetite Particles: Good Paleomagnetic Recorders?	Almeidal, Trevor P., Takeshi Kasama, Adrian R. Muxworthy, Wyn Williams, Lesleis Nagy and Rafal E. Dunin-Borkowski	*Geophys. Res. Lett.,* v41, pp7041, 2014	The analysis of remanence-induced magnetite (Fe3O4) particles' thermomagnetic behavior using off-axis electron holography. The Fe3O4 grain's vortex state is demonstrated with electron holograms taken at 100° C intervals through in situ heating.
Initiation and Reaction in Al/Bi/2O3 Nanothermites: Evidence for the Predominance of Condensed Phase Chemistry	Piekel, Nicholas W., Lei Zhou, Kyle T. Sullivan, Snehaunshu Chowdhury, Garth C. Egan and Michael R. Zacharia	*Combust. Sci. Technol.,* v186, pp1209, 2014	The examination of the Al-Bi2O3 nanoparticle reaction when exposed to high heating rates along with temperature-jump/time of flight mass spectrometry, rapid sample heating and high speed imaging using a scanning electron microscope.
Novel Heterostructured Ge Nanowires Based on Polytype Transformation	Vincent, L., G. Patriarche, G. Hallais, C. Renard, C. Gardès, D. Troadec and D. Bouchier	*Nano Letters,* v14, pp4828, 2014	The demonstration of a strain-induced phase transformation in (111)-oriented Ge nanowires under external shear stresses, in which the nanowires' standard diamond structure developed toward a hexagonal diamond phase (2-H allotrope). In addition, the researchers examined the 2H domains' thermal stability using in situ TEM for annealing up to 650° C.
Structure of δ-Alumina: Toward the Atomic-Level Understanding of Transition Alumina Phases	Kovarik, Libor, Mark Bowden, Arda Genc, János Szanyi, Charles H. F. Peden and Ja Hun Kwak	*J. Phys. Chem. C,* v118, pp18051, 2014	The use of a combination of high-angle annular dark field EM imaging, X-ray diffraction refinement and density theory calculations to produce the first detailed atomic-level analysis of δ-Al2O3. The study also investigates the energy degradation of relevant Al2O3 transition phases and how it affects the structural disorder and complex intergrowth of Al2O3 variants.
Observation of Sublattice Disordering of the Catalytic Sites in a Complex Mo-V-Nb-Te-O Oxidation Catalyst Using High-Temperature STEM Imaging	Blom, Douglas A., Thomas Vogt, Larry F. Allard and Douglas J. Buttrey	*Top. Catal.,* v57, pp1138, 2014	The imaging of a Mo-V-Nb-Te-O oxidation catalyst with STEM at 780 K, slightly above its operating temperature. The researchers observed the sublattice disordering of corner-sharing octahedra forming catalytic sites containing catalytic sites containing V5+, and they proposed that sublattice disordering of catalytic sites allows them to adapt to various oxidation states while remaining within a more solid superstructure.
Investigating the Local Degradation and Thermal Stability of Charged Ni-Based Cathode Materials Through Real-Time Electron Microscopy	Hwang, Sooyeon, Seung Min Kim, Seong-Min Bak, Byung-Won Cho, Kyung Yoon Chung, Jeong Yong Lee, Eric A. Stach, et al.	*ACS Appl. Mater. Interfaces,* v6, pp15140, 2014	The observation of thermally-induced decomposition of LixNi0.8Co0.15Al0.05O2 (NCA) cathode surface materials after exposure to various states of charge (SOC).
Dynamic Observation of Phase Transformation Behaviors in Indium (III) Selenide Nanowire-Based Phase Change Memory	Huang, Yu-Ting, Chun-Wei Huang, Jui-Yan Chen, Yi-Hsin Ting, Kuo-Chang Lu, Yu-Lun Chueh and Wen-Wei Wu	*ACS Nano,* v8, pp9457, 2014	The observation of dynamic changes in the phase transformation of indium (III) selenide (In2Se3) after Au/In2Se3-nanowire/Au phase change memory devices underwent a RESET/SET process in a TEM. The researchers used both pulsed and DC voltage swept modes. The switching showed that a long pulse width could force the transformation to amorphous or polycrystalline states depending on the pulse amplitudes. This discovery could aid the improvement of PCRAM writing speed, endurance and retention.
Observing Gas-Catalyst Dynamics at Atomic Resolution and Single-Atom Sensitivity	Helvega, S., C.F. Kisielowski, J.R. Jinschek, P. Specht, G. Yuan and H. Freib	*Micron,* v68, pp176, 2014	The use of low electron dose rates in TEM combined with inline holography and aberration-correction at low-voltage (80kV) to maintain sensitivity and atomic resolution during in situ catalyst analysis. Exit wave reconstructions of TEM images of a nanocrystalline Co3O4 catalyst material proved the benefits of using progressive in situ technology.
In Situ High-Pressure Transmission Electron Microscopy for Earth and Materials Sciences	Jun, Wu and Peter R. Buseck	*Am. Mineral.,* v99, pp1521, 2014	The demonstration of crystallographic defects' role in carbon concentration and analog storage to minerals found deep inside Earth.
Chemistry and Mineralogy of Earth's Mantle: Evidence for Multiple Diamondite-Forming Events in the Mantle	Mikhail, Sami, Daniel Howell and Francis M. McCubbin	*Am. Mineral.,* v99, pp1537, 2014	The investigation of 35 diamondite samples to determine their infrared spectroscopic characteristics. While the researchers observed a positive correlation between sample's platelet intensity and their peak position, there is no correlation between their paragenesis and any infrared traits. Although the researchers do not have independent determination of the samples' residence age or temperatures, they infer that the diamondite formed in short stages over a long total time period. Their conclusion corresponds with the theory that C-O-H diamond- and diamondite-forming fluids are produced in small, localized events.
Growth Mechanism for Single- and Multi-Layer MoS2 Nanocrystals	Hansen, Lars Pilsgaard, Erik Johnson, Michael Brorson and Stig Helveg	*J. Phys. Chem. C,* v118, pp22768, 2014	The observation of the multi-layer MoS2 nanocrystal formation at the atomic scale and noted that it is a more dynamic process in comparison to that of single-layers. The researchers concluded that the difference in characteristics can explain why process parameters can modify the relative fraction of single- to multi-layer MoS2 nanocrystals.
Catalyst Faceting During Graphene Layer Crystallization in the Course of Carbon Nanofiber Growth	Maurice, J-L, D. Pribat, Z. Hea, G. Patriarche, C.S. Cojocaru	*Science,* v79, pp93, 2014	The study of graphene layers' nucleation and growth at the surface of crystalline catalyst particles. The researchers observed the development of characteristic catalyst forms due to step bunching in certain growth conditions. They concluded that controlling the faceting and step bunching could lead to precise structuring of MWCNTs grown at low temperatures.
In Situ TEM Observation of a Microcrucible Mechanism of Nanowire Growth	Boston, Rebecca, Zoe Schnepp, Yoshihiro Nemoto, Yoshio Sakka, Simon R. Hall	*Science,* v44, pp623, 2014	The observation of molten nanoparticles migrating through a porous yttrium and copper-rich matrix, which produces nanowire outgrowth.
Chirality-Specific Growth of Single-Walled Carbon Nanotubes on Solid Alloy Catalysts	Yang, Feng, Xiao Wang, Daqi Zhang, Juan Yang, Da Luo, Ziwei Xu,Yan Li, et al.	*Nature,* v510, pp522, 2014	The observation of W□Co□ alloy nanoparticles maintaining crystalline form when heated in a vacuum to 1100° C.
Nanoparticle Metamorphosis: An In Situ High-Temperature Transmission Electron Microscopy Study of the Structural Evolution of Heterogeneous Au Fe2O3 Nanoparticles	Baumgardner, William J., Yingchao Yu, Robert Hovden, Shreyas Honrao, Richard G. Hennig, Héctor D. Abruña, Tobias Hanrath, et al.	*ACS Nano,* v8, pp5315, 2014	The observation of Au and Fe2O3 particles' structural transformations through in situ electron microscopy and spectroscopy. The particles fuse together at temperatures below their size-reduced melting points. Under increasingly higher temperatures, the fused particles transform from surface alloy to phase-segregated and finally core-shell structures. The in situ microscopy and spectroscopy provided the researchers with a more detailed view of the fundamental thermodynamic and kinetic aspects behind the heterogeneous nanostructures' formation.
WO3 Nano-Ribbons: Their Phase Transformation from Tungstite (WO3-H2O) to Tungsten Oxide (WO3)	Ahmadi, Majid, Satyaprakash Sahoo, Reza Younesi, Anand, P.S. Guar, et al.	*J. Mater. Sci.,* v49, pp5899, 2014	The collection of tungsten oxide (WO3) nano-ribbons produced by annealing tungstite (WO3-H2O) nano-ribbons. The nano-ribbons were created with a simple, ecologically-friendly and cost-effective treatment consisting of hydrochloric acid and diluted sodium tungstate solutions (Na2WO2-2H2O). The researchers observed that the transformation from Na2WO4-2H2O to WO3-H20 initiated between 200° to 300° C. The nano-ribbons' crystallographic structure then changed from WO3H20 to monoclinic WO3. Ex situ and in situ methods allowed the researchers to study the phase transformation in detail, while powder X-ray diffraction, electron diffraction, electron energy-loss spectroscopy and X-ray photoelectron spectroscopy enabled precise characterization.
Real-Time Observation of the Solid-Liquid-Vapor Dissolution of Individual Rutile-Type Nanowires within the Indium-Tin-Oxide Solid Solution	Hudak, Bethany M., Yao-Jen Chang, Lei Yu, Guohua Li, Danielle N. Edwards and Beth S. Guiton	*ACS Nano,* v8, pp5441, 2014	A series of heating studies administered in situ in a TEM. The researchers studied metal oxide nanowires as they dissipated completely into the metal catalyst particles located at their tips. The researchers then used a solid-liquid-vapor type mechanism to demonstrate their observations. The mechanism allowed the catalyst droplet to both evaporate at the liquid-vapor interface and adhere to the substrate surface. These processes factor into the overall rate of dissolution.

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Controlled Growth of a Line Defect in Graphene and Implications for Gate-Tunable Valley Filtering	Chen, J-H., G. Autés, N. Alem, Gargiulio, A. Gautam, M. Linck, A. Zettl, et al.	*Phys. Rev. B, PRB,* v89, pp121407, 2014	A new procedure for executing a controlled production of highly regular "5-5-8" line defects in graphene. The procedure involves simultaneously conducting electron irradiation and Joule heating applied electrical currents. The researchers performed first-principles transport calculations and discovered that across the defect, the valley polarization of the charge carriers depends strongly on energy. Their observations led to the proposal of a compact, electrostatically gated "valley valve" device.
Effect of Surface Carbon Coating on Sintering of Silver Nanoparticles: In Situ TEM Observations	Asoro, M.A., D. Kovar and P.J. Ferreira	*Chem. Comm.,* v50, pp4835, 2014	The analysis of the effects of a carbon capping layer on sintering of silver nanoparticles. The researchers measured the surface diffusity of carbon-coated silver nanoparticles both directly and in real time. They concluded that the carbon surface coating could significantly suppress sintering in silver nanoparticles.
Direct Observation of Carbon Nanostructure Growth at Liquid-Solid Interfaces	Fei, Lin-feng, Tie-yu Sun, Wei Lu, Xiao-gi-ang An, Zhuo-feng Hu, Jimmy C. Yu, W. Yang, et al.	*Chem. Comm.,* v50, pp826, 2014	The Fusion heating capabilities were used in a JEOL 2100F TEM to observe the liq-uid-solid nucleation and growth of graphene nanostructures from Pt3Co. It was found that graphene (carbon was sourced from the amorphous support film already on the thermal E-chip) nucleates near Co atoms at step edges at temperatures above 500° C. It's been reported that defects such as step ledges lead to nucleation of carbon crystals. Additional growth through oriented attachment was also observed. The high stability of the Fusion system at high temperatures enabled the researchers to visualize this process in real time at high resolution.
Enhanced Shape Stability of Pd-Rh Core-Frame Nano-cubes at Elevated Temperature: In Situ Heating Trans-mission Electron Microscopy	Lu, N., J. Wang, S. Xie, Y. Xia and M.J. Kim	*Chem. Comm.,* v49, pp11806, 2013	Applications using nanoparticles, especially catalysis, are highly dependent on the surface properties. The authors used the Fusion heating capabilities to understanding surface changes of Pd nanocubes as a function of temperature. They discovered that significant changes occurred at temperatures lower than typical operating tempera-tures for catalyst activity. These changes included rounded corners and sintering with neighboring nanocubes. To increase the thermal stability the researchers coated the Pd nanocubes with an Rh frame, creating a Pd-Rh core-frame nanocube. They found that the Rh increased the thermal stability by up to 100° C. While pure Pd nanocubes formed rounded edges at 400° C after only 8.5 min, Pd-Rh nanocubes continued to have sharp corners after 1 hr. at 500° C. High resolution TEM and STEM images and EDS spectrum images were taken on a JEOL ARM200F.
Synthesis of Au-MoS2 Nanocomposites: Thermal and Friction-Induced Changes to the Structure	Scharf, T.W., R.S. Goeke, P.G. Kotula and S.V. Prasad	*ACS Appl. Mater. Interfaces,* v5, pp11762, 2013	In this study, Au nanoparticles are incorporated into the MoS2 matrix at room tempera-ture using a custom sputter coater. A TEM sample was created with FIB and placed on a Fusion thermal E-chip and loaded into an FEI F30. As the temperatures were increased from 200° C to 600° C, the Au nanoparticles coarsened primarily through Oswald ripen-ing. Heating pure MoS2 to temperatures above 700° C, hollow spheres were observed. However, when the MoS2 had Au nanoparticles incorporated into the matrix, no MoS2 hollow spheres were observed leading the authors to conclude that the Au inhibited hollow sphere formation. Hollow sphere formation is important in solid lubricants, because it significantly reduces dangling bonds, which inhibit performance.
Multifunctional Properties of Multistage Spark Plasma Sintered HAÐBaTiO3-Based Piezobiocomposites for Bone Replacement Applications	Dubey, A.K., E.A. Anumol, K. Balani and B. Basu	*J. Am. Ceram. Soc.,* v96, pp3753, 2013	In this paper the authors report the synthesis and characterization of a HA - BaTiO3 alloy. Adding BaTiO3 (BT) to HA creates a better analog to bone, closely mimicking the electrical and mechanical properties. After HA and BT powders were made, den-sification was done via spark plasma sintering, where an electrical current is passed through the powder. The electrical current heats the sample and the powder sinters. This method results in better mechanical properties compared to more traditional sintering techniques. The authors used a Fusion 100 system to visualize the densifica-tion process in situ inside an FEI Tecnai T20 TEM. They heated the samples up to 950°C and imaged densification as a function of temperature and ramp rate. They found that samples sintered differently when temperature ramp rates were controlled - fast ramp rates (100° C/min) resulted in denser agglomerates, while slower rates (10° C/min) the particles were less dense.
In Situ Transmission Electron Microscopy Observations of Sublimation in Silver Nanoparticles	Asoro, M.A., D. Kovar and P.J. Ferreira	*ACS Nano,* v7, pp7844, 2013	In this report, TEM electron beam effects on nanoparticles was investigated. The elec-tron beam, especially on nanoparticles and at high current density, can have non trivial effects on samples. The authors used silver nanoparticles as a representative material, and showed that sublimation temperatures depend on nanoparticle/substrate con-tact geometry, intensity of the electron beam and size of the particle. Observations backed up this claim, where nanoparticles of a similar size sublimated at different temperatures indicating different contact geometries. Other observations included stepwise sublimation of particles when the particles were faceted, which were usual particles 30 nm in diameter, and larger particles that were nearly spherical sublimated continuously.
Dynamic Evolution of Conducting Nanofilament in Resis-tive Switching Memories	Chen, Jui-Yuan, Cheng-Lun Hsin, Chun-Wei Huang, Chung-Hua Chiu, Yu-Ting Huang, Su-Jien Lin, Wen-Wei Wu and Li-Juann Chen	*Nano Letters,* v13, pp3671, 2013	Using the electrical biasing features of the Fusion 300 system, a resistive RAM (ReRAM) device was analyzed in the TEM. By applying a voltage to a metal-insulator-metal stack, in this case Pt-ZnO-Pt, the electrical behavior of the device was visualized in real time in the TEM while simultaneous current-voltage measurements were taken. The research-ers used a combination of bright and dark field and high resolution imaging, diffraction and EELS to determine the behavior of the device. It was found that a metallic filament is created as the voltage is increased, until the filament bridges the gap between the Pt electrodes creating a low resistance path for electrical current. This process is revers-ible and the device can be reset.
Strain Solitons and Topological Defects in Bilayer Graphene	Alden, J.S., A.W. Tsen, P.Y. Huang, R. Hovden, L. Brown, J. Park, P.L. McEuen, et al.	*Proc. Natl. Acad. Sci.,* v110, pp11256, 2013	The authors used dark field and high resolution STEM to image bilayer graphene. Shear stress and strain between the two layers creates different atomic registry, or displacement, between each sheet, which can have a significant effect on the electronic properties of the material. The structure of the bilayer was probed with TEM and found that the displacement in each sheet created grains with well-defined boundaries with soliton-like behavior. Using the Fusion heating system, they observed the dynamic behavior of the solitons at high temperatures. At temperatures of 800° C and below, the solitons did not change or move. However, when the temperature was increased to 1000° C, solitons became dynamic. The bilayer began to anneal, and the boundaries between grains became straighter and shorter. Movies of soliton movement at high temperatures were also taken.
Atomic Resolution Imaging of Grain Boundary Defects in Monolayer Chemical Vapor Deposition-Grown Hexago-nal Boron Nitride	Gibb, A.L., N. Alem, J. Chen, K.J. Erickson, J. Ciston, A. Gautam, A. Zettl, et al.	*J. Am. Chem. Soc,* v135, pp6758, 2013	The defect structure of single layer sheets of CVD synthesized hexagonal boron nitride was imaged at atomic resolution using the Fusion system. At temperatures of 450° C, grain boundaries and associated defects were studied. The defects evolved over time, and the dynamics were captured in sequential images. The high stability of the Fusion system enabled the collection of this high quality data. All images were taken with the TEAM 0.5 TEM at NCEM/LBNL.

FUSION™

BIBLIOGRAPHY — JOURNAL ARTICLES

Title	Authors	Citation	Description
Mechanistic Insights into a Non-Classical Diffusion Pathway for the Formation of Hollow Intermetallics: A Route to Multicomponent Hollow Structures	Anumol, E.A., C. Nethravathi and N. Ravishankar	*Part. Part. Syst. Charact.,* v30.7, pp590, 2013	The authors show a non-classical method for developing hollow nanoparticles. Beginning with a Pt nanoporous core and depositing a Bi layer on the shell which has a high diffusion constant, they are able to create hollow nanoparticles through heating. Using the Fusion system in an FEI T20, they visualized the process in situ. They explain that it is not a Kirkendall process, but a non-classical diffusion process resulting from the physical structure of the particles. Bi has a larger diffusion constant than Pt, so if it were a Kirkendall diffusion process, Bi would diffuse into the Pt core. However, just the opposite occurs. They hypothesize that the Pt prefers to aggregate towards the concave region in the Bi shell, leaving behind a void in the core. This material system is applicable in catalyst systems due to its large surface area, and it's been shown that when Pt is alloyed with another metal it is less susceptible to CO poisoning.
Coalescence in the Thermal Annealing of Nanoparticles: An In Situ STEM Study of the Growth Mechanisms of Ordered Pt-Fe Nanoparticles in a KCl Matrix	Chen, H., Y. Yu, H.L. Xin, K.A. Newton, M.E. Holtz, D. Wang, F.J. DiSalvo, et al.	*Chem. Mater.,* v25, pp1436, 2013	The Fusion system was used in an FEI F20 in STEM mode to analyze the phase change and coarsening of FePt nanoparticles < 5nm in size. The ferromagnetic nanoparticles are candidates for ultra-high density media, however require an annealing step after nanoparticle synthesis to 600 C. The as synthesized nanoparticles are disordered FCC, and the anneal step initiates a phase change to a tetragonal structure which makes the particles magnetic. A KCl matrix was used as a support to help inhibit coarsening. In situ heating was used to determine the coarsening mechanism, and it was found the particles primarily coarsened via coalescence. In some incidences Ostwald ripening occurred, and direct observations of each process was reported.
An In Situ Experimental Study of Grain Growth in a Nanocrystalline Fe91Ni8Zr1 Alloy	Kotan, H., K.A. Darling, M. Saber, R.O. Scattergood and C.C. Koch	*J. Mater. Sci.,* v48, pp2251, 2013	Using in situ heating in a Hitachi HF-2000 TEM and ex situ analysis with XRD, the authors analyzed the thermal stability of an iron alloy, Fe91Ni8Zr1. The as synthesized material had a polycrystalline grain structure with grain sizes on the order of 50 nm and smaller. The material is thermally stable until around 500° C where grain growth begins to appear, with grains growing to larger than 100 nm, and occurring and ceasing quickly after the change in temperature. They found that the material was initially of the body-centered cubic (bcc) phase at room temperature and up roughly 700° C, where there was a phase change to face-centered cubic (fcc) associated with larger grain growth, and loss of thermal stability. This alloy is a model material for study of grain growth kinetics.
Heating-Induced Microstructural Changes in Graphene/Cu Nanocomposites	Sola, F., J. Niu, and Z.H. Xia	*J. Phys. D Appl. Phys.*, v46, 065309 , 2013	Studied the effects of temperature on Cu and Cu2O nanoparticles on graphene sheets using the Fusion system in a Zeiss Auriga SEM system. Imaged and analyzed neck formation, coalescence, sublimation and Ostwald ripening of nanoparticles of sizes between 20 nm and a few hundred nanometers in diameter. Noted differences in the nanoparticle evolution at particular temperatures. Coalescence of particles occurred with the addition of Ostwald ripening at higher temperatures. It was also noted that the Cu nanoparticles did not wet the surface of the graphene at high temperatures. The authors report that the Cu/graphene nanocomposite may be the most temperature metal/graphene composite system and are relevant for highly sensitive chemical sensors.
Reactive Sintering: An Important Component in the Combustion of Nanocomposite Thermites	Sullivan, K.T., N.W. Piekiel, C. Wu, S. Chowdhury, S.T. Kelly, T.C. Hufnagel, M.R. Zachariah, et al.	*Combust. Flame,* v159, pp2, 2012	Heated oxide-coated Al nanoparticles that are used in energetics. Studied the influence of the oxide shell on release of the highly reactive Al. Fast heating pulses (1-10 ms) were required, with temperatures up to 1200° C.
Synthesis of Mesoporous Palladium with Tunable Porosity and Demonstration of its Thermal Stability by In Situ Heating and Environmental Transmission Electron Microscopy	Cappillino, P.J., K.M. Hattar, B.G. Clark, R.J. Hartnett, V. Stavila, M.A. Hekmaty, D.B. Robinson, et al.	*J. Mater. Chem. A,* v1, pp602, 2012	The authors report on novel synthesis method for creating mesoporous palladium metal particles with tunable pore sizes. Using diblock copolymers (BCP) arranged in hexagonal arrays in solution as templates, palladium salts were introduced and reduced around the BCP creating metal particles with hexagonal arrays of pores. Palladium is of interest for hydrogen storage. The particles will operate at elevated temperatures, thus the thermal stability characteristics of the particles and pores must be understood. Using the Fusion holder in a JEOL 2010F it was found that particles with 7 nm pores were stable up to 300° C and particles with 13 nm pores were stable up to 600° C. In situ testing with a Protochips gas cell was also performed in a JEOL 2100. Similar thermal stability characteristics were found when heating in 1 atm H2, however, the pores collapsed at lower temperatures.
Nanoporous Pd Alloys with Compositionally Tunable Hydrogen Storage Properties Prepared by Nanoparticle Consolidation	Cappillino, P.J., J.D. Sugar, M.A. Hekmaty, B.W. Jacobs, V. Stavila, P.G. Kotula, D.B. Robinson, et al.	*J. Mater. Chem.,* v22, pp14013, 2012	Heated nanoporous Pd/Rh alloy particles synthesized via a two-step method. Initially nanoparticles were formed within dendrimers. The dendrimers were dissolved and the nanoparticles coalesced to form larger nanoporous alloy particles. The pore thermal stability studied the pore stability as a function of temperature. The TEM used was a JEOL 2010F.
Stability of Porous Platinum Nanoparticles: Combined In Situ TEM and Theoretical Study	Chang, S.L.Y., A.S. Barnard, C. Dwyer, T.W. Hansen, J.B. Wagner, R.E. Dunin-Borkowski, H. Xu, et al.	*J. Phys. Chem. Lett.,* v3, pp1106, 2012	This paper explores the thermal stability of nanoporous Pt as a function of temperature. Pt is used as a catalyst material, and it is thought that it is more active with increasing surface area, but porous particles must be stable at elevated temperatures for use in real world applications. The TEM used was an FEI Titan.
L10 Ordering of Ultra-Small FePt Nanoparticles Revealed by TEM In Situ Annealing	Delalande, M., M.J.-F. Guinel, L.F. Allard, A. Delattre, R. LeBris, Y. Samson, P. Reiss, et al.	*J. Phys. Chem. C,* v116, pp6866, 2012	The authors visualize a phase change from fcc to L10 in FePt nanoparticles. L10 FePt nanoparticles show strong uniaxial magnetocrystalline anisotropy, and show promise for a new type of data storage media. The phase change is shown in high resolution using a JEOL 2200FS Cs corrected STEM.
In Situ Studies on the Shrinkage and Expansion of Graphene Nanopores Under Electron Beam Irradiation at Temperatures in the Tange of 400–1200 °C	Lu, N., J. Wang, H.C. Floresca and M.J. Kim	*Carbon,* v50, pp2961, 2012	Visualized the growth and shrinkage of nanopores in graphene as a function of temperature. Show that the size of the nanopore can be controlled via a combination of electron beam effects and temperature.
Effect of Rhodium Distribution on Thermal Stability of Nanoporous Palladium−Rhodium Powders	Ong, M.D., B.W. Jacobs, J.D. Sugar, M.E. Grass, Z. Liu, G.M. Buffleben, D.B. Robinson, et al.	*Chem. Mater.,* v24, pp996, 2012	Used multiple tools including XPS, XRD, Porosimetry and the Fusion system in the TEM to determine hydrogen storage properties, pore stability and rhodium distribution, via EDS spectrum imaging, in nanoporous rhodium/palladium particles. Rhodium has a higher melting point than palladium and it was found that rhodium significantly increases the pore thermal stability over pure palladium particles without compromising hydrogen storage properties.
In Situ Transmission Electron Microscopic Investigations of Reduction-Oxidation Reactions During Densification of Nickel Nanoparticles	Matsuno, M., C.S. Bonifacio, J.F. Rufner, A.M. Thron, T.B. Holland, A.K. Mukherjee and K. van Benthem	*J. Mater. Res.,* v27, pp2431, 2012	Studied the reduction and sintering characteristics of nickel oxide nanoparticles at high temperatures in situ. It was discovered that in the presence of carbon the reduction temperature of the surface oxide is reduced, and significantly alters the densification characteristics. When no carbon was present the oxide layer prevented neck formation and densification of nanoparticles. This also showed that reduction of the surface oxide preceded neck formation.
In Situ Observation of Pt Nanoparticles on Graphene Layers under High Temperatures Using Aberration-Corrected Transmission Electron Microscopy	Hashimoto, A., and M. Takeguchi	*J. Electron Microsc.,* v61, pp409-413, 2012	Imaged the behavior of Pd nanoparticles on the surface of exfoliated multilayer graphene. Used aberration corrected TEM and STEM to visualize the evolution of Pd nanoparticle and single Pd atoms on the surface. Found that Pd nanoparticles and atoms were more stable when anchored to the edges of graphene.
Carbohydrate-Derived Hydrothermal Carbons: A Thorough Characterization Study	Yu, L., C. Falco, J. Weber, R.J. White, J.Y. Howe and M-M. Titirici	*Langmuir,* v28, pp12373, 2012	Studied the behavior of hydrothermal carbons (HTC) via several characterization techniques. Used the Fusion system to heat the HTC in vacuum in the TEM to high temperatures to study the types of formations that occur.