University of Birmingham

Professor David Book

Professor of Energy Materials

School of Metallurgy and Materials (/schools/metallurgy-materials/index.aspx)

Contact details

Telephone **(+44) (0) 121 414 5213 (tel:+44 0 121 414 5213)**

Email **d.book@bham.ac.uk (mailto:d.book@bham.ac.uk)**

School of Metallurgy and Materials
University of Birmingham
Edgbaston
Birmingham
B15 2TT
UK

About

David Book is a Professor of Energy Materials and Head of the Hydrogen Materials Group.

David has published research papers in scientific journals as well as book chapters in the fields of hydrogen storage, hydrogen energy, permanent magnets.

He has received major grants from the EPSRC (including the SUPERGEN programme), EC, TSB, and the Carbon Trust.

Qualifications

PhD in Materials Science, Birmingham, 1995
MEng in Materials Engineering, Birmingham, 1990

Biography

David Book received his MEng in Materials Engineering from the University of Birmingham (1990) and completed his PhD (1995) at the same institution working on the processing of rare-earth permanent magnets. He then spent 18 months in the Department of Materials Science, Tohoku University (Sendai, Japan) as an EU-JSPS Postdoctoral Fellow and was appointed lecturer in the same Department in 1996. He returned to Birmingham in 2001 and subsequently became Head of the **Hydrogen Materials Group (http://www.hydrogen.bham.ac.uk)** (2004), a Senior Research Fellow (2007), Reader (2011) and Professor (2014).

David's research centres on: various solid-state hydrogen storage materials (porous, Mg alloys, complex hydrides and nanocarbon); dense-metal membranes for hydrogen separation; microstructural processing of materials using hydrogen; hydrides within cladding materials of nuclear fission reactors; nanoscale catalysts and permanent magnetic materials.

The research support includes: **EPSRC "Hydrogen and Fuel Cell Supergen Hub" (http://www.h2fcsupergen.com)** ; **EPSRC "Cleaning Land for Wealth (CL4W)"; (http://www2.warwick.ac.uk/fac/sci/wmg/research/sustainable_materials_and_manufacturing/projects/cl4w/) EPSRC "Engineering Safe and Compact Hydride Energy Reserves (ESCHER)" (http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/K021117/1)** ; and **EC MC-ITN "Novel Complex Metal Hydrides for Efficient and Compact Storage of Renewable Energy as Hydrogen and Electricity (ECOSTORE)" (http://www.hzg.de/mw/ecostore/index.html.en)**

Previous projects have included: EPSRC SUPERGEN "**UK Sustainable Hydrogen Energy Consortium (UK-SHEC) (http://www.uk-shec.org.uk/)** "; EPSRC "Supply Chain Research Applied to Clean Hydrogen (SCRATCH)"; the **22-partner EC Framework 6 NESSHY project (http://www.nesshy.net/)** ; and the Birmingham Science City "**Hydrogen Energy Project (http://www.rcs.bham.ac.uk/hydrogenproject/index.shtml)** ".

David has coordinated 2-year bilateral networks with Japan and Korea: EPSRC "**UK-Japan H2 Storage Research Network (http://www.h2net.com/)** ", and the DBERR/OSI "UK/KOREA Focal Point Program for Hydrogen Storage". Also, he has been a UK expert in the **International Energy Agency Tasks 22 and 32 on Hydrogen Storage (http://www.hydrogenstorage.org/)** since 2005.

Teaching

- Tutor for the MRes in Materials for Sustainable Energy Technologies (MRes-MSET) course
- BEng/MEng Energy Engineering course

Postgraduate supervision

David is interested in supervising masters or doctoral research students in the following areas:

- Nanostructured magnesium alloys for hydrogen storage
- Non-palladium dense metal membranes for hydrogen separation
- In situ Raman spectroscopy on hydrogenation and rehydrogenation reactions in complex hydrides
- Porous materials for hydrogen storage and carbon dioxide storage / separation
- Nanostructured carbon-lithium-based materials for hydrogen storage and lithium battery electrodes
- Hydrogen processing for the microstructural modification of transition-metal alloys
- Development of low or zero rare-earth content permanent magnets

If you are interesting in studying any of these subject areas please contact David on the contact details above, or for any general doctoral research enquiries, please email: **met-postgrad@bham.ac.uk (mailto:met-postgrad@bham.ac.uk)**

Research

RESEARCH THEMES

Solid-state Hydrogen Storage, Hydrogen Separation Membranes, Permanent Magnets, Hydrogen Embrittlement.

RESEARCH ACTIVITY

Hydrogen is widely regarded as the most promising alternative to carbon-based fuels: it can be produced from a variety of renewable resources, and - when coupled with fuel cells - offers near-zero emissions of pollutants and greenhouse gases. However, developing hydrogen as a major energy carrier, will require solutions to many scientific and technological challenges.

Solid-state Hydrogen Storage

One challenge is to how to effectively store hydrogen on vehicles. Conventional storage solutions include liquefaction or compression, however there are energy efficiency and major safety concerns associated with both these options. Therefore, there is a great need to develop viable solid-state storage materials.

- Magnesium: With a theoretical reversible hydrogen uptake value of 7.6 weight%, Mg is a candidate for a new storage medium. However, the hydrogen sorption temperature needs to be reduced (from around 300 °C to 100-150 °C), and the kinetics need to be accelerated. It has been shown that the sorption kinetics can be greatly improved by: introducing a nanoscale microstructure to provide a pathway for hydrogen diffusion; and by catalyzing the surface. The thermodynamics now need to be improved by alloying Mg to form a new compound or phase. Our work is investigating nanostructured Mg alloys produced by ball-milling, thin-film multilayers, and by rapid solidification.
- Complex Hydrides: Borohydride compounds are promising hydrogen storage materials (e.g. lithium borohydride is able to store up to 18 wt%), but which require elevated temperatures (200 – 300 °C) for hydrogen desorption and suffer poor reversibility (i.e. re-absorption of hydrogen is difficult). We are investigating Transition-metal-based borohydrides, produced by ball-milling and by high-pressure synthesis. We have found that the hydrogen desorption temperature in such compounds can be greatly reduced. We are now using in situ XRD and Raman spectroscopy (with 100 bar hydrogen cells) to study the phases that form during hydrogen desorption and reabsorption, with the aim of producing more reversible materials.
- Nanocarbons: nanostructured graphite-based materials may store up to 7 wt% hydrogen, which offers the prospect of an inexpensive, widely available storage medium. However, this material needs to be heated to 800 °C to remove all the hydrogen, and reversibility is poor (limited to a few cycles after mixing with LiH). In order to improve the reabsorption process, we are studying how the hydrogen is stored, the role of carbon 'dangling bonds', and the effect of microstructure.

Hydrogen Separation Membranes

Any important challenge is how to provide extremely pure hydrogen, for use with PEM Fuel Cells?

Hydrogen produced from natural gas reformers and from biomass sources, usually contains small amount of impurity gases, such as carbon monoxide, methane, and sulphur. A PEM Fuel Cell converts hydrogen and oxygen gases into electricity; however, even very small amounts of impurities in the hydrogen can reduce the operating life of the Fuel Cell. In addition, there are applications in semiconductor and LED manufacture that require ultra-pure hydrogen.

Metallic diffusion membranes can be used to purify hydrogen: certain Pd-based alloys will allow only hydrogen gas to pass through (the impurity gas molecules are too large), resulting in parts-per-billion level pure hydrogen. However, the conventional membrane alloy used (Pd-Ag) is rather expensive, and cannot be used in the presence of impurities such as CO and S. We are investigating materials with less or no Pd with comparable membranes properties. We have also been studying the fabrication of thin-film and rapidly solidified membranes.

Permanent Magnets

Permanent magnets are now essential components in many fields of technology, and have found applications in a wide range of devices. In 1984, the $Nd_2Fe_{14}B$ magnet phase was developed by: powder metallurgy to form anisotropic, fully dense sintered magnets; and melt-spinning to produce isotropic magnetic powders, which can then be compacted to form bonded magnets. Although bonded magnets have poorer magnetic properties, the ability to form complex geometries has lead to bonded magnets becoming the fastest growing sector of the permanent magnet market.

Therefore, there was great interest in 1989, when a new technique – which came to be called Hydrogen Disproportionation Desorption Recombination (HDDR) – was developed, that subsequently allowed the production of anisotropic magnetic powders (anisotropic magnet powders have better magnetic properties than isotropic). The HDDR process involves exposing ingots of Nd-Fe-B to a series of carefully controlled heat treatments under hydrogen and vacuum. However, the mechanism behind the formation of anisotropic material still requires further study.

Other activities

- Member of the Institute of Materials, Minerals and Mining (UK)
- Member of the Japan Institute of Metals
- Member of the Materials Research Society (USA)

Publications

Book Chapters

- Darren Broom and David Book (2014), "Hydrogen Storage in Nanoporous Materials". In: Angelo Basile and Adolfo Iulianelli (eds.) **Advances in hydrogen production, storage and utilization**, Woodhead Publishing (ISBN: 0857097687)
- S Sugimoto, S. and D Book, D. (2005), "HDDR Process for the Production of High Performance Rare-Earth Magnets". In: Y Liu, DJ Sellmyer, D Shindo, JG Zhu, and GC Hadjipanayis (eds.) **Handbook of Advanced Magnetic Materials**. Springer (ISBN: 1402079834)

Recent Journal Papers

- Shahrouz Nayebossadri, John Speight, David Book (2014). Effects of Low Ag Additions on the Permeability of Pd-Cu-Ag Hydrogen Separation Membranes. **Journal of Membrane Science** 451 216-225
- Tuan K. A. Hoang, Leah Morris, Daniel Reed, David Book, Michel Trudeau, David M. Antonelli (2013). Observation of TiH5 and TiH7 in bulk-phase TiH 3 gels for Kubas-type hydrogen storage. **Chemistry of Materials** 25 (23) 4765-4771
- Sheng Guo, Hoi Yan Chan, Daniel Reed and David Book (2013) Investigation of dehydrogenation processes in disordered γ-Mg(BH4)2. **Journal of Alloys and Compounds** 580 S296-S300
- Lydia Pickering, Jing Li, Alexander Bevan, Daniel Reed and David Book (2013) Ti-V-Mn based metal hydrides for hydrogen storage. **Journal of Alloys and Compounds** 580 S233-S237
- Bjarne R. S. Hansen, Dorthe B. Ravnsbæk, Daniel Reed, David Book, Jørgen Skibsted, Carsten Gundlach, Torben R. Jensen (2013) Hydrogen storage capacity loss

in a $LiBH_4$−Al composite. **Journal of Physical Chemistry C** 117 (15) 7423-7432

- S.B. Choi, H. Furukawa, H.J. Nam, D-K. Jung, Y.H Jhon, A. Walton, D. Book, M. O'Keeffe, O. M.Yaghi, and J. Kim (2012) Reversible Interpenetration in a Metal-Organic Framework Triggered by Ligand Removal and Addition. **Angewandte Chemie** 51 8791-8795
- B. Paik, A. Walton, V. Mann, D. Book, I. P. Jones, and I. R. Harris (2012) Electron energy-loss spectroscopy study of MgH_2 in the plasmon energy range. **Applied Physics Letters** 100, 193902
- R. Liu, D. Reed, and D. Book (2012) Decomposition properties of $Mn(BH_4)_2$ formed by ball-milling $LiBH_4$ and $MnCl_2$. **Journal of Alloys and Compounds** 515 32-38
- Y. Zhang and D. Book (2011) Effect of Milling Conditions on the Purity of Hydrogen Desorbed from Ball-Milled Graphite. **Journal of Physical Chemistry C** 115 (51) 25285-25289
- Y Zhang, D Book (2011) Hydrogen storage properties of ball-milled graphite with 0.5 wt% Fe. **International Journal of Energy Research**, DOI: 10.1002/er.1903.
- D Reed and D Book (2011) Recent applications of Raman spectroscopy to the study of complex hydrides for hydrogen storage. **Current Opinion in Solid State and Materials Science** 15 62-72
- S Tedds, A Walton and D Book (2011), Characterisation of Porous Hydrogen Storage Materials: Carbons, Zeolites, MOFs and PIMs. **Faraday Discussions** 151 75-94
- AI Bevan,A Züttel,D Book,and IR Harris (2011) Performance of a metal hydride store on the "Ross Barlow" hydrogen powered canal boat. **Faraday Discussions** 151 353-367
- D Ravnsbæk, C Frommen, Y Filinchuk, M Sørby, B Hauback, HJ Jacobsen, D Book, F Besenbacher, J Skibsted, TR Jensen (2011) Structural studies of lithium zinc borohydride by neutron powder diffraction, Raman and NMR spectroscopy. **Journal of Alloys and Compounds**, 509 S698-S704
- B.S. Ghanem, M. Hassan, K.D.M. Harris, K.J. Msayib, M. Xu, P.M. Budd, N. Chaukura, D. Book, S. Tedds, A. Walton and N.B. McKeown (2010) Triptycene-based polymers of intrinsic microporosity: organic materials that can be tailored for gas adsorption. **Macromolecules** 43 5287-5294
- DB Ravnsbæk, LH Sørensen, Y Filinchuk, D Reed, D Book, HJ Jakobsen, F Besenbacher, J Skibsted and TR Jensen (2010) Mixed-anion and Mixed-cation Borohydride $KZn(BH_4)Cl_2$: Synthesis, Structure and Thermal Decomposition. **European Journal of Inorganic Chemistry** 2010 1608-1612
- Y Kim, D Reed, Y-S Lee, J-H Shim, HN Han, D Book, YW Cho (2010) Hydrogenation reaction of CaH_2 - CaB_6 - Mg mixture. **Journal of Alloys and Compounds** 492 597-600
- J-H Shim, J-H Lim, S Rather, Y-S Lee, D Reed, Y Kim, D Book and YW Cho (2010) Effect of Hydrogen Back Pressure on Dehydrogenation Behavior of $LiBH_4$-Based Reactive Hydride Composites. **Journal of Physical Chemistry Letters** 1 59-63
- D Reed and D Book (2009) In situ Raman Studies of the Decomposition of Lithium Borohydride. **Materials Research Society Symposium Proceedings** 1216 1216-W06-05
- Y Kim, D Reed, Y-S Lee, J Lee, J-H Shim, D Book, YW Cho (2009) Identification of the Dehydrogenated Product of $Ca(BH_4)_2$. **Journal of Physical Chemistry C** 113 5865-5871
- Y Pivak, R Gremaud, K Gross, M Gonsalez-Silveira, A Walton, D. Book, H Schreuders, B Dam and R Griessen (2009) Effect of the film substrate on the thermodynamic properties of the PdH_x studied by hydrogenography. **Scripta Materialia** 60 348-351
- AJ Ramirez-Cuesta, PCH Mitchell, DK Ross, PA Georgiev, PA Anderson, HW Langmi, A Walton and D Book (2007) Dihydrogen in zeolite CaX—An inelastic neutron scattering study. **Journal of Alloys and Compounds** 446-447 393-396
- PM Budd, A Butler, J Selbie, K Mahmood, NB McKeown, B Ghanem, K Msayib, D. Book, A. Walton (2007) The potential of organic polymer-based hydrogen storage materials. **Physical Chemistry Chemical Physics** 9 1802-1808
- AJ Ramirez-Cuesta, PCH Mitchell, DK Ross, PA Georgiev, PA Anderson, HW Langmi, A Walton and D Book (2007) Dihydrogen in cation-substituted zeolite X—An inelastic neutron scattering study. **Journal of Materials Chemistry** 17 2533-2539
- NB McKeown, PM Budd, D Book (2007) Microporous polymers as potential hydrogen storage materials. **Macromolecular Rapid Communications** 28 995-1002

Expertise

Investigatingthe interaction of hydrogen with different materials; new powders that can absorb large amountsof hydrogen and metal films that produce ultra-pure hydrogen both used infuel cell technology; using hydrogen to modify the microstructure ofmaterials, such as rare-earth permanent magnets

Alternative contact number available for this expert: **contact the press office (http://www.birmingham.ac.uk/news/contacts/index.aspx)**