CASE SCHOOL OF ENGINEERING
CASE WESTERN RESERVE UNIVERSITY

The 2023 Van Horn Distinguished Lecture Series

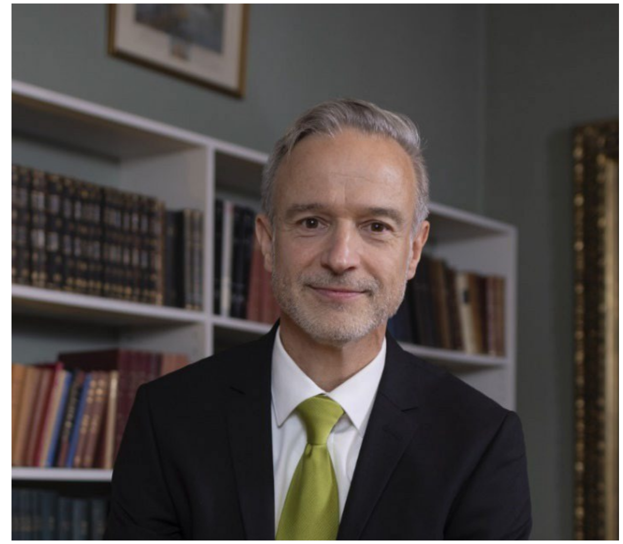
Presented By

The Department of Materials Science and Engineering

October 9th – 11th, 2023

The *Kent R. van Horn Lectureship* honors the 1926 alum, who had a distinguished career as a metallurgist, director of research, and ultimately corporate vice-president of Alcoa. Provision for endowing the lectureship was made possible by his sons, Karl and Neil Van Horn. Three lectures on varied topics of interest to academia and industry are to be delivered over three successive days.

All lectures are free and open to the public. Parking is available in Lot 53, Veale Parking Garage, 2158 Adelbert Rd., Cleveland, OH. Livestream information available upon request.



Dierk Raabe

Dierk Raabe studied music, metallurgy, and metal physics. After his doctorate 1992 and habilitation 1997 at the RWTH Aachen, he received a Heisenberg fellowship of the German Research Foundation and worked as postdoctoral researcher at Carnegie Mellon University (Pittsburgh, USA) and at the National High Magnet Field Lab (Tallahassee, USA). He joined the Max-Planck Society as a director at the Max-Planck-Institut für Eisenforschung in 1999. His interests are in sustainable metallurgy, computational materials science, phase transformation, alloy design, hydrogen, and atom-probe tomography. He received the Leibniz award (highest research award in Germany), 2 ERC Advanced Grants (highest research grant in the European Union), and the Acta Materialia Gold Medal Award. He is a professor at RWTH Aachen in Germany, honorary professor at KU Leuven in Belgium, and honorary Doctor at NTNU in Norway. He is a member of the German National Academy Leopoldina.

Lecture I

Monday, October 9th, 2023 White 411, 4:00

The 2 Billion Ton Question—How Can Metals Become More Sustainable?

The lecture introduces the challenges associated with the sustainability of metals. Only metallic materials exhibit properties as diverse as strength, hardness, workability, damage tolerance, weldability, ductility, and toughness, often combined with functional properties such as corrosion resistance, thermal and electrical conductivity, and magnetism. Today we produce and consume around 2 billion tons of metals every year.

The production of this gigantic amount of metals and alloys per year is responsible for about 40% of all industrial greenhouse gas emissions, consumes 10% of the world's available energy and requires 3.2 billion tons of ores to manufacture. In addition, production and processing generate huge amounts of often toxic waste products, which in total have a volume 15 to 20 times larger than the total amount of metal produced itself. This is because the metal content of some ores for important metals such as copper, nickel or cobalt is in part below 1%. These numbers are growing rapidly and will double by 2050, creating tremendous pressure to circularize a large part (50-70%) of the materials production and manufacturing chain. However, recycling rates are often low, especially for some of the most strategic metals with recovery rates sometimes below 1%.

The lecture gives an overview of the big numbers and leverage effects in this economically important field and shows some of the many exiting research opportunities to improve the sustainability of metals, including CO_2-free reduction of metals from their ores, electrification of metal synthesis, challenges behind recycling, scrap-compatible material design and the science of 'dirty' alloys.

Lecture II

Tuesday, October 10th, 2023 White 411, 4:00

The Materials Behind Green Steel

More than 1.8 billion tons of steel are produced every year, making it the most important alloy in terms of volume, business, economic leverage and environmental impact. While steel is a sustainability enabler, through lightweight car parts, rail tracks, wind farms and magnets, its primary production is not. Iron is reduced from oxidic ores using fossil carbon-based reductants. This produces >2t CO_2/t of steel, standing for >30% of the global CO_2 emissions in manufacturing. These emissions can be reduced when replacing carbon by hydrogen or its carriers as reductants, by the use of higher scrap fractions and by the electrification of oxide reduction.

The lecture presents recent progress in understanding the key mechanisms of hydrogen-based solid-state direct reduction and hydrogen-based plasma smelting reduction of iron ores. The kinetics of the reactions strongly depend on mass transport kinetics, nucleation during the multiple phase transformations, the oxide's chemistry and microstructure, and on damage and fracture associated with the phase transformation and mass transport phenomena occurring during reduction. Understanding these effects is key to make hydrogen-based reduction of iron ores commercially viable, enabling massive CO_2 reductions in this sector.

In summary, the key questions addressed in the lecture are: (a) How to make green steel by direct reduction and by plasma reduction? (b) Which are the bottleneck research questions in green steel making? (c) Which oxide and reductant feedstock types can be used in green steel making?

Lecture III

Wednesday, October 11th, 2023 White 411, 4:00

The Interplay of Lattice Defects and Chemistry at Atomic Scale and Why it Matters for the Properties of Materials

Lattice defects such as interfaces, stacking faults and dislocations determine many mechanical, functional, and kinetic properties of materials. Lattice defects do not merely constitute structural imperfections, but they are often chemically decorated by solutes. The interplay of structure and chemistry at lattice defects can lead to a wide range of phenomena and manipulation opportunities, including Suzuki and Cottrell effects, confined elemental partitioning, complexion formation, linear and planar phase-like states, decomposition and low-dimensional transformations. All these effects alter defect-energy, mobility, structure, cohesion, and transport properties.

The lecture presents and discusses several aspects in that context:

First, recent progress is presented, which allows imaging of structure and composition features at lattice defects by using correlative imaging through field-ion microscopy, atom-probe tomography, and electron microscopy. Some of these observation methods are enhanced by atomistic mechanical simulations.

Second, atomic-scale experiments on classes of several materials ranging from metals to thermoelectrics are presented, which reveal that the interplay between defect structure and chemistry can lead to a much larger variety in compositional – structural states than commonly assumed. Examples are confined phase formation, hydrogen embrittlement, athermal transformations, spinodal decomposition or inter-defect partitioning at lattice defects, to name but a few phenomena.

Third, some thermodynamic considerations are discussed, which may guide better understanding and utilization of these phenomena.

VAN HORN DISTINGUISHED LECTURERS

Joseph E. Burke	1974
Raymond F. Decker	1975
Robert T. Wei	1977
Ray E. Smallman	1978
John W. Cahn	1979
Robert D. Pehlke	1980
David Turnbull	1981
John P. Hirth	1982
Anthony G. Evans	1983
Martin E. Glicksman	1984
Michael F. Ashby	1985
Peter Haasen	1986
Mats Hillert	1988
James Rice	1989
S. Amelinckx	1990
William D. Nix	1991
Robert W. Balluffi	1992
Peter Hirsch	1993
L. Michael Brown	1994
William D. Kinger	1995
Manfred Rühle	1996
Robert O. Ritchie	1997
Herbert Gleiter	2000
William J. Boettinger	2001
David Embury	2002
Sumino Iijima	2003
Terence E. Mitchell	2004
Peter W. Voorhees	2005
Sheldon Wiederhorn	2006
Subra Suresh	2008
Angela Belcher	2009
A. Lindsay Greer	2010
Yet-Ming Chiang	2011
M. K. Finnis	2012
Eduard Artz	2013
Tresa Pollock	2014
H.K.D.H. Bhadeshia	2015
Wayne D. Kaplan	2016
Christopher Schuh	2017
Harry Atwater	2018
Gerbrand Ceder	2019
Susan Trolier-McKinstry	2022
Dierk Raabe	2023

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