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Chemical interactions with the atmosphere during sintering of metallic powder compacts

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Abstract

In addition to the physical aspects of sintering, the transport within the metallic phase, also chemical reactions have to be considered. All metal powders that have ever been exposed to air are covered by surface layers containing oxides which are however bonded with varying strength, depending on the thermodynamic stability of the respective oxides. In order to grant sound interparticle bonding, these surface layers have to be removed or at least penetrated during sintering. In many sintered materials, this removal is attained by interactions with the atmosphere, either with reducing components such as H_2 or by reduction with elements contained in the specimen itself, such as carbon, the atmosphere removing the reduction products. Here, it has to be distinguished between the "free" atmosphere and that within the pore space of the powder compact; only the former can be markedly influenced from outside. It is shown that these deoxidation processes occur in clearly defined temperature intervals that are defined by the stability of the oxides. Problems will arise if these deoxidation intervals intersect with the temperature range for densification. Furthermore, heterogeneous oxygen affinity within the compact has to be considered, as e.g. in compacts from mixes: here "internal guttering" may occur, that is oxygen transfer from the base powder particles to those of the alloy elements through the atmosphere, which renders complete deoxidation more difficult. Such phenomena may however also occur in pre-alloyed powders, in this case rather diffusion of the oxygen-affine alloy elements being the controlling mechanism. Finally it is shown that removal of carbon from sintered steels, the dreaded surface decarburization, can occur not only through oxygen or oxygen compounds but in certain temperature ranges also by H_2 if specific alloy elements are present.

About the speaker

Herbert Danninger is Full Professor for Chemical Technology of Inorganic Materials at Technische Universität Wien (Vienna University of Technology), Vienna, Austria, and currently Dean of the Faculty of Technical Chemistry. He has been active in powder metallurgy for more than 35 years and is author of more than 400 publications on powder metallurgy topics as well as several books and book chapters. He has worked mainly on high strength and high density sintered steels, with particular focus on sintering, microstructural characterization and high cycle fatigue. He served as co-chairman of the Powder Metallurgy World Congress 2004 in Vienna, Austria. Currently he is chairman of the "Gemeinschaftsausschuss Pulvermetallurgie", the PM association of the German-speaking countries. Herbert Danninger received the "Skaupy lecture" award of the "Gemeinschaftsausschuss Pulvermetallurgie" in 2006 and was elected Fellow of APMI in 2010. He holds an honorary doctoral degree of Technical University Cluj-Napoca (Romania).

Professor G.V. Samsonov (1918-1975)

Professor Grigorii Valentinovich Samsonov was born on 15th February 1918 in a town near Leningrad (now St. Petersburg). After earning his first degree at the Nonferrous Metals Institute in Moscow, he joined Soviet Navy. At the end of the Second World War, he was stationed in the Soviet occupied zone of Austria. It was here he became intimately connected with the extensive refractory metal and their compounds. After the cessation of the war, Samsonov returned to Moscow and resumed his higher studies and research under the guidance of Professor M. A. Merson (Institute of Steel and Alloys), a noted powder metallurgist of the then USSR. After completion of his Ph.D. degree, Samsonov joined the Institute of Metalkeramika (powder metallurgy) in the Ukrainian Academy of Science at Kiev as a senior scientist. The Institute was later renamed 'Institute of Materials Problem'. Within few years, he was elevated to the post of Deputy Director. Simultaneously, he was invited to head the Powder Metallurgy Department of Kiev Institute of Technology. Samsonov's scientific activity began with the synthesis of inorganic compounds. Soon he extended his area in the study of structure-properties-processing-performance relations of inorganic materials. By structure he included all types: electronic, atomic, micro- and macro, although the electronic structure fascinated him the most. To achieve this goal he insisted on the crucial bond between chemistry and physics. Samsonov authored nearly 1500 papers and authored/edited 50 books and monographs. One of the seminal books authored by Samsonov is 'Configurational Model of Matter.' Probably, there is no paper on refractory compounds, where he is not referred. The inorganic compounds in which Professor Samsonov contributed were carbides, nitrides, borides, silicides, germanides, selenides, phosphides, etc. He has also investigated in detail the hard cermets based on refractory compounds. His numerable past students are spread throughout the world.

About the donor

Prof. Gopal Shankar Upadhyaya joined the department of Metallurgical Engineering (now Materials Science and Engineering) at the Indian Institute of Technology Kanpur as Professor in the year 1976. Prior to that he was Associate professor at the University of Roorkee (now IIT Roorkee) from 1964-1975. He was awarded doctorate degree from the Kiev Institute of Technology, Ukraine in 1969 under the guidance of internationally renowned Materials Scientist Professor G.V. Samsonov. Professor Upadhyaya's publications list exceeds 300 papers and 16 authored/edited books. He has served on the Advisory Boards of practically all the major conferences and journals in powder metallurgy. Professor Upadhyaya's past graduate and doctorate students are actively engaged in powder metallurgy research and industry. After retiring from IIT Kanpur (in 2001), Professor Upadhyaya currently resides in Varanasi.

Previous Speakers

2012: Professor E.J. Mittemeijer (Max Planck Institute for Materials Science, University of Stuttgart, Stuttgart, Germany)
2013: Professor G.S. Upadhyaya (Formerly, Professor IIT Kanpur)
2014: Professor R.A. Andrievski (Institute of Problems of Chemical Physics, Russian Academy of Sciences)
2015: Professor K.A. Padmanabhan (Formerly, Director IIT Kanpur)