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Editorial

Phase transformations and other structural changes in materials, special issue in honor of Professor Valery I. Levitas

This special issue is dedicated to Professor Valery I. Levitas who received the 2018 Khan International Award for outstanding contributions to the field of plasticity, especially for his pioneering works on the interaction between phase transformations and plasticity in materials under high pressure at multiple length scales.

Prof. Levitas was born on April 3, 1956 in Kiev, Ukraine (former USSR). He received his MS with honors in Mechanical Engineering in 1978 from the Kiev Polytechnic Institute; Ph.D. in Materials Science and Engineering in 1981 from the Institute for Superhard Materials of the Ukrainian Academy of Science; Doctor of Sciences, Physics & Mathematics (second degree after PhD, to some extent similar to habilitation in Germany), in Continuum Mechanics in 1988 from the Institute of Electronic Machine Building, Moscow, USSR; and Doctor-Engineer habilitation in Continuum Mechanics in 1995 from the University of Hannover, Germany.

Prof. Levitas worked for 16 years at the Institute for Superhard Materials in Kiev as an engineer (78–81), a junior researcher (81–84), a senior researcher (84–88), a leading researcher (89–94), and the leader of a research group (82–94). He significantly expanded the theory of large elastoplastic deformations under high pressure and developed the first models and computer programs for simulating the technological process of diamond synthesis in high-pressure apparatuses. Simulations included FEM solutions of coupled problems of large-strain thermoplasticity, electric heating, and phase transformations, with contact interaction between a dozen elements of high-pressure apparatuses made of ceramics, metals, and rocks. Based on the developed methods of evaluating and optimizing the durability of elements of the apparatuses, his group developed a new technology of their assembly, which was patented and implemented in the diamond-producing industry.

Valery's first dozen papers appeared as a result of his student work, without a supervisor, on the development of extremum principles in nonequilibrium thermomechanics, with applications to plasticity, complex media, and friction. This was far from his major in machine and technology of metal forming. Dr. Levitas worked at the University of Hannover (Germany) as the Humboldt–Research Fellow (93–95) and Visiting and Research Professor (95–99). At the Texas Tech University (Lubbock, TX), he was Associate Professor (99-02), Professor (02–08), and Director of the Center for Mechanochemistry and Synthesis of New Materials (02–07). He then moved to Iowa State University as Schafer 2050 Challenge Professor in the Departments of Aerospace Engineering, Mechanical Engineering, and Material Science and Engineering, as well as Faculty Scientist at DOE Ames Laboratory. Currently, Dr. Levitas is Anson Marston Distinguished Professor in Engineering and Vance Coffman Faculty Chair Professor. Dr. Levitas also worked as a consultant for Los Alamos National Laboratories, NIST, Geophysical Laboratory of the Carnegie Institution of Washington, as well

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as Seyeon E&S Corporation and Gyeongsang National University (South Korea). Results of these works were published in a variety of highly ranked journals.

Prof. Levitas has made seminal contributions to the understanding of interaction between plasticity and phase transformations across a wide range of length scales with several approaches. In particular, he brought a unique device to the USA from his former laboratory in Kiev, the rotational diamond anvil cell, for the in-situ study of phase transformations and plastic flow in materials under high pressure and large plastic shear, using synchrotron radiation facilities. He has formulated the concept that these strain-induced phase transformations under high pressure differ fundamentally from traditional high-pressure phase transitions, and they require completely different thermodynamic and kinetic descriptions and experimental characterizations. His theory describes the mechanochemical processes at four length scales. At the atomistic scale, DFT and MD simulations have been utilized to find the phase transformation criteria under a general stress tensor. At the nanoscale, his group considers phase nucleation at various defects, generated during plastic deformation, using MD and the new phase field approach. At the microscale, a microscale phase field approach was developed and applied to derive the strain-governed kinetic equation for phase transformations. At the macroscale, his group has developed theory and FEM approach to study large-strain 3D contact problems with plastic strain-induced transformations for a sample in rotational diamond anvils. Combination of the results from their experiments and four-scale theory has had significant impact on the field and led to the discoveries of a variety of new phenomena and phases, methods for controlling phase transformations and searching for new materials, as well as determination of the material's transformational and deformational properties. In particular, predicting and utilizing a "rotational plastic instability" phenomenon to induce large plastic strain and phase transformation allowed Dr. Levitas' group to reduce the transformation pressure for obtaining superhard BN by a factor of 10 (from 55 to 5.6 GPa). Their theoretical predictions also led to unprecedented plastic shear-induced reduction of the transformation pressure from graphite to diamond from 70 GPa to 0.7 GPa! Both results may have significant technological potential. Methods developed by Dr. Levitas can be applied to various other pressure-shear processes, e.g., in geophysics, during friction, high-pressure torsion, cutting, polishing, armor penetration, and ball milling, among many others.

Dr. Levitas has brought the phase field approach to a new level for understanding phase transformations, twinning, dislocations, fracture, and their interaction at the nano- and microscales, by introducing advanced finite-strain mechanics, new lattice instability conditions, and surface- and interface-induced stresses and phenomena in these computational methods.

Another mechanochemical phenomenon that Dr. Levitas discovered and has explored using his theory is a new mechanism of phase transformation in solids, stress relaxation and plastic flow via "virtual melting", occurring far below the melting temperature. Experimental confirmation for virtual melting has been found for polymorphic transformations in explosives and pharmaceuticals, for high pressure amorphization in geological and electronic materials, and for surface-induced transformations in nanowires. Recently, he found a new mechanism of plastic deformation and stress relaxation at high strain rates (10^9-10^{12} s-1), under which the virtual melting substitutes for classical plasticity at temperatures 4000K below the melting temperature. Dr. Levitas developed the first continuum thermomechanical theories to the above phenomena, then much more detailed phase field approaches.

One more advance that Dr. Levitas made is a mechanochemical melt dispersion-mechanism for the reactions of Al nano and micron scale particles. This mechanism and corresponding theories mechanistically explained a number of puzzling experimental phenomena observed during combustion. Since this mechanism is completely different from traditional mechanisms, Dr. Levitas suggested a series of major changes in the synthesis of Al particles (in particular, producing prestressed particles) for energetic applications, improving their performance.

Professor Levitas has published 434 scientific papers, including 3 monographs, 11 book chapters, and 277 refereed journal papers, as well as 11 patents. Most of his recent papers are in highly ranked interdisciplinary journals, including Science (2 papers), Nature Communications, PNAS (2), Nano Letters, and Physical Review Letters (12). He has published 20 papers in IJP.

At each university, Prof. Levitas developed a series of high-level research-oriented graduate classes. Thus far, at Iowa State he has taught multiple times phase transformations, phase field approach to structural changes, nanomechanics of materials, micromechanics of structural changes in materials, continuum mechanochemistry, phase transformations and plasticity, mechanics of interface- and surface-induced phenomena, and high-pressure mechanics and phase transformations. His undergraduate teaching, due to his highly interactive classes, was recognized with the Best Professor Award at Texas Tech.

Besides the above honors, Dr. Levitas was awarded by various others, including Richard von Mises Award of GAMM (Germany), Best Paper Award from International Journal of Engineering Sciences, and Iowa State and Texas Tech Distinguished Research Awards. Dr. Levitas serves for 20 years on Editorial Board of IJP. He is also on Editorial Board of Scientific Reports (Nature Publishing Group) and Journal for Superhard Materials. Dr. Levitas organized/co-organized 17 different symposia at Plasticity International Conferences, as well as multiple symposia at various conferences.

Finally, I am grateful to the Editor-in-Chief of IJP, Professor Akhtar Khan, for the opportunity for this special issue in honor of Valery Levitas, and to all authors for their contributions.

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