

Mark L. KACHANOV

Professor of Mechanical Engineering

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Highest degree earned

1981	Ph.D. in Solid and Structural Mechanics Brown University
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Appointments

1988-present	Professor of Mechanical Engineering Tufts University
1983-1988	Associate Professor of Mechanical Engineering Tufts University
1980-1983	Assistant Professor of Mechanics and Materials Science Rutgers – State University of New Jersey

Visiting appointments

Ecole Normale Supérieure (France): Visiting Professor

Darmstadt Polytechnic Institute and U. of Munchen (Germany): von Humboldt Research Professor

SHELL Research & Development (Netherlands): Visiting Scientist

Technion – Israel Institute of Technology: Visiting Professor

Sandia National Laboratory (USA): Visiting Scientist

National Institute of Standards and Technology (USA): Visiting Scientist

University of Minnesota: Visiting Professor (sponsored by MTS Corporation)

Career Highlights

- Science Citation Index (Web of Science) : 2,800 +, H-index: 31
- Distinguished Fulbright Chair
- Von Humboldt Research Award for Senior Scientists (Germany)
- Editor-in-Chief of *International Journal of Engineering Science*
- Five of former students/postdocs won professorships at US Universities

Research fields

- Mechanics of heterogeneous materials; Multiple cracking and damage

- Rough contacts: Mechanics and conductance

- Geophysics and rock mechanics; Applications to oil exploration

- Industrial Applications :
 - Thermal barrier coatings
 - Porous ceramics (fracture under compression, thermal loading)
 - Oil exploration (multiple fractures, anisotropy, rough surfaces, wavespeeds)
 - Nano-indentation of piezoelectrics

Federal research grants

- "Crack-Damage Interactions", Air Force Office of Scientific Research (\$72,050)
- "Stress Analysis in Elastic Solids with Multiple Cracks," Army Research Office (\$60,365)
- "Further Analysis of Elastic Solids with Multiple Cracks," Army Research Office (\$40,400)
- "Effective Properties of Cracked Solids," U.S. Department of Energy (\$107,000)
- "Modeling of Materials with Multiple Defects" Army Research Office (\$202, 490)
- "Effective Conductivity of Heterogeneous Materials", U.S. Department of Energy (\$180,000)
- "Multiple Site Damage in Aging Aircraft," U.S. Department of Transportation (\$20,000)
- "Fracture of Materials under Compression", U.S. Department of Energy (\$190,000)
- "Localization of Deformation in Brittle Materials", Air Force Office of Scientific Research (\$182,000)
- "Mechanics of Anisotropic Materials with Damage", Army Research Office (\$217,000)
- "Heat Conduction in Ceramic Coatings", NASA (\$79,374)
- "Micromechanics of Materials with Defects of Various Shapes", National Science Foundation (\$127,000)
- "Crack Dynamics in Ice", jointly with Dartmouth College, National Science Foundation (\$ 127, 400)
- "Microstructure-Property Connections in Ceramic Coatings ", NASA (\$185,783)
- "Extraction of Information on Damage from Wavespeeds in Materials with Cracks and Pores of Various Shapes", U.S. Department of Energy (\$190,050)
- "Statistical Cracks- and Porosity Modeling", Sandia National Laboratories (\$60,000)
- "Macroscopic stress-strain relations with microcrack induced inelasticity", Sandia National Laboratories (\$55,000)
- "Nanoelectromechanics of Piezoelectric Indentation and Applications to Scanning Probe Microscopies", National Science Foundation (\$180, 300)

Industrial projects

- **Oil exploration** (SHELL-Netherlands; SHELL-USA; Marathon Oil; Schlumberger):
 - Information on fractures from seismic signatures and well-log data
 - Quantitative characterization of rough large-scale fractures
 - Fluid-saturated rocks, wavespeed signatures of fluid presence
 - Modeling of siliclastic rocks in consolidated and unconsolidated regimes
- **Thermal barrier coatings** (General Electric; Alstom Power-Switzerland)
 - Conductive and elastic properties of plasma-sprayed ceramic coatings
 - Modeling of the mechanical response of physical-vapor deposition (PVD) coatings
 - Optimization of coating microstructure for combined conductive-elastic performance
- **Porous ceramics under compression and under thermal loading** (Corning)
 - Aluminum titanate under compression: modeling of hysteresis behavior
 - Nonlinearities in compression and tension, underlying micromechanisms
 - Microcracking in polycrystalline ceramics induced by thermal loads
- **Thermal and electric conductance of rough contacts in microchips** (Axelis): proprietary
- **Explosive fragmentation of materials:** development of computer codes (SRI International)

Selected invited lectures and seminars

Universities:

Harvard University
Massachusetts Institute of Technology
Northwestern University
Louisiana State University, distinguished lecture series
Stanford University
University of Minnesota
University of Connecticut
University of California – Berkeley
California Institute of Technology

Ecole Normale Supérieure (France)
University of Paris-6 (France)
University of Hannover (Germany)
Free University of Berlin (Germany)
Madrid Polytechnic Institute (Spain)
University of Muenchen (Germany)
University of Tampere (Finland)
University of Cyprus
University of Toronto (Canada)
Federal Institute for Materials Research (Germany)

Industries:

Siemens Research Center (Germany)
United Technologies Research Center (distinguished lecture series)
General Motors
Caterpillar
General Electric Research and Development Center (distinguished lecture series)
Shell (Netherlands and USA)
Marathon Oil
Merck Research Center (Germany)
Alstom Power (Switzerland)

Mini-Courses

Harvard University
Darmstadt Polytechnic University (Germany)
NATO Summer School on Physical Aspects of Fracture (France)
Technion – Israel Institute of Technology
Corning, Inc.
Schlumberger, Inc.

PUBLICATIONS (*total number:140*)

Books

Micromechanics of Materials, in progress (completion expected in 2013)

Handbook of Elasticity, *Kluwer Academic Publishers*, 2003

Book Chapters and Invited Reviews

Effective Elastic Properties of Cracked Solids, *Applied Mechanics Reviews* **45**(8), 305-336, 1992

Elastic Solids with Many Cracks and Related Problems, pp. 256-426, in "*Advances in Applied Mechanics*", Academic Press, 1994.

Effective Properties of Solids with Cavities of Various Shapes, with I.Tsukrov and B.Shafiro, *Applied Mechanics Reviews*, **47**(1), pp. 151-174, 1994

Mechanics of Anisotropic Materials with Multiple Cracks, with C.Mauge, pp. 3-46, in "*Key Engineering Materials*", 1996

Tutorial: "Effective Elasticity of Fractured Rocks", with V.Grechka, *Geophysics*, **71** (6) pp. W45-W58, 2006

Connections between Elastic and Conductive Properties of Heterogeneous Materials, with I.Sevostianov, in "*Advances in Applied Mechanics*", pp. 69-255, Academic Press, 2008

Effective Properties of Porous and Microcracked Rocks, with Y. Gueguen, in "*Microstructure and Properties of Rocks*", pp. 73-125, Springer, 2011

Non-Interaction Approximation in the Problem of Effective Properties, with I.Sevostianov, in "*Effective Properties of Heterogeneous materials*", pp. 1-96, Springer, 2013

Selected articles

A. Multiple cracks and damage

"Continuum Theory of Medium with Cracks," with A. Vakulenko *Izvestiya Akademii Nauk SSSR, Mekhanika Tverdogo Tela (Transactions of the Academy of Sciences of USSR, Mechanics of Solids)*, v. 4, pp. 159-166, 1971 (in Russian)

"Continuum Model of Medium with Cracks," *Journal of the Engineering Mechanics Division*, ASCE, v. 106, no. EM5, pp. 1039-1051, 1980

"Interaction of a Crack with a Microcrack Field," with A. Chudnovsky, *International Journal of Engineering Science*, v. 21, pp. 1009-1018, 1983

"Interaction of a Crack with Certain Microcrack Arrays," with E. Montagut, Engineering Fracture Mechanics, v. 25, pp. 625-636, 1986

"Elastic Solids with Many Cracks: a Simple Method of Analysis," International Journal of Solids and Structures, v. 23, pp. 23-45, 1987

"On Modelling of Anisotropic Damage in Elastic-Brittle Materials," in Damage Mechanics in Composites, ed. A. Wang and G. Haritos, pp. 99-105, 1987

"Statistical Aspects of Crack-Microcrack Interactions," with E. Montagut, International Journal of Fracture, v. 37, R55-62, 1988

"Three Dimensional Problems of Strongly Interacting Cracks," with J. Laures, International Journal of Fracture, v. 42, pp. 289-313, 1989

"Intersecting Cracks and Cracks Intersecting a Hole," with E. Montagut, International Journal of Fracture, v. 40, R61-65, 1989

"On Relationship Between Fracturing of Brittle Microcracking Solids and its Elastic Properties," in Damage Mechanics in Engineering Materials, ed. F. Ju, et. al., ASME, pp. 11-15, 1990

"Mechanics of Crack-Microcrack Interactions," with J. Laures and E. Montagut, Mechanics of Materials, v. 10, pp. 1-13, 1990

"On Possible Correlations between Fracture and Stiffness Degradation", in Toughening Mechanisms in Quasi-Brittle Materials, pp. 373-378, 1991

"Three-Dimensional Interactions of a Crack Front with Microcrack Arrays," with J. Laures, International Journal of Fracture, v.48, pp.255-279, 1991

"Effective Elastic Properties of Cracked Solids: Critical Review of Some Basic Concepts", Applied Mechanics Reviews, v. 45, no.8, pp. 305-336, 1992

"Effective Elastic Properties of Anisotropic Materials with Arbitrarily Oriented Cracks", with C.Mauge, Journal of the Mechanics and Physics of Solids, v.42, pp. 1-24, 1994

"Effective Properties of Solids with Randomly Located Defects", with I.Tsukrov and B.Shafiro, in Probabilities and Materials, ed. by D.Breusse, Kluwer Publ., pp. 225-240, 1994

"On the Concept of Damage under Creep Conditions and in Brittle-Elastic Materials", International Journal of Damage Mechanics, v. 3, pp. 329-337, 1994

"Three-Dimensional Interactions of a Crack with Dipoles, Centers of Dilatation and Moments", with E.Karapetian, International Journal of Solids and Structures, v. 33(27), pp. 3951-3967, 1996

"Stress Concentrations and Microfracturing Patterns in a Brittle-Elastic Solid with Interacting Pores of Diverse Shapes", with I. Tsukrov, International Journal of Solids and Structures , v. **34**, pp.2887-2904, 1997

"Green's Functions for a Transversely Isotropic Material Containing a Circular Crack", with E.Karapetian, Acta Mechanica, **126**, 169-187, 1998

"On the Stress Intensity Factor for the Elliptical Crack", with B.Nuller and E.Karapetian, International Journal of Fracture, v. **92**, no.2, pp. L17-20, 1998

"Moderately Non-Circular Cracks", with E.Karapetian, International Journal of Fracture, v. **92**, no. 2, pp. L21-26, 1998

"Construction of the Displacement and Stress Fields in a Plane with Multiple Cracks", with L.Gorbatikh, Engineering Fracture Mechanics, v. **60**, pp. 53-65, 2000

"Elastic compliance of an annular crack", with I.Sevostianov, International Journal of Fracture, **110**, L31-34, 2001

"Elastic Compliances of Irregularly Shaped Cracks", with I.Sevostianov, International Journal of Fracture, v.**114**, pp. 245-257, 2002

"On the Crack Coalescence Problem", International Journal of Fracture, v **120**, pp.537-543, 2003

"Elastic Compliances of Non-Flat Cracks", with M. Mear and I. Sevostianov, International Journal of Solids and Structures, **44**, 6412-6427, 2007

"On Absence of Quantitative Correlation between Strength and Stiffness in Microcracking Materials", International Journal of Fracture, **164**, 155-158, 2010

"Compliance of cracks with shape irregularities", International Journal of Fracture, with W. Fauriaut, **170 (2)**, 207-210, 2012

B. Micromechanics of materials with complex microstructures

"Solids with Holes of Irregular Shapes: Effective Moduli and Anisotropy", with I.Tsukrov, International Journal of Fracture, v. 64, pp. R9-12, 1993

"Effective Properties of Solids with Cavities of Various Shapes", with I.Tsukrov and B.Shafiro, Applied Mechanics Reviews, v. 47, no.1 pp. 151-174, 1994

"Stress Concentrations and Microfracturing Patterns for Interacting Elliptical Holes", with I.Tsukrov, International Journal of Fracture, v. **68**, 89-92, 1994

"Longwave Speeds in Materials with Cracks and Cavities of Various Shapes", with B.Shafiro, in Review of Progress in Quantitative Non-Destructive Evaluation, 1994

"On the Effective Elastic Properties of Rocks with Pores of Various Shapes", in Mechanics of Jointed and Faulted rocks, Balkema Press, pp.81-84, 1995

"On the Concept of Approximate Elastic Symmetry and Its Application to Materials with Defects", International Journal of Fracture, Reports of Current Research, 74: R33-R38, 1995

"On Microfracturing Patterns in Solids with Interacting Holes", with I. Tsukrov, Computer Methods in Composite Materials, **6**, 341-350, 1998

"Microstructure of the Cortical Bones and Their Effective Elastic Properties", with I. Sevostianov, International Journal of Fracture, v. **92**, no.1, pp. L9-14, 1998

"Solids with Non-Spherical Cavities: Cavity Compliances and the Overall Anisotropy", with B. Shafiro, Journal of the Mechanics and Physics of Solids, v.**46**(2), pp 1-21, 1998

"Compliance Tensors of Ellipsoidal Inclusions", with I. Sevostianov, International Journal of Fracture, v.**96**, no.1, L3-7, 1999

"Anisotropic Material with Elliptical Holes of Arbitrary Orientational Distribution", with I. Tsukrov, International Journal of Solids and Structures, v.**37**, pp.5919-5941, 2000

"Osteonal Cortical Bone: Impact of Porous Microstructure on the Overall Elastic Properties" with I. Sevostianov, Journal of Biomechanics, v.**33** (7), pp. 881-888, 2000

"Elastic Space Containing a Rigid Ellipsoidal Inclusion Subjected to Translation and Rotation", with E. Karapetian and I. Sevostianov, in Multiscale Deformation and Fracture in Materials and Structures (J. Rice Anniversary Volume), Kluwer Acad. Publ., pp. 123-143, 2001

"On the Yield Condition for Elastic-Plastic Anisotropic Porous Materials", with I. Sevostianov, Materials Science and Engineering-A, v.**313**, pp. 1-15, 2001

"Recovery of Information on Microstructure from the Effective Elastic/Conductive Properties, with L. Gorbatikh, Materials Science and Engineering, v. **A-318**, pp 1-14, 2001

"On the Perfectly Plastic Flow in Porous Material", with T. Zohdi and I. Sevostianov, International Journal of Plasticity, v. 18, pp 1649-1659, 2002

"On Elastic-Conductive Cross-Property Correlations for Granular Materials", Proceedings of the Royal Society A-**460**, pp.1529-1534, 2004

"On Quantitative Characterization of Microstructures and Effective properties", with I. Sevostianov, International Journal of Solids and Structures **42**, 309-336, 2005

"Relations between compliances of inhomogeneities having the same shape but different elastic constants", International Journal of Engineering Sciences, **45**, 797-806, 2007

"Approximate elastic symmetries and elliptic orthotropy", International Journal of Engineering Sciences, with I. Sevostianov, **46**, 211-233, 2008

"Elastic fields generated by inhomogeneities: Far-field asymptotics, its shape-dependence and relation to effective elastic properties", International Journal of Solids and Structures, with I. Sevostianov, **48**, 2340-2348, 2011

"Rice's internal variables formalism and its implications for the elastic and conductive properties of cracked materials and for the attempts to relate strength to stiffness", Journal of Applied Mechanics, **79**, 031002-1 - 10, 2012

C. Nano

“Homogenization of a Nano-particle with Graded Interface”, International Journal of Fracture, **139**, 121-127, 2006

“Effect of interphase layers on the overall elastic and conductive properties of matrix composites. Applications to nano-size inclusions”, International Journal of Solids and Structures, **44**, 1304-1315, 2007

D. Conductivity and cross-property connections

"Anisotropic Effective Conductivity of Materials with Non-Randomly Oriented Inclusions of Diverse Ellipsoidal Shapes", with B.Shafiro, Journal of Applied Physics, v.**87**(12), pp.8561-8569, 2000

"Cross-Property Correlations for Anisotropic Porous Microstructures", with I.Sevostianov & B.Shafiro, Journal of the Mechanics and Physics of Solids, v.**49**, pp.1-25, 2001

“Explicit Cross-Property Correlations for Anisotropic Two-Phase Composite Materials”, with I.Sevostianov, Journal of the Mechanics and Physics of Solids, v. **50**, pp253-283, 2002

“Cross-Property correlations for short fiber reinforced composites with damage and their experimental verification”, with V.Verijenko and I. Sevostianov, Composites, part B, v. **33**, pp. 205-213, 2002

“Correlations between Elastic Moduli and Thermal Conductivities of Anisotropic Short Fiber Reinforced Thermoplastics: Theory and Experimental Verification”, with I.Sevostianov, Materials Science and Engineering, v. **360**, pp 339-344, 2003

“Plastic Yield Surfaces of Anisotropic Porous Materials in Terms of Effective Electric Conductivities”, with I.Sevostianov, Mechanics of Materials, **38**, 908-923, 2006

“Resistances of non-flat cracks and their relation to crack compliances”, with M.Mear et al, International Journal of Engineering Sciences, with I. Sevostianov, **47**, 754-766, 2009

“Local minima and gradients of stiffness and conductivity as indicators of strength reduction of brittle-elastic materials”, International Journal of Fracture, **164**, 147-154, 2010

E. Rough contacts

“Contacting rough surfaces: Hertzian contacts vs welded areas”, with I. Sevostianov, International Journal of Fracture, **145**, 223-228, 2007

“Contact of rough surfaces: a simple model for elasticity, conductivity and cross-property connections”, with I. Sevostianov, Journal of the Mechanics and Physics of Solids, **56**, 1380-1400, 2008

“Normal and tangential compliances of interface of rough surfaces with contacts of elliptical shape”, International Journal of Solids and Structures, with I. Sevostianov, **45**, 2723-2736, 2008

“Elasticity-conductivity connections for contacting rough surfaces: An overview”, Mechanics of Materials, **41**, 375-384, 2009

“Compliance and resistance of contacts and contact clusters: implications of cross-property connection”, with I. Sevostianov, International Journal of Engineering Science, v **47**, 974-989, 2009

“Contacts and cracks of complex shapes: Crack-contact dualities and normal and shear compliances”, with A.Kiris, International Journal of Engineering Science, v. **50**, 233-255, 2012

F. Coatings

"Effect of Microcracks and Pores on the Elastic Properties of Plasma-Sprayed Materials" , with F.Kroupa, in Modeling of Material Structure from Microscale to Product, Denmark, p. 1-6, 1998

"Modeling of the Anisotropic Elastic Properties of Plasma-Sprayed Coatings in Relation to Their Microstructure", with I.Sevostianov, Acta Materialia, v.**48**(6), pp. 1361-1370, 2000

"Thermal Conductivity of Plasma Sprayed Coatings in Relation to Their Microstructure", with I.Sevostianov, Journal of Thermal Spray Technology, v.**9**(4), pp.478-482, 2001

"Plasma-Sprayed Ceramic Coatings: Anisotropic Elastic and Conductive Properties in Relation to the Microstructure; Cross-Property Correlations", with I.Sevostianov, Materials Science and Engineering-A, v.**297**, pp. 235-243, 2001

“On the elastic properties of PVD coatings in relation to their microstructure”, with J.Ruud and I. Sevostianov , Materials Science and Technology, v. **124**, pp.246-250, 2002

“Elasticity and Conductance of Plasma-Sprayed Coatings in Relation to Microstructure: A Critical Overview”, with I.Sevostianov, Journal of Thermal Spray Technology, v.**18**, pp.822-834, 2009 – *Best Paper Award at International Congress on Coatings (Singapore)*

G. Piezoelectrics

"Point Force and Point Electric Charge in Piezoelectric Transversely Isotropic Solids", with E.Karapetian and I.Sevostianov, Philosophical Magazine-B, v.**80** (3), pp. 331-359, 2000

"Penny-Shaped and Half-Plane Cracks in the Piezoelectric Transversely Isotropic Solid, with E.Karapetian and I.Sevostianov, Archive of Applied Mechanics, v. **70** (1-3), pp. 201-229, 2000

"Microcracking in Piezoelectrics Reduces the Electromechanical Coupling and Alters Its Directionality", with I.Sevostianov, International Journal of Fracture, v.**101**, pp. L3-8, 2000

"Piezocomposites: effective piezoelectric constants and design with the prescribed overall properties", with I.Sevostianov, Archive of Applied Mechanics, v. **71**, pp 733-747, 2001

"A Principle of Correspondence for the Piezoelectric Solids", with E.Karapetian and I.Sevostianov, Archive of Applied Mechanics, v. 72, pp. 564-587, 2002

"Nanoelectromechanics of Piezoresponse Force Microscopy", with S.Kalinin and E. Karapetian, Physical Reviews-B, **70**, 184101-181124, 2004

"Simultaneous Elastic and Electromechanical Imaging by Scanning Probe Microscopy", with S.Kalinin and E. Karapetian, Journal of Vacuum Science and Technology B-23, 2102-2108, 2005

"Nanoelectromechanics of Piezoelectric Indentation and Applications to Scanning Probe Microscopies of Ferroelectric Materials", with S.Kalinin and E. Karapetian, Philosophical Magazine, **85** (10), 1017-1951, 2005

"Nanoelectromechanics of Polarization Switching in Piezoresponse Force Microscopy", Journal of Applied Physics, **97**, 074305-074311, 2005

"Indentation of Punches into Piezoelectric Half-Space with Frictional Sliding: Applications to Scanning Probe Microscopy", with A.Makagon, E.Karapetian and S. Kalinin, Physical Review-B, **76**, 064115-064129, 2007

"Piezoelectric indentation of a flat circular punch accompanied by frictional sliding and applications to scanning probe microscopy", with A.Makagon et al, International Journal of Engineering Sciences, **47**, 221-239, 2009

"Stiffness relations for piezoelectric indentation", with Karapetian and Kalinin, Journal of the Mechanics and Physics of Solids, **57**, 673-688, 2009

H. Geophysics and oil exploration

"Microcrack Model of Rock Inelasticity. Part I: Frictional Sliding on Pre-existing Microcracks, Mechanics of Materials, v. 1, pp. 19-27, 1982. Part II: Propagation of Microcracks, Mechanics of Materials, v. 1, pp. 29-41, 1982. Part III: Time-Dependent Growth of Microcracks (Stress Corrosion Cracking), Mechanics of Materials, v. 1, pp. 123-129, 1982

"Microcrack-induced Elastic Wave Anisotropy of Brittle Rock", with C.Sayers, Journal of Geophysical Research, v.100 (B3), pp. 4149-4156, 1995

"On Stress-Strain Relations for Cracked Rocks in Compression", with F.Lehner, in Mechanics of Jointed and Faulted rocks, Balkema Press, pp.49-61, 1995

"Fluid-Saturated Rocks: Fluid Pressure Polarization and Effective Elastic Response", with B.Shafiro, International Journal of Fracture, v. **73**: R61-R66, 1995

"On Modelling of Winged Cracks Forming in Rocks Under Compression", with F.Lehner, International Journal of Fracture, v. **77**, pp. R69-75, 1996

"Materials with Fluid-Filled Pores of Various Shapes: Effective Moduli and Fluid Pressure Polarization", International Journal of Solids and Structures, v. **34**, pp. 3517-3540, 1997

"Non-Uniform Frictional Sliding on Cracks under Cyclic Loading", with B.Nuller and L.Gorbatikh, International Journal of Solids and Structures, v.**39**, pp 89-104, 2002

"Sliding on Cracks with Non-Uniform Frictional Characteristics", with B.Nuller and L.Gorbatikh, International Journal of Solids and Structures, v. **42-43**, pp7501-7524, 2002

"Seismic Characterization of Multiple Fractures: Does Orthotropy Suffice?" with V.Grechka, Geophysics, **71** (3), D93-D105, 2006

"Effective Elasticity of Fractured Rocks", with V.Grechka, The Leading Edge, 152-156, 2006

"Effective Elasticity of Rocks with Closely Spaced and Intersecting Fractures", with V.Grechka, Geophysics, **71** (3), D85-D91, 2006

"The Influence of Crack Shapes on the Effective Elasticity of Fractured Rocks", with V.Grechka, Geophysics, **71** (5), D153-D160, 2006

"Effective Elasticity of Fractured Rocks: A Snapshot of Work in Progress", a Tutorial, with V.Grechka, Geophysics, **71**, W45-58, 2006

"Modeling elastic properties of siliclastic rocks", with Vernik, Geophysics **75** (6), 171-182, 2010

"Incremental response of rocks containing multiple rough fractures: Similarities and differences with traction-free cracks", Geophysics, **75** (1), 1-11, 2010

"Some controversial issues in rock physics and oil exploration", The Leading Edge 636-642, 2012

References

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