



# Effect of external influences on the strength and plasticity of metals and alloys

Book of the International  
Workshop Articles



Barnaul-Belokurikha  
15-20 September 2015

Ministry of Education and Science of the Russian Federation  
Russian Foundation for Basic Research  
I.I. Polzunov Altai State Technical University  
Advanced Materials Institute of Tsinghua University  
Siberian State Industrial University  
Tomsk State University of Architecture and Building  
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Siberian Physics Technical Institute

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AltSTU Publ.

Barnaul-2015

UDK 669.419:621.778:539.4  
BBK 34.232.4:34.5,3:34.206.22  
E43

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Effect of external influences on the strength and plasticity of metals and alloys: Book of the International seminar articles, 15 - 20 September 2015/ Ed. by M.D. Starostenkov; LI. Polzunov Altai State Technical University - Barnaul: AltSTU Publ., 2015. - 187 p.

ISBN 978-5-7568-1113-1

The reports made at the Russian-Chinese International seminar are brought in this edition. The problems of the external energy fields action on the structure, phase composition, defect substructure of different metals and alloys during deformation are discussed.

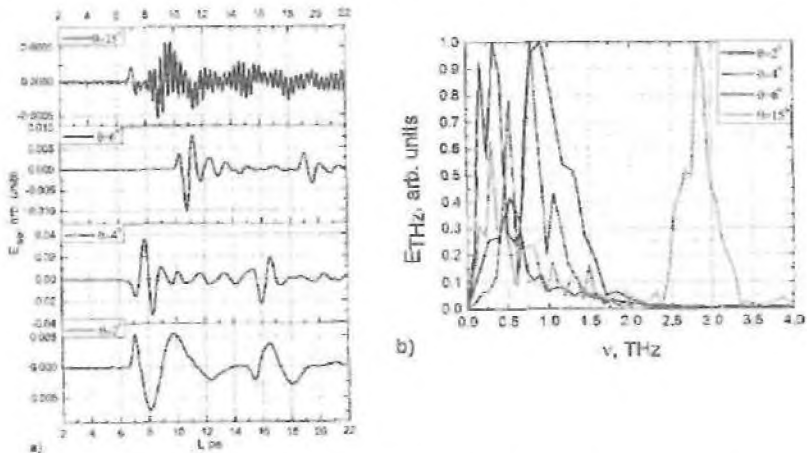
The book of articles is intended for the material science and metallurgy specialists and can be usefully for the post graduate student of corresponding specialist.

ISBN 978-5-7568-1113-1

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influence of GaSe doping with sulfur on phase-matching conditions and efficiency of terahertz generation by optical rectification of femtosecond laser pulses is evaluated. Basing on analysis of phase matching conditions we demonstrate also a narrowband tunable electro-optical detection in a centimeter size GaSe crystal at optical probe and pump pulses having time duration about 12 fs, as it is shown in figure.



Temporal (a) and wave (b) forms of terahertz pulses generated in InAs a n-d detected in thick GaSe sample tilted at different angles. The detection efficiency is tuned by tilting the crystal.

## DOPING AS A MEAN TO IMPROVE MECHANICAL PROPERTIES FOR GaSe

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In last two decades the birefringent GaSe crystal was the mostly used in laboratories as (non-phase matched) optical rectifier and phase matched difference frequency generator (DFG) operating in extreme wide spectral band

from near IR (2.7  $\mu\text{m}$ ) to sub-centimeter (0.57 cm) wavelength. It is due to outstanding physical properties: the extreme wide transparency range 0.62-20  $\mu\text{m}$  and from 50  $\mu\text{m}$  further into the THz range, large nonlinearity coefficient  $d_{22}=54.6$  pm/V, and low nonlinear absorption. The prodigious birefringence  $B=0.35$  in the mid-IR and about 0.79 in the THz range, and low group velocity dispersion allow phase-matched DFG of long and ultrashort pulses almost all over the entire transparency range. GaSe is cheap in synthesis and can be manufactured as centimeter size samples.

However, impressive physical properties have not allowed it to achieve the ubiquity of other nonlinear materials such as  $\text{ZnGeP}_2$  in commercial and industrial applications. This is because GaSe is difficult to grow and process as large, high optical quality single crystal samples due to its layered structure with weak inter-layer Van-der-Waals type bonding. The crystal cleaves readily along the  $\langle 001 \rangle$  plane. With careful preparation it is possible to produce optical quality surfaces along this direction which is orthogonal to the  $c$ -axis. Access to other crystallographic directions is hampered, as GaSe is too soft to be cut and polished to optical quality. Its hardness has been measured as close to 2 on the Mohs' scale.

In this work, we report strengthening GaSe structure by reasonable isovalent element (Al, S, In, Te, Er) doping with saving basic optical properties or even their improving. The highest optical properties demonstrated heavily (2.5 mas.%) S-doping in line increasing hardness from for GaSe for 20-25%. The highest impact on hardness shown Al-doping that does not form binary compound AlSe. Small, 0.5 at. %, doping increases it for up to 2 times. Additive effect of S and Al-doping was also observed. As a result, the lattice structure strengthens enough to be cut and polished in arbitrary direction, especially if the crystal is first prepared by setting in a polymer matrix that shrinks slightly during polymerization. Simultaneously, the mid-IR optical absorption coefficient decreases by a factor of 2-3, while the optical damage threshold increases fivefold at the optimal mixing ratio and optical properties in the THz range are also improved.

*The research was supported by The Tomsk State University Academic D.I. Mendeleev Fund Program (research grant No 8.1.51.2015).*

Scientific Education

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*Book of the International workshop articles*

*Russia-China  
International workshop  
15-20 September, 2015*

Edition in Chief: Professor Sc. D. (Physics & Mathematics) M.D. Starostenkov

Technical editing, design : E.V. Chernykh

Format 60x84 1 / 16 . Offset. Press.  
Volume 10,81 print sheets. 100 copies. Order 2015 - 189  
I.I. Polzunov Altai State Technical University  
656038 Barnaul, Lenin St., 46  
Printed in AltSTU Publishing and printing center