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Book of Abstracts

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The book consists of the abstracts of oral and poster contributions to the 8th International Workshop on Subsecond Thermophysics, September 26–28, 2007, Moscow, Russia. This is the eighth of a series of well-established workshops on both experimental and theoretical aspects of thermophysical behavior of matter in the millisecond to femtosecond time regimes. It includes rapid resistive or inductive heating, laser pulse heating, shock and release waves, and levitation techniques. The emphasis is on measurements and modeling of thermophysical properties and phase transitions at high temperatures and pressures up to the vicinity of the critical point of high-melting substances. In this region, laser pulse and resistive heating, container-less techniques and adiabatic-release techniques are unique approaches to study the behavior of matter under conditions near and distant from thermodynamic equilibrium.

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Ohmic heating

THERMOPHYSICAL PROPERTIES OF METALS AT VERY HIGH TEMPERATURES OBTAINED BY DYNAMIC OHMIC HEATING: RECENT ADVANCES

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Since the 1960s, pulse resistive self-heating techniques, associated with 10^4 – 10^{10} K · s^{−1} heating rates, have been widely developed in order to study both solid and liquid states of pure and alloyed metals at very high temperature (up to 10,000 K). This paper is a review of main recent results and advances obtained with such techniques.

Thermophysical properties such as electrical resistivity, heat of fusion, melting points, volume expansion (density), heat capacity, thermal conductivity, thermal diffusivity, heat capacity, etc. of solid and liquid metals are then reachable throughout these high-speed experiments. This large set of thermophysical data may be completed with critical points determination as well as elastic constants data and equation-of-state parameters.

LIQUID CARBON DENSITY

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The results of pulse experiments with the graphite of high initial density (2.2 g/cm³) and low density (1.6–1.9 g/cm³) are under investigation. It was discovered in microseconds pulse experiment [1], that graphite specimens with low initial density (1.83 g/cm³) converted to high density

(2.2 g/cm³) in solid state before melting. This compression has happened at temperatures from $T = 3200$ K up to 4000–4100 K according to our evaluation. Only after that compression graphite continue to expand monotonically at temperatures T more than 4000 K up to the density 1.2 g/cm³ at the melting line. This important information was applied to our results of different fast experiments with graphite specimens. As it appeared the liquid carbon volume density at the melting line (under low pressures) is small (1.2 g/cm³). At low pressures (but higher 110 bar) and under temperatures more than $T = 4800$ K liquid carbon aspire to active expansion. It should be formed different carbon structures (from isolated atoms, their complexes up to extensive fragments) under the next expansion of liquid carbon along the melting line. In all probability the structure of these formations should be depends on the outer pressure values and on the next cooling of carbon. The outer pressure influence over the liquid carbon may give important technological applications under pulse heating of the graphite. The density of liquid carbon at high pressures is much larger: 1.8 g/cm³ at 50 kbar pressure.

The true dependence of carbon melting temperature versus pressure is not established up to now. It leads to considerable differences in carbon phase diagrams at high pressures and temperatures. There is a good reason to believe that future efforts of scientists should be directed to the measurement of pulsed pressure with the help of the shifting of ruby luminescence r-lines (near 700 nm) in carbon spectrum. This method is widely used in steady-state conditions (diamond anvil). The method of plane loading for metal foils (convenient also for graphite) is constructed already under pulse electrical heating [2].

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ELECTRICAL RESISTIVITY OF HIGH TEMPERATURE METALLIC MELTS

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Electrical Resistivity Measurement of High Temperature Metallic Melts is the title of an Austrian Space Applications Programme (ASAP) project, sponsored by the FFG (see below). The project's main intent is the refinement of electrical resistivity data via a comparison between two very different experiments: fast pulse-heating and electromagnetic levitation. The latter is planned to be carried out under μg -conditions at the ISS in 2010 (for details see [1] and [2]). This arrangement comprehends subsecond ohmic versus quasistatic inductive heating and ground-based versus space-flight facility.

During the calculation of the *specific electrical resistivity* the volume expansion of the sample has to be taken into account. At the Subsecond Thermophysics laboratory at TU Graz this is achieved with a fast CCD-camera which allows a monitoring of the radial expansion of the exploding wire. Consequently the change in density as a function of temperature is obtained.

We will give a general survey of the project's approaches and present results of the pulse-heating experiment for Hf, Re, Fe, Co, and Ni with respect to *enthalpy*, *resistivity* and *volume-expansion* up into the liquid phase.

The project "*Electrical Resistivity Measurement of High Temperature Metallic Melts*" is sponsored by the FFG by the Austrian Space Applications Programm (ASAP), Sensengasse 1, 1090 Wien, Austria.

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NON ADIABATIC THIN-FILM (CHIP) NANOCALORIMETRY FOR FAST (10^5 K/s) SCANNING AND AC-CALORIMETRY

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Utilizing a thin film chip sensor as a fast calorimeter we are able to extend the scanning rate range of commercial DSC's (10^{-5} K/s to 10 K/s) to rates as high as 100,000 K/s. The gauge is placed in a thermostat with controlled gas pressure and temperature to be utilized as a device for fast scanning and AC-calorimetry of sub microgram samples with sensitivity 1 nJ/K in scanning and pJ/K in AC-mode. The nanocalorimeters are used in combination with conventional DSC in scanning, isothermal, and AC-mode (TMDSC) to study melting, crystallization, recrystallization, and glass transition of polymers and polymer clay nanocomposites. With these sensors we are able to measure at controlled cooling at the same high rates as on heating. Because of the fast equilibration time isothermal experiments can be performed after scanning at several thousand Kelvin per second. The dead time after such a quench is in the order of 10 ms and the time resolution is in the order of milliseconds. These ultra fast calorimeters allow us to study the kinetics of extremely fast processes in semicrystalline polymers. For example, we are able to follow isothermal crystallization of Polycaprolactone (PCL) and isotactic polypropylene (iPP) in the whole temperature range between melting and glass transition.

Heat capacity can be measured in AC mode for sample masses below one nanogram as needed for the study of the glass transition in nanometer thin polymeric films. The calorimeter allows for the frequency dependent measurement of complex heat capacity in the frequency range from 1 Hz to 1 kHz. The glass transition in thin polystyrene and PMMA films (50–4 nm) was determined at well defined experimental time scales. No thickness dependency of the glass transition temperature was observed within the error limits (± 3 K) — neither at constant frequency (40 Hz) nor for the trace in the activation diagram (1 Hz–1 kHz).

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**MEMBRANE BASED ULTRAFAST NANOCALORIMETRY
FOR SUBMILLISECOND MEASUREMENTS AT HEATING
AND COOLING RATES UP TO 10^6 K/s**

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To study phase transition kinetics, as well as for thermal processing, of sub microgram samples on submillisecond time scale ultrafast scanning nanocalorimetry was developed [1, 2]. The method is based on commercially available microchips, XEN-3935, -3940, -3969, -3973, from Xensor Integration, NL [3]. The gauges consist of a submicron silicon nitride membrane with a film-thermopile and a film-heater, which are located at the central part of the membrane. The gauges are placed in a thermostat with controlled helium gas pressure and temperature to be utilized as devices for calorimetry with resolution ~ 1 nJ/K. Controlled cooling and heating up to 10^6 K/s was attained. The characteristic rate corresponding to the quasi-static limit of the temperature change in the membrane-gas system was determined to be 1^5 K/s for different membrane gauges in helium gas. The method was applied for the measurements of the superheating phenomenon in a set of linear polymers.

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3. Technical data available on the website:
<http://www.xensor.nl/txtfiles/hfdfiles/prodstan.htm>

COMPARISON OF THE SHORT-TIME THERMAL STABILITY FOR POLYMERIC SAMPLES BY THE SHOCK HEATING METHOD

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We are developing experimental approach to the investigation of superheated (short-lived) states of substances based on the procedures of automatic selection of heating function for a thin wire probe, the monitoring of a time dependence of the heat flux from the probe, and the calculation of effective thermophysical properties of substances from the data of pulse experiment and the model of the process.

Our report is dealt with a study of the density of heat flux from a pulse-heated probe through polymeric samples and with searching for methods of estimating of thermophysical properties and temperature-time conditions of the thermal decomposition onset of these samples. The selection of results is based on the analysis of time dependencies of the heat flux in a series of pulses with the pre-assigned heating function.

The problem lies in the reduction of the life time of a system in the course of penetration into the region of superheated states (with respect to the temperature of thermal decomposition in quasi-static process). We sought to reduce the pulse length in order to increase as much as possible the depth of the penetration while maintaining the initial structure of substance. In general, the method is based on a combine using of the technique of thermal stabilization of the pulse-heated probe and technique of shock heating with the pulse length less than 1 microsecond. The run of the curve of the subsequent probe cooling is recorded.

The report presents the results of comparison of thermal resistance and short-time thermal stability for polymeric samples prepared by polymerization of monomer or curing of low-molecular weight reactive compositions.

INVESTIGATION OF THE THERMOPHYSICAL PROPERTIES OF SUBSTANCES IN SUPERHEATED STATES

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The properties of liquids are usually investigated in stable states of a system. Such states are retained as long as one likes under invariant environmental conditions and, therefore, are convenient for performing measurements. In particular, measurements of the thermophysical properties of liquids are carried out under small temperature perturbation with respect to the bulk temperature. As a result, the wide region of phase diagram beyond the line of absolute stability remains poorly known so far.

We are interested in the region of relatively stable (superheated) states of a substance characterized by a set of finite life times. These states for a liquid are observed when the system crosses the line of liquid-vapor equilibrium without undergoing of a phase transition.

The experimental part of our investigation is based on the method of controlled pulse heating of a thin wire probe, immersed into a sample. The important point consists in a selection of heating function for the probe suitable for the following calculation of the thermophysical properties for superheated liquids. The time dependences for the both heating power and probe temperature are recorded in the course of experiment. Then the time dependence of the heat flux density through the sample is calculated. A search of the thermophysical properties for superheated liquids from the experimental data is carried out by the numerical method. Availability of the thermophysical properties temperature dependence is taken into account. We are developing the technique of integro-interpolation modeling of heat exchange between the probe and sample for this purpose.

Pulse measurements have been carried out by the constant power technique, as a convenient particular case of a heating function. Heating pulse length was in the range from 1 to 10 milliseconds. The measurements were performed in the course of gradual increase of the value of superheat up to 200 K. The objects under investigation were the low-molecular-weight hydrocarbons (reference substances in thermophysical measurements), as well as complex systems, such as industrial oils and polymer melts.

REMODELED OPTICAL EXPANSION CAMERA FOR A FAST PULSE-HEATING EXPERIMENT

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Over the years, the ohmic pulse-heating technique has proven to be a valuable tool to obtain thermophysical data of conducting samples in the solid and the liquid states on a subsecond time-scale. Directly accessible properties with such a setup include temperature, specific enthalpy, isobaric heat capacity, and electrical resistivity. The latter can further be used to calculate thermal conductivity and thermal diffusivity provided the thermal expansion of the sample material is known. At first, electrical resistivity obtained from the recorded current and voltage signals is limited to the initial room temperature geometry and does not include any volume expansion. To overcome this limitation, temperature-dependent thermal expansion (in our case radial expansion) has to be measured simultaneously during such experiments. This knowledge of the thermal expansion also yields density as a function of temperature as a by-product.

This presented work describes the implementation of an improved and remodelled CCD-expansion camera using a channel plate as a fast shutter and an inventive exposure/shift algorithm to overcome time restrictions to the pulse-heating setup at TUG. It is the intention to explain the outline of the camera, describe its mode of operation, take a look at its limitations, and finally demonstrate its capabilities with thermal expansion and density data for silver and gold gathered with the expansion camera.

This current project is sponsored by *Österreichische Forschungsförderungsgesellschaft mbH (FFG)* as part of *Österreichisches Weltraumprogramm (ASAP)*, Vienna, Austria.

PHYSICAL PROPERTIES AND NORMAL SPECTRAL EMISSION OF HAFNIUM UP TO 3500 K

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At the Institute of Experimental Physics, Graz University of Technology, Austria, a constantly improved pulse-heating setup with microsecond time resolution has been used for more than 25 years now to determine thermophysical properties of metals and alloys in the solid and the liquid states. Furthermore, a division-of-amplitude photopolarimeter has been added to the setup with different perspectives: To improve the accuracy of the optical (pyrometric) temperature measurement, to fulfil the growing need of industry for optical material information, and for scientific reasons, as, in the majority of cases, only few emittance data can be found for molten materials in literature.

The before mentioned techniques, helped to systematically study a wide variety of pure, commercially available metals throughout the periodic system, to create a database on material information. Due to various reasons such as availability, purity, or price, some metals, such as hafnium, have long time been excluded from investigations.

This work is dedicated to report our recent results on hafnium for both, thermophysical data in the solid and the molten states, as well as normal spectral emittance obtained at a wavelength of 684.5 nm up to 3500 K. The newly obtained values will be presented, discussed, and compared with available literature data.

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DYNAMICS OF A DROP IN A DROP — THE MATROSHKA PROBLEM

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The equilibrium configuration of a drop of two immiscible liquids, wetting each other, consists of a liquid core, encapsulated by the second liquid phase. The oscillation spectrum of such a compound drop corresponds to that of two coupled oscillators, one being driven by the surface tension, while the other is due to the interfacial (liquid-liquid) tension between the two immiscible liquids. Therefore, in principle, the values of both, the surface and the interfacial tension, can be derived from the frequencies of the coupled oscillations. Such a configuration can be approximately realized by electromagnetic levitation, preferably under microgravity conditions. In this paper, the theory relating the frequency spectrum to the surface and interfacial tensions is presented, together with some preliminary results obtained for the Cu-Co and Ag-Cu-Ni alloy systems during short-term parabolic flights.

CRITICAL POINT LOCATION PROBLEM FOR URANIUM-BEARING COMPOUNDS

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Perspectives for moderate (~ 1 kJ/g) impulse energy deposition for study of thermophysical properties of uranium and uranium-bearing compounds are considered. Two physical phenomena are discussed as promising goal for the study: (A) Problem of uranium critical point location. (B) Problem of non-congruent phase transitions (NPT) in uranium-bearing compounds (uranium dioxide, carbide etc.) Both problems are of great fundamental and applied importance. Phenomenology and range of uncertainty in both problems are discussed.

Advantages of volumetric heavy ion beam (HIB) heating of highly dispersive porous materials are discussed for arrangement of uniform ‘quasi-isobaric’ heating without hydrodynamic movement. This regime can be used for measurement of thermal expansion properties of liquid uranium

and uranium-bearing compounds. It is valuable in resolution of both the problems. Laser and electron beam surface heating has an advantage for measurement of high-temperature vapor pressure of uranium as well as for parameters of non-congruent evaporation in uranium dioxide and other uranium-bearing compounds. Strong shock compression with subsequent isentropic release can be used for examination of theoretical model of equation of state for uranium and uranium-bearing compounds.

SPINODAL DECAY OF UNSTABLE LIQUID PHASE IN THE PROCESS OF PULSE HEATING

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Equations for spinodal and quazispinodal were obtained. Area of unstable liquid phase's existing was defined on the diagram of states. Non-stationary process of homogeneous nucleation of vapor cavity in the superheated metastable liquid near spinodal was considered, the formula for distinctive time of this process was obtained. The velocity of liquid heating at which spinodal exceed into the unstable phase's field is possible was defined. This velocity is constrained with current density during matter heating by electric pulse. For example, these parameters were determinate for pulse heating of liquid cesium.

Distinctive peculiarities for a process of unstable liquid phase's spinodal decay were examined. It is shown that during this decay local area of abrupt increase temperature and pressure are appearing, this anomaly size is depending on velocity of energy receiving into unstable liquid phase in the process of pulse heating. The distinctive time of spinodal decay of unstable liquid phase was estimate.

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STUDY OF DYNAMICS OF PLASMA GENERATED UNDER ELECTRICAL EXPLOSION OF METAL TUBE BY MEGAAMPERES CURRENT

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We present the study of the dynamics of the dense plasma formed in the explosion of a thin metal tube by nanosecond megaamperes current pulse. A series of experiments was carried out in the S-300 facility (3 MA, 0.15 Ohm, 100 ns). We also present results of numerical simulations. To take into account the hydrodynamic effects under phase transitions we use a semiempirical multi-phase equation of state [1] for different metals and models of conductivity describing substance properties in wide range of thermophysical parameters. It was study the regimes with almost homogeneous distribution of the current density through the cross section of the tube (skin-layer thickness is greater than the wall thickness of the tube) and regimes with nonhomogeneous heating through the cross section of the tube.

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THERMOPHYSICAL PROPERTIES OF SOLID-PHASE TITANIUM IN A WIDE TEMPERATURE RANGE

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This paper presents experimental results on thermophysical properties of pure polycrystalline titanium samples in a wide temperature range, from 250 to 1800 K. Heat capacity and specific electrical resistivity were measured from 250 to 1800 K, total hemispherical emissivity and normal spectral emissivity from 1000 to 2100 K, and thermal diffusivity in the range

from 250 to 1500 K. From these data, thermal conductivity and Lorenz function of titanium are computed in the range from 250 to 1500 K. For necessary corrections, recent literature data on thermal linear expansion have been used. In measuring heat capacity, specific electrical resistivity, and both emissivities, the subsecond pulse calorimetry has been used, and the laser flash method for measuring thermal diffusivity. The first method used specimens in the form of a thin rod, 2–3 mm in diameter and 200 mm in length, and the second method specimens in the form of a thin disk, about 3 mm thick and 10 mm in diameter. Measurement uncertainties for these methods do not exceed 3% for heat capacity, 1% for specific electrical resistivity, 5 to 10% for two emissivities, and 2% for thermal diffusivity. The results are compared with available literature values and discussed.

Laser heating

THERMAL DIFFUSIVITY OF THE ALUMINUM ALLOY Al-5Mg-2Si-Mn (MAGSIMAL-59) IN THE SOLID AND LIQUID STATE

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The thermal diffusivity of the aluminum alloy Al-5Mg-2Si-Mn (Magsimal-59) in the temperature range from room temperature to 670 °C was measured using the laser flash technique. This alloy is typically used for high-pressure die-casting parts in the automotive industry. These castings have an excellent ductility without heat treatment and a good weldability; therefore they are used as structural parts which need a high fracture elongation during impact on car crash. The thermal diffusivity data are required for numerical simulation of castings within the industrial production process.

A commercial laser flash system (NETZSCH LFA 427) was used for measurements. A short laser pulse of 300 μs was applied to heat the bottom surface of a disk shaped specimen, resulting in a time-dependent temperature increase at the top surface. A correction for the laser pulse-length as well as the surface radiation and convection was applied in order to evaluate the half time value of the temperature increase. Thermal diffusivity was calculated from the specimen thickness and the half time value.

A sapphire crucible was used to contain the specimen in the mushy region and in the liquid state. As the laser is firing from below at the bottom surface of the specimen, the thickness of the melt has to be slight to avoid significant buoyancy. The thermal diffusivity of the alloy in the liquid is drastically lower than in the solid state of the alloy.

**DEVELOPMENT OF TRANSPORT
PROPERTY-COMPOSITION RELATIONSHIP
BY THERMAL MODIFICATION OF ALLOY
COMPOSITION PROFILE**

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There are innumerable pyro-metallurgical pathways along which a batch of a metallic alloy may be processed. The elemental composition profile of such a specimen has been found to evolve in a position dependent manner for a wide class of alloys. Consequently, transport properties become dependent of processing history, affecting their measures significantly when the elemental composition is made to vary in a position-dependent manner. This state of affair has persisted for two basic reasons: one, there has not been any robust development of a theoretical framework in mesoscopic scales that bridges the microscopic lattice-level analysis and the macroscopic thermo-chemical models; and two, there had not been any commensurate experimental methodologies for composition profile based characterization of thermophysical properties until now.

This paper presents a new study in which measurements of selected transport properties and local elemental composition are made simultaneously. We actively modify the composition profile of a refractory alloy specimen of 80 mass% Ni and 20 mass% Cr by means of two different heating schedules: a) uniform heating; or b) non-uniform heating. The resulting elemental composition profiles are measured to be reproducible under an identical thermal cycling schedule. Simultaneous measurements are carried out by real-time spectroscopy of the emissions from a laser-produced plasma (LPP) plume off the specimen's surface. The total ablated mass in the plume provides a measure of thermal diffusivity when the plume is produced in a manner representative of the local alloy composition; the total mass is determined from the quantitative spectroscopy. Continued applications of thermal cycling cause the composition profile to evolve at essentially constant bulk composition, and the thermophysical properties undergo further changes. Both the thermal diffusivity and spectral emissivity are determined at each stage of the evolution of the composition profile. A set of several such matched measurements provides snapshots of the functional relationship between transport properties and elemen-

tal composition profile for the same specimen. The overall strategy for independent theoretical calculation of the relationship will be discussed.

EXPERIMENTAL DETERMINATION OF THE NORMAL SPECTRAL EMISSIVITY OF TITANIUM AT THE MELTING POINT BY THE THIN PLATE METHOD

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The Infinitely Thin Plate (ITP) method has been used to determine the normal spectral emissivity ε_{λ}^n of titanium at the melting point.

A schematic of the working section of the ITP method consists of the sample in the form of thin plate with thickness H , the laser with beam diameter $d_1 \gg H$ and pyrometer, for which the diameter of the sighting spot d_2 , obeys $H \ll d_2 \ll d_1$. The radiance temperature (wavelength $\lambda = 0.665 \mu\text{m}$) of hot surfaces can be determined using calibrated pyrometer very accurately. The sample of titanium was heated up to destruction, that is, until a hole in the foil appeared at the heating spot. The determination ε_{λ}^n is based on the using Planck's law along with the knowledge of the true melting temperature. The true melting temperature of titanium is well known value $T_{\text{melt}} = 1944 \pm 5 \text{ K}$.

In work the substantiation of reliability of measurement radiance temperature during fusion in the given experimental conditions is resulted. The substantiation is lead on the basis of the numerical decision of the non-stationary equation of heat conductivity at complex (the density of a heat flux depends on radius of a spot of heating it is described by law Gausse) nonlinear (losses of heat submit to law Stephen-Boltzmann boundary conditions which corresponded to experimental conditions).

This study was supported by the Russian Foundation for Basic Research (project No. 07-08-00670-a).

MASS SPECTROMETRIC STUDY OF THE LASER VAPORISATION OF URANIUM DIOXIDE UP TO 3500 K

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The analysis of possible nuclear reactor accidents requires a precise experimental knowledge of the behaviour of the fuel at very high temperature, and in particular, of its equilibrium vapour pressure and composition. In this purpose, a new method of high-temperature mass spectrometry (MS) with laser-induced vaporisation (LV) was developed in ITU [1]. Using it, fast time-resolved MS measurements of uranium dioxide vapour were performed over a large mass interval up to 3500 K. Obtained sublimation and vaporisation enthalpies of UO_2 are in a good agreement with the literature [2],[3]. Besides, the partial pressure ratios $p(\text{UO}_2)/p(\text{UO})$, $p(\text{UO}_3)/p(\text{UO}_2)$ and $p(\text{UO}_2^+)/p(\text{UO}^+)$ were measured at around 3300 K and indicate, by comparison with a newly developed thermodynamic model [4], that the vaporisation occurs in a regime close to thermodynamic equilibrium.

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CONTINUOUS-WAVE LASER SURFACE HEATING SET-UP AT ITU

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An extended “laser-flash” technique, the so-called CLASH-apparatus (continuous-wave laser surface heating), has been developed at the ITU for the measurement of the thermal diffusivity and heat capacity. Two laser beams are heating the sample, applied on the front and rear side, to the desired temperature and a third beam is applying an energy pulse on the front surface. Both thermodynamics quantities are determined simultaneously by means of an accurate numerical fitting of the experimental thermograms. This set-up allows measurements at high temperature, up to the melting point, of nuclear fuels. A new laser device allows us to increase the experimental accuracy due to the excellent power homogeneity of the laser beam and due to the perfect knowledge of the pulse power. The CLASH-apparatus and the experimental method will be discussed in detail as well as the improvements in respect to the conventional laser-flash set-up. Some results will be presented.

JUMP OF THE ABSORPTION COEFFICIENT OF MOLTEN ALUMINA AT SUBSECOND LASER HEATING

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The experimental data on the normal-hemispherical reflectivity R of the aluminum oxide ceramics for the wavelengths of 0.488, 0.6328, 1.15, and 3.39 microns and the effective (radiance) temperatures T_{ef1} and T_{ef2} for 0.55 and 0.72 microns were obtained in the process of rapid subsecond heating by CO_2 laser radiation in air and vacuum from room temperature to forming of thin molten layers of 0.6–0.7 mm thick and in the process of subsequent rapid cooling with solidification of melt when the laser radiation was switched off.

Experimentally and by numerical calculation of combined radiation and conduction heat transfer the influence of heating radiation flux in condition of forming of thin melt on the surface of ceramics on the jump increase of T_{ef1} , T_{ef2} and T_{ef} in the infrared spectral range from 2 to 11 microns at melting and on its decrease at solidification were studied. The radiation heat flux density was varied from 500 W/cm² to 2000 W/cm². The results of numerical calculation show that an isothermal two-phase zone forming at the beginning of melting is of very small thickness (6–7 microns) which does not depend on the radiation heat flux. The radiation outgoing from the melt in semitransparent wavelength region is determined by not only this isothermal two-phase zone but also in considerable part by deeper lying more cold crystal layers. Therefore the both T_{ef1} and T_{ef2} in the course of melting process in this zone are much smaller than the melting temperature.

In studying of the influence of heating flux, the experiments in contrast to the calculations do not discover the formation of two-phase zone at the initial stage of melting. It is caused by fluctuations of the density of heating flux on the heating spot and by roughness of the sample surface.

The main distinction consists in the fact that in all experiments after arrest of change of T_{ef1} and T_{ef2} at the initial stage of melting their abrupt increase (jump) is to be observed. The reason of the jump is the large increase of the absorption coefficient k of melt due to change of coordination of Al atoms in melt. This change leads also to increase of k at the heating radiation wavelength of 10.6 micron that brings to the jump of real temperature in the emitting layer. It is obtained that not only the density of heating flux, but also surroundings (air, vacuum) influence on the kinetics of k change and structure rearrangement.

PECULIARITIES OF INTERACTION OF INFRARED LASER IRRADIATION WITH REFRACTORY OXIDES

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In our earlier publications [1, 2] in investigation of thermal radiation properties of refractory oxides at high temperatures by the method of the probing flash we experimentally discovered a number of interesting physical

phenomena connected with interaction of infrared laser irradiation with the refractory oxides.

In interaction of the laser irradiation with the refractory materials in the atmosphere of inert gas the following phenomena have been experimentally revealed:

1. Phenomenon of “absorption flash” manifested as a sharp drop in temperature of the irradiated sample surface on the heating curves.

2. Threshold vapor condensation of the refractory oxides manifested as an intensive energy peak on the cooling curves of the sample investigated.

3. Dependence of the intensity and position of the condensation peak on the cooling curve from the radiant flux density. Prehistory influence of laser heating on the free sample cooling.

4. Forming the stable vapor zone near irradiated spot which determine the absorption flash and the threshold vapor condensation. Existence of this zone leads to accumulate the energy of the laser radiation during heating stage and to the sharp release of energy during the cooling stage.

In the present work a new phenomenon of the multi-step threshold condensation of the vapor of aluminum oxide has been presented for the first time. The detected phenomenon has been manifested as a set of consistent intensive energy peaks on the cooling curves. The magnitude and the recurrence rate of the peaks depend on the conditions of the laser heating. Possibility of using the discovered phenomena for determination of thermophysical properties of refractory materials at high temperatures by the methods of subsecond thermophysics has been discussed.

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EXPERIMENTAL INVESTIGATION OF IRON NANOPARTICLES PROPERTIES BY PULSE LASER HEATING

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Application of nanoparticles in many fields of science and technology inspires the activity of nanoparticles properties studies. There are many

evidences that thermo-physical properties of nanoparticles differ from the properties of bulk material and depend of their size. One of the non-intrusive methods of nanoparticle diagnostics is the laser-induced incandescence. The nanoparticles are heated up by a short laser pulse to the temperature when thermal radiation (incandescence) could be observed. Time resolved laser-induced incandescence (TiRe-LII) intensity shows the fast increase during the laser pulse within the time of about 10 ns and after that decreases due to particle cooling. Thus the TiRe-LII signal carries the information about optical and thermo-physical particle properties. The important optical property is absorption coefficient E_m which is a function of complex refractive index $m = n - k_i$. The value of E_m can be determined by consideration of maximal particle temperature T_0 amounted during laser heating. T_0 can be measured by two different methods — two-color pyrometry and laser energy absorption method. Two color pyrometry allows calculating T_0 from the experimental traces of incandescence intensities measured at two different wavelengths. From the other hand, the maximum value of the particle temperature T_0 can be extracted from the measured laser energy R_0 and known absorption coefficient. The final value of E_m could be determined by fitting the data of two above methods.

In this work the iron nanoparticles were synthesized from a supersaturated iron vapor generated by laser pulse photolysis of $\text{Fe}(\text{CO})_5$ at room temperature [1]. The temporal changes of iron nanoparticle sizes at different experimental conditions were measured by TiRe-LII. The iron nanoparticle absorption coefficient E_m at wavelength 1064 nm was determined. The translational energy accommodation coefficient of argon and helium molecules with iron nanoparticle surface was found. The data obtained allow investigating the kinetic of iron nanoparticle formation from supersaturated iron vapor produced by pulse laser photolysis of $\text{Fe}(\text{CO})_5$.

This work is supported by RFBR and DFG.

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EXPERIMENTAL INVESTIGATION OF MELTING IN GENERATION IV NUCLEAR MATERIAL SYSTEMS VIA SUBSECONd LASER METHODS

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A profound understanding of the behaviour of nuclear materials in extreme conditions is of prime importance for the analysis of the operation limits of nuclear fuels, and the prediction of possible nuclear reactor accidents, relevant to the general objectives of nuclear safety. In the context of the material research aimed at supporting the development of nuclear plants of the fourth Generation, renewed interest has recently risen not only in oxide fuel systems, but also in nitrides and carbides. These latter are foreseen for application in advanced nuclear reactors as fuel and inert matrices containing Pu and minor actinides. The experimental investigation of the melting behaviour of Generation IV nuclear material systems presents peculiar difficulties depending on the particular system under analysis. In this scenario, new challenges rise for the measurement of material properties in systems which often show high volatility and poor chemical stability especially at high temperature. In this work, a roadmap is presented for the study of melting transitions in Generation IV high melting nuclear materials via subsecond laser methods. At temperatures higher than 2500 K, equilibrium conditions are difficult to obtain or instable. It is therefore necessary to create optimised conditions (e.g. experimental measurements in the millisecond range, containerless conditions, high-pressure buffer gas, . . .) requiring high technology applications (laser heating under buffer gas at high- or medium-pressure, high-speed multi-channel pyrometers, precision thermograms, probe laser detection of sample reflectivity). Melting experiments on one- and two-component systems are presented. Further measurements are introduced, particularly focused on oxide, nitride and carbide systems candidate for Generation IV fast reactor fuels (GFR, LFR, SFR).

FEMTOSECOND ABLATION (FSA): CALCULATED AND MEASURED ABLATION THRESHOLDS AGREE FOR THE FIRST TIME

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There is growing interest to the physics of FSA — the subject which is in the crossover of the two Virtual Journals (VJ) “Nanoscale Science and Technology” and “Ultrafast Science” among the five VJ published online by the AIP/APS. The Report presents the theory with its application to the new experiments done by pump-probe technique with chromium-forsterite laser $\lambda = 1240$ nm at first and second harmonics with pulse duration 100 fs, time delays 0.1 ps – 4 ns, fluence 0.1–10 J/cm², and spot diameter 40–70 μ m. Calculations include: (i) the two-temperature model (Anisimov et al., 1974) with hydrodynamics based on EOS of Al (Bushman, Lomonosov, Fortov, Khishchenko) with the thermal conductivity and the electron-ion energy exchange coefficients taken from literature; (ii) the molecular dynamics (MD) simulation with Lennard-Jones (LJ) pair potential and many-body potential (EAM) for Aluminum (Mishin et al., 1998). High-performance auto-balancing parallel MD code allows to perform simulations with a large number of atoms ($\sim 100 \cdot 10^6$ for LJ and EAM) which is necessary to study the influence of transverse dimensions on foam formation. Near ablation threshold the strong metallic foam plays an exclusive role in nanospallation where the thickness of spallated layer is $\sim \delta_{skin} \sim 10$ nm (it is *transparent* for the probe light). Frenel-Drude based calculation and direct calorimeter measurements are used to define the absorbed part F_{abs} of incident fluence F_{inc} . It should be emphasized that the absorption coefficient is rather small therefore these measurements are very important for calculation of ablation threshold for F_{inc} . There are the short first (up to several ps) and the long second (after 50 ps) stages of ablation. At the stage I the small (at $F_{inc} \simeq 1$ J/cm²) amount of hot matter is ablated. This amount disperses with high velocities uncovering (stage II) the slow

moving dense material.

We calculate and measure the ablation thresholds for Al. For the first time, the calculated threshold for *incident* fluence agrees well with experimental one. Supported by RFBR 07-02-00764.

METASTABLE STATES OF METALS AFTER ULTRASHORT LASER IRRADIATION

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A numerical hydrodynamic study of femtosecond laser irradiation of metal targets (Al, Au, Cu) is presented. Parameters of laser pulses are chosen as follows, wave length is $\lambda = 800$ nm, full width at half maximum is $\tau = 100$ fs, maximal intensity is $I = (1 \div 50) \cdot 10^{12}$ W/cm². A detailed analysis of laser induced phase transitions, melting wave propagation and material decomposition is performed using a thermodynamically complete two-temperature equation of state with separate stable and metastable phase states and phase boundaries. Material evaporation from the target surface and fast melting wave propagation into the bulk are observed. Investigation of the phase trajectories of different target layers shows the presence of the metastable states in rarefaction wave. The lifetime of the metastable liquid state is estimated by means of the theory of homogeneous nucleation. Mechanical fragmentation of the target material at high strain rates is controlled with the help of Grady criterion. As a result, several ablation mechanisms are observed. A major fraction of the ablated material, however, is found to originate from the metastable liquid phase region, which is decomposed either *thermally* in the vicinity of the critical point into a liquid–gas mixture, or *mechanically* at high strain rate and negative pressure into liquid droplets and chunks. The calculation results explain available experimental findings.

PRESSURE DYNAMICS OF EXPLOSIVE BOILING IN TRANSPARENT LIQUIDS ON ABSORBING TARGETS EXPOSED TO PAIRS OF SHORT LASER PULSES

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Besides the various practical issues of the laser-induced superheating of liquids in contact with solid surface followed by explosive phase transitions, these phenomena are also of significant fundamental interest in view of peculiarities of non-equilibrium phase transitions. We investigated such processes using acoustic registration of pressure pulses induced by pairs of laser pulses following each other with nanosecond delays. The research aimed to trace dynamic properties of vapor cavity using the second laser pulse as a probe.

The absorbing target was covered by acoustically thick layer of transparent liquid (water, acetone, alcohol) and exposed to short nanosecond pulses (2 ns) on YAG:Nd laser. The induced pressure pulses in the target were recorded by fast acoustic transducer based on lithium niobate crystal. Typical bipolar photoacoustic pressure signals were observed with no liquid layer on the target, while monopolar ones were recorded under such layer, which followed the time profile of the exposing laser pulse at low energy level. Increasing of laser energy modified the rear front of the pressure pulse due to explosive boiling. Additional pressure pulse appeared here in this case duration of which depended on energy level. If the delay between the boiling and probing pulses was fixed, the probing pulse appeared at the same spot either within or after boiling. The shape of pressure signal induced by the probing exposure was of particular interest. It was found that its shape was nearly not affected by explosive boiling and the vapor cavity appearing at the surface in spite of presumably significant variation of density of adjacent layer.

This paradox result is discussed in terms heat and mass transfer across the liquid layer taking into account non-equilibrium kinetics of phase transitions.

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ENERGY TRANSFER IN DENSE, STRONGLY COUPLED TWO-TEMPERATURE PLASMAS

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Intense lasers or ion beams creates dense plasmas in extreme nonequilibrium states. After an ultrafast relaxation that establishes Fermi/Boltzmann distributions for both electrons and ions, the system can be regarded as a two-temperature system. The subsequent temperature equilibration evolves for solid density systems on a time scale from a few to hundreds of picoseconds. Throughout the equilibration it influences most thermodynamic and transport properties of the system.

The main process during the temperature relaxation stage is the transfer of kinetic energy between electron and ions. Several approaches describing this process, including binary collisions and collective electron-ion modes, will be briefly discussed. However, this is not the only energy transfer process in strongly coupled plasmas: changes in the correlation energy and the ionization/excitation levels can also represent large sources or sinks for the transferred kinetic energy. It is shown that small changes in strong ion correlations can be responsible for long gaps in the ion heating. On the other hand, recombination after the creation of the plasma can drive considerable electron heating even for systems with hot electrons and cold ions.

Although partially based on the picture of relaxation stages, the examples reveal that the different equilibration processes strongly interdepend even if their characteristic time scales are much different. They also demonstrate that dense, relaxing electron-ion systems can be a valuable tool to obtain information about the (quasi) equation of state in the warm dense matter region.

Shock waves

INVESTIGATION OF NEAR CRITICAL STATES OF LIQUID–VAPOR PHASE TRANSITION OF MAGNESIUM FROM RESULTS OF SHOCK-WAVE EXPERIMENTS

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Investigation of near-critical states of liquids-vapor phase transition of magnesium has been carried out. For generation of the near-critical states of liquids-vapor phase transition of magnesium, the fast heating of metal free surface by shock-compressed helium has been employed [1]. The experimental assembly for generation of near critical states of magnesium was analogous to that, used in method of isentropic expansion [1]. Shock compressed samples were expanded in helium with various initial pressure (0.1–40 bar), producing shock wave. The shock wave velocity in helium was measured by the optical base length technique. Particle velocity and pressure of expansion were calculated from the equation of state of helium (chemical plasma model). The temperature of the sample surface was measured by multichannel optical pyrometer. Two series of measurements have been carried out. In the first series temperature “plateau” was observed on experimental temperature time profile. The value of temperature on “plateau” was treated as the binodal temperature. In the second series the thin layer of glue was placed between bottom of experimental assembly and sample. It was the source of weak waves, disturbing the free surface of metal during the expansion [1]. As a result, the heat transfer on the free surface was intensified, and the sample was overheated up to the temperature close to the spinodal temperature. At the pressure of 0.205 GPa the rise of temperature and considerable divergence of brightness temperatures at different wavelengths were observed. This effects one probably indicating that pressure is close to the critical, when more intensive mixing of liquid metal with hot helium takes place. The critical

point parameters of magnesium were estimated as $T_c = 3700 \pm 300$ K, $P_c = 0.2 \pm 0.02$ GPa.

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INVESTIGATION OF NEAR CRITICAL POINT STATES OF TANTALUM, LITHIUM AND SODIUM BY PULSE HEATING UNDER LAUNCHING

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The near critical point states of the liquid-vapor phase transition of tantalum, lithium and sodium were investigated. The heating of tantalum foil samples in 1-D geometry was carried out by multiple-shocked helium from back side of the tantalum foil and heating of lithium and sodium — by shocked helium from the front side under dynamically created isobaric conditions. The temperature of sample was measured by fast 8-channel optical pyrometer. The pressure was obtained from measured shock velocity in helium using base length technique. Generated states of metal under investigation during pulse heating near free surface were analyzed. State with highest temperature before the starting of plasma formation at pressures below pressure of critical point of liquid-gas transition is due to state on spinode line. Intersection of interpolating line of such states in pressure range below critical point with such line in pressure range above critical point allows evaluate metal critical point temperature. Three sets of experiments with various history of heating were carried out, allowed to evaluate the critical point location of the studied metals in $P - T$ plane.

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ADIABATIC EXPANSION OF SHOCK-COMPRESSED CHROMIUM AND ZINC AT HIGH TEMPERATURES AND PRESSURES

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Equation of state and phase transitions of shock-compressed and heated metals are interesting for numerical simulation of physical processes at high temperatures and pressures. In this work experimentally investigated is expansion of liquid chromium and zinc in adiabatic release waves. Liquid states with densities of $\rho \simeq 1.2\rho_0$ (where ρ_0 is normal density of a substance) and temperatures of $T \simeq 14$ kK are generated by shock compression of porous samples up to pressures of $P \simeq 110$ GPa. We have measured parameters of both metals on two release isentropes in density range down to $\rho \sim 0.01\rho_0$. The onset of evaporation is experimentally fixed in chromium as additional increase of the expansion rate within the two-phase liquid–vapor region on the phase diagram. We propose new semiempirical equations of state for metals with taking into account the melting, evaporation and ionization effects. The critical analysis of calculated results in comparison with the newly acquired and available at high pressures and temperatures experimental data for chromium and zinc is made.

THERMAL CONDUCTIVITY OF SOLIDS UNDER HIGH COMPRESSIVE AND TENSILE PRESSURE

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In some subsecond thermophysics problems the temperature dependence of thermal conductivity under high pressure is needed. So, under

high compressive pressures (up to 150 GPa) $k(P)$ is required for interpretation of “window” technique for shock temperature measurements [1]. Because the sample and the window are usually at different temperatures when shocked, heat can flow from the hot sample to the colder window, altering the temperature that the pyrometer measures. Once the thermal conductivity of the window and the sample are known, experimenters can correct their data to derive a more accurate temperature of the sample’s interior. Another example of high tensile pressure is destruction of solid under the action of ultrashort laser pulse [2]. In this report the relation for thermal conductivity versus temperature both under compressive and tensile high pressures are presented for such model material as ringwoodite.

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THERMOPHYSICAL PROPERTIES AND ELECTRICAL CONDUCTIVITY OF SCANDIUM UNDER SHOCKWAVE COMPRESSION

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Scandium has an incommensurate phase at high pressure [1,2]. The incommensurate structures of metals have been found out and being studied basically under the static isothermal compression. Studying of physical properties of these structures in shock waves till now was not undertaken. In the given work an electrical conductivity was measured and thermodynamic properties of scandium in a range of shock compression up to 90 GPa are investigated as well. The experimental data on change low-pressure phase Sc-I electrical conductivity and a high-pressure incommensurate phase Sc-II at shock compression are received. It is shown, that at shock compression the low-pressure phase of Sc-I undergoes polymorphic transition to incommensurate phase Sc-II. On the calculated Hugoniot areas of existence of various phases of scandium are revealed: Sc-I, incommensurate phase Sc-II, and also area of the subsequent phases of a high pressure. The equations of state of Sc-I and high pressure incommensurate phase scandium Sc-II have been designed.

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PHYSICAL PROPERTIES OF C_{60} UNDER HIGH MULTIPLE SHOCK COMPRESSION

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The electrophysical properties of a C_{60} fullerene sample have been investigated [1,2] under high multiple shock pressure conditions using a shock wave reverberation technique. The numerical calculation of the shock wave interaction and the release wave in the measuring cell was carried out to obtain details of the pressure-temperature dependence of the conductivity of fullerite C_{60} under step shock loading. The one dimensional flat flow was simulated. The Mie-Gruneisen equation of state in the form [3] was used for C_{60} fullerite. The temperature of shock compressed fullerite was calculated with the use of the temperature dependence of heat capacity. Electrical resistance, shock pressure measurements and calculated pressure-volume-temperature states show evidence of C_{60} specific electroconductivity maximum at pressure 19.8 GPa and temperature 520 K. The X-ray diffraction studies of shock recovered samples have revealed the mixture of fcc C_{60} and x-ray amorphous component of fullerite C_{60} , which evidently leads to the formation of an insulating. At pressure exceeding $P = 19.8$ GPa and temperature exceeding $T = 520$ K the shock compressed fullerite presents itself the two-phase mixture of fcc C_{60} fullerite and x-ray amorphous component presumably consisting of the nucleators of polymer 3DC₆₀ fullerite. The electroconductivity reduction of fullerite can be explained by the percolation effect caused by the change of pressure, size and number of polymeric phase nucleuses.

This work is carried out under financial support of the program of the Presidium Russian Academy of Sciences "Investigations of matter in extreme conditions" and Russian foundation for basic research, the grant No. 06-02-16522A.

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NONEQUILIBRIUM RADIATION AND IONIZATION OF IRON CLUSTERS IN SHOCK WAVE FRONT

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The opportunity of nonequilibrium effects in a zone of a translational relaxation of a shock wave have been first proposed in [1]. Later, in support of this idea, the peaks of nonequilibrium radiation at a front of a shock wave in the light gases containing small admixture of chemically active heavy molecules were experimentally observed [2, 3]. On the other hand, in [4, 5] an effect of nonequilibrium radiation in a relaxation zone of the shock wave containing small admixtures of iron and carbon carbonyls ($\text{Fe}(\text{CO})_5$ and $\text{C}(\text{CO})_2$) was attributed to an electronic excitation of small clusters actively growing after fast decomposition of initial molecules and formation of iron or carbon vapor. Anyhow, both offered mechanisms allow assuming that presence of an admixture of metal clusters can cause not only nonequilibrium radiation, but also ionization of these particles in a shock wave. For experimental studying and definition of real mechanisms of observed nonequilibrium phenomena several series of experiments with the measurement of spectra of radiation and concentration of negative and positive charges in a front of a weak shock wave, propagating on various inert gases (Ar, Ne, He), containing small admixture of $\text{Fe}(\text{CO})_5$ have been carried out. The intensive peaks of radiation with the non-resolved structure of a spectrum in the range 450–650 nm have been registered, that can be regarded to radiation of overheated iron clusters. Besides that the peaks of electric current on the probes, corresponding to concentration of free electrons in the range 10^8 – 10^9 cm^{-3} have been observed. The obtained results testify to a primary role of fast exothermic reactions of recombination and growth of iron clusters in observed effects of nonequilibrium radiation and ionization in a relaxation zone of a shock wave.

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Posters

STUDY OF THERMOPHYSICAL PROPERTIES OF THE ZIRCONIUM FUEL CLADDINGS WITH THE TECHNIQUE OF THE SUBSECOND PULSE RESISTIVE HEATING

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Electrical pulse heating technique has proved its efficiency in picking up the temperature dependency of enthalpy, specific heat resistivity and emissivity of metals and alloys. At the choice of proper parameters of the electric power supply it can be applied for study of relatively massive specimens, for instance, of the reactor fuel claddings.

In the paper an experimental installation is described and results of the cycle of the studies of properties of nuclear reactor alloys and of pure zirconium are systematized.

The control of the heating rate of specimens within $10^2 \div 10^5$ K/s has allowed to get reliable data on the named characteristics both for alpha- and for beta-phases of metals, to measure the values of their heat effect for HCP-BCC solid state phase transitions and latent heat of melting.

The heating rate dependence for the temperature of HCP-BCC conversions has been revealed. It is shown that for round-robin processes of the heating-cooling it is characteristic the presence of the hysteresis of the phase transition temperature. It is also shown that the intensity of the heating in marked limit does not influence upon the solidus temperature of this alloys.

A specific procedure for the pulse oxidation of specimen was offered to make a natural ampoule on the specimen from its own oxide. The temperature range of the existence of that sort ampoule was found with the measurements of the specimen emissivity. Exactly with such an ampoule it was succeeded to hold the specimen in the molten state and to measure the latent heat of its fusion.

Specific physical effects, accompanying measurements run and influenc-

ing upon accuracy of the determination heat effect were discussed. Data obtained are matched with data, got by other methods.

ADVANCED ULTRAFAST NANOCALORIMETRY: SUPERHEATING IN LINEAR POLYMERS

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To study phase transition kinetics on submillisecond time scale a set of new membrane gauges for ultrafast scanning nanocalorimetry were constructed. Controlled ultrafast cooling, as well as heating, up to 1 million K/s was attained. The dynamic model describing the temperature distribution at ultrafast temperature change in the membrane-gas system was developed. The characteristic rate corresponding to the quasi-static limit of the temperature change in the membrane-gas system was determined. The rate equals 0.1 million K/s for different gauges in helium gas. The method was applied for the measurements of the superheating phenomenon in a set of linear polymers iPS, PBT, PET, iPP. A power law relation between the superheating and the heating rate was observed in the range 0.01–10000 K/s of heating rates. A superheating limit about 0.1 of the melting temperature was fined out at the rates above 0.01–0.1 millions K/s. This limit depends on the sample crystallization temperature. The observed superheating limit, as well as the power law, can be accounted for the internal stress induced by the superheating near the crystalline-amorphous interfaces in the semicrystalline polymers.

DENSITY AND SURFACE TENSION OF LIQUID IRON OXIDES

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The properties of the liquid iron oxides are not very well known. Large discrepancies have been reported in the past for density as well as surface tension data. There are, however, needs for such data in particular for a better assessment of the scenario of nuclear accidents (behaviour of corium melts). We present new data in the temperature range 1800–2200 K determined from contactless diagnostics performed on millimetric laser heated liquid drops that are levitating on a stream of gas of known composition. The composition of the drop was measured after the fast cooling of the liquid and its solidification by a thermogravimetric method. It consisted of measuring the change of weight after re-equilibration at 1000°C in a flowing CO₂ gas in order to obtain stoichiometric Fe₃O₄. Results are compared with previous data. They confirm in particular that the surface tension of liquid iron is to a good extent independent of its composition.

EXPERIMENTAL INVESTIGATION OF CARBON PHASE DIAGRAM IN THE VICINITY OF SOLID–VAPOR–LIQUID TRIPLE POINT

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In this paper has been defined the temperature dependence of the vapor pressure above liquid carbon within the range of 5000–6800 K by the boiling points method. An isotropic graphite sample referred to as MPG-6 was installed in a helium chamber and heated by a laser pulse. The sample temperature was measured by a brightness-temperature pyrometer with the carbon radiant emittance correction equal to 0.89. The latter was determined with the aid of a spectrophotometer by the sample reflection value after the liquid layer solidification. There had been observed

“plateaus” on the thermograms obtained related to the sample boiling. The values of temperatures on the “plateaus” were approximated by a function $\ln p = (8.66 \pm 0.38) - (3.07 \pm 0.22) \cdot (10^4/T)$ within the range of pressures 15–70 MPa. The extrapolation of this expression for the graphite melting temperature (4800 K according to [1]) gave the value of pressure 9.6 MPa.

There had been also investigated the HOPG graphite heating zone morphology. Here again the graphite was heated up in the helium atmosphere at 8–15 MPa. The absence of liquid carbon in a form of solidified drops has been detected at a pressure lower than 10.7 MPa. The latter was adopted as the graphite triple point pressure.

Thus, the graphite melting temperature obtained before in [1], triple point pressure and the boiling curve both found in this paper were obtained in one and the same experimental unit and form a correlated data array which is compared with the results given in the references.

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NEAR-CRITICAL STATES AND PHASE TRANSITIONS INDUCED BY HIGH POWER LASER IRRADIATION OF CONFINED METAL SURFACE

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The results of the study of near-critical states and phase transitions (lead melting and mercury boiling) induced by high power laser irradiation of metal surface confined by a transparent dielectric are presented here. Since the laser pulse energy is absorbed in confined volume it is possible to obtain high pressure (up to 10–50 kbar) and high temperature (up to 10–50 kK) states in skin depth of metal [1, 2]. The thermodynamic state change dynamics is analyzed by measurements of pressure pulse that propagates from the heated surface, reflectivity and heat radiation of target surface.

The pressure pulse and heat radiation measurements made it possible to register sub-critical states of lead melting at pressure up to $P_{max} \sim 1$ kbar and over-critical states of mercury ($P_{max} \sim 7$ kbar). It was showed that before the phase transition the pressure pulse amplitude is proportional to the intensity of laser irradiation, and after the melting threshold it is defined by the absorbed laser pulse energy value. The momentum of transformation of pressure pulse corresponds to the beginning of melting of lead and the boiling of mercury. During the laser heating in the thin subsurface layer the temperature rises (up to over-critical values for mercury) and the metal density falls considerably. These factors lead to a great decrease (5–6 times) of reflectivity and electro conductivity of metal.

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NUMERICAL ANALYSIS OF SPINODAL DECAY BEGINNING IN SUPERHEATED LIQUID

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Explosive boiling of superheated liquid can be initiated either by nucleation processes or spinodal decomposition if the liquid is in unstable state. We investigated the latter case with the help of 1d hydrodynamic code and continuous equation of state for liquid with a free surface absorbing nanosecond radiation pulses which brought it to unstable state. Absorption length and pulse duration varied from 1 to 100 microns and from 20 to 200 ns. Our calculations showed that spinodal decay began with appreciable (of nanosecond order) delay after spinodal line was crossed. The delay dependence on radiation intensity, absorption length and code parameters were investigated.

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PRESSURE PULSES GENERATED IN WATER BY 3 MICRON LASER RADIATION

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Exposure of absorbing media to laser pulsed radiation gives rise to pressure generation induced by variety of physical processes: heat expansion, vaporization and others, manifesting themselves either during such exposure or after it.

In our experiments, we registered pressure pulses in water irradiated by sub-millisecond pulses of Er-laser. Two kinds of pressure transducers were used based on PVDF films and lithium niobate crystal located at a depth of 5–40 mm under the irradiated surface. The laser delivered up to 50 mJ pulses into a spot of 0.5–1.0 mm in diameter.

The observed pressure pulses followed, at sufficiently low intensity, the microsecond pulse structure of laser radiation. Increasing of laser energy resulted in an abrupt growth of the pressure signal delayed by tens of microseconds with respect to the radiation pulses, which can be attributed to explosive boiling processes. A much more intense (three orders of magnitude) and short (~ 5 microsecond) pulse of pressure was observed in this case with the delay in the range 0.2–0.6 ms, which increased at growth of the incident laser energy. The observed peak was attributed to collapse of arising cavitations bubbles. Experiment with additional optical diagnostics and shorter pulses of laser radiation are in progress.

The research was partially supported by RFBR grant 06-08-01440.

**FRONT AND BACK SIDE NANOSPALLATIONS OF FOIL
AFTER ULTRASHORT LASER PULSE (USLP)
AND PROPOSAL FOR PRECISE ULTRAFAST OPTICAL
DIAGNOSTICS OF THE BACK SPALLATION**

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Thermomechanical “loading” of metal or semiconductor targets by USLP is a reason of nanospallation. Appearance of the Newton rings (NR) and formation of the “hole” within the monotonic sequence of the microinterferometric fringes (MIF) are caused by existence of the nanospallation dome in the laser plume. The pump-probe method used to obtain the NR and MIF provides the high accuracy of EOS and spallation related measurements. Analysis of MIF gives velocity of the spallation dome $v_{front-spall}(t)$ which is a source of information about the strength of materials at nanoscales. So we may say that the MIF is a kind of the “VISAR for nanoscales”.

The USLP results in a compression wave (CW) propagating into the bulk. If the target has a finite thickness (a foil) then the CW reflects from the back boundary of the foil. At a sufficient amplitude it causes the back spallation. Therefore the USLP may result in double (forward and back) spallations. We propose to use the MIF at the *back* side to measure velocity $v_{back-spall}(t)$ for the back spallation (usually the MIF is used at the front side). Observations of the NR from the back side is possible for ultrathin foils where the thickness of back spallation dome is comparable with a skin-depth. The Report presents results of calculation (including absorption, two-temperature model, EOS, MD simulation) for foils. The MD (molecular dynamics) for aluminum (Al) with EAM potential (Mishin et al. 1998) traces the kinetics of decay of strongly stretched metastable states of Al. By comparison with known EOS we have checked accuracy of the EAM potential for high temperatures obtained by USLP near ablation/spallation threshold (AST). We have compared: (i) pressure and heat capacity at the isochor of an initial density (2.7 g/cc); (ii) the binodal shape up to the critical point; (iii) the release adiabats together with negative pressure region up to the spinodal; and (iv) the Hugoniot adiabat up to the melting curve. The calculated front AST coincides with the ex-

perimental one (see another our Report in the conference). The calculated back AST approximately twice exceeds the frontal one for foil thickness near 1 μm (at present there are no experimental check for this prediction) and the back spallation dome is more than four times thicker. The work is supported by RFBR grant No. 07-02-00764.

DYNAMICS OF METAL CLUSTER IONIZATION PRODUCED BY INTENSE FEMTOSECOND LASER FIELD

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It is well known that cluster nanoplasma is a perspective source of short pulse X-rays and fast ions. Important parameter which controls their characteristics is atoms ionicity. As it was revealed in [1] even at sub-relativistic intensities of femtosecond laser fields acting on large metal clusters which radius exceeds skin depth ionicity at the initial stage of inverse bremsstrahlung heating in the domain of non-ideal warm dense plasmas can reach significant value. So, appropriate description of thermal impact ionization is needed in the case of strongly coupled plasmas as in the case of weakly non-ideal plasmas. Use of hybrid ion-sphere — Debye-Hückel potential [2] permits us to investigate influence of screening effects on ionization dynamics in dense cluster plasmas in wide range of electrons temperatures from about Fermi energy to a few keV.

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PLASMA DIAGNOSTICS BY X-RAY THOMSON SCATTERING

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X-Ray Thomson scattering is one of the few potential diagnostics methods applicable for dense plasmas. In the visible spectrum, it has already

proven its ability to yield detailed information on both the ion and the electron properties. Recent experiments with X-rays have also demonstrated its capability to measure the electron densities and collision rate in solid-density plasmas. Although the ion structure results in a well-pronounced peak for low frequency shifts, this information cannot be used to infer the ion properties yet. The missing link is a reliable theoretical description of the ion structure and the nonlinear response of the electrons to the ions.

We calculate the ion properties as well as the electron response from multi-component hypernetted chain (HNC) equations which intrinsically incorporate all nonlinearities in the system. The outcome are the ion-ion structure factor and the corresponding electron densities. A first version, that models a two-component electron-ion system, is used to determine the difference to the usually used linear electron response in the high-density region. We use different kinds of pseudo-potentials that model quantum diffraction and degeneracy effects. Calculations using these potentials are tested against density functional molecular dynamics simulations and a quantum statistical weak coupling theory. Furthermore, we demonstrate how the consideration of multiple ion species with different charge states, modifies the ion structure compared to calculations with only one ion species that carries an average (often non-integer) charge state. Finally, the calculated data are used to generate artificial Thomson scattering spectra. Since the HNC calculations can also model systems with different ion and electron temperatures, these spectra can also be used to study the relaxation behaviour in strongly coupled plasmas.

MULTI-SPECTRAL THERMOMETRY BASED ON GA-BP ALGORITHM

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Considering some defects of back-propagation neural network (BP) such as likely to fall into local minima, a new algorithm combining genetic algorithm (GA) with BP neural network was described. The application of GA-BP to the data processing of multi-spectral thermometry was proposed. Simulation experiments were made based on GA-BP algorithm and BP neural network, respectively. Results show that the recognition precision of trained emissivity samples is 5 K and 10 K respectively, and that of untrained emissivity samples is 10 K and 20 K, respectively. Either

GA-BP algorithm or BP neural network is used, in general, recognition precision of trained emissivity samples is higher than that of untrained emissivity samples. The recognition precision of true temperature is lower near the edge of sample sets. The GA-BP algorithm was more efficient than the BP neural network in the true temperature measurement.

EXPERIMENTAL STUDY OF HEAT RELEASE OF CARBON NANOPARTICLES FORMATION FROM C_3O_2 BEHIND SHOCK WAVES

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The investigation of condensed particles formation in shock wave pyrolysis processes continuously attracts the close attention. In this work the first direct observations of the heat release of carbon particle formation during shock wave pyrolysis processes are presented. For this goal optical density and time-resolved temperature profiles of process of carbon nanoparticle formation during gas phase pyrolysis of C_3O_2 behind shock waves in the temperature range $1500\text{ K} < T < 2200\text{ K}$ have been measured. Temperature measurements were performed in the mixtures $3\%C_3O_2 + 5\%CO_2 + Ar$ by means of emission-absorption spectroscopy in the vibrational band of CO_2 (1, 0, 1) at $\lambda = 2.7\text{ }\mu\text{m}$. From the observed temperature rise after the onset of particle formation the heat release was determined, which was shown to increase with increasing of initial temperature behind reflected shock wave. The enthalpy of carbon particle formation was estimated to be about 1.0-1.6 kJ/mol in temperature range 1800–2200 K. It was found, that at the pressures about 3 bar a growth rate of particles formation was limited by the rate of decomposition of C_3O_2 molecules.

The results of this work demand to reconsider the accepted concepts of temperature dependency of particle formation during pyrolysis behind shock waves.

This work is supported by RFBR and DFG.

NONEQUILIBRIUM RADIATION AND CONDUCTIVITY IN THE WEAK SHOCK WAVES IN He AND Ar FEEBLY DILUTED BY Mo(CO)₆

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Multichannel emission spectroscopy and the high sensitivity electrostatic probe in the flow core were applied to investigate nonequilibrium radiation peaks in UV and visible range in a front of the weak shock waves (SW) [1]. High vacuum shock tube was used to generate the incident shock waves in He and Ar diluted by Mo(CO)₆, Mach numbers $M = (2.5 \div 3.6)$, equilibrium temperature and pressure behind the SW — $T_2 = (853 \div 1497)$ K, $P_2 = (0.109 \div 1.124)$ bar, Mo(CO)₆ concentration was varied in the range $20 \div 200$ ppm in He and 120 ppm in Ar. He and Ar of high purity was used only. The essential peculiarity of this work was to disregard collisions Mo(CO)₆ + Mo(CO)₆, because of four orders factor of difference of concentrations Mo(CO)₆ and noble gas.

Special construction electrostatic probe of small drag and space resolution (0.2 mm) was set in a flow core. Emission of the front was measured in two separated channels from one side 313.3 ± 6 nm, 520 ± 0.5 nm. Emission spectrum was measured by spectrograph with CCD-camera in the range $250 \div 750$ nm. To measure absolute values of emission calibrated tungsten light source was applied. The narrow conductivity zone was revealed in the front of the weak SW. Estimated concentration of charged particles was more than 10^5 cm⁻³. It was established the UV-emission profiles shape and conductivity ones were very close or similar up to maximum of the signals reaching. Time profiles of the probe current and radiation was measured on dependence of Mo(CO)₆ concentration, pressure behind shock wave, Mach number and a type of the noble gas. It was found out weak signals of a probe current and emission arrived some earlier the gradient of density arrival to the measuring plate. It was established the probe current maximum was increasing as a square of Mo(CO)₆ concentration and decreasing when general pressure in shock wave was increasing. The dependences were obtained. All probe current data were summarized as dependence of the probe current normalized on reversal translation energy of molybdenum hexacarbonyl molecule relatively shock wave front. The efficient ionization potential was revealed to be 2.7 ± 0.2 eV.

Mechanism of the ionization and the charges separation in SW front is under discussion. The work was supported by RAS and RFBR.

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SHOCK-INDUCED PHASE TRANSFORMATIONS OF FULLERITE C₇₀

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Shock-induced phase transitions of C₇₀ fullerite were studied with use of recovery assemblies of planar geometry. Two types of starting material were investigated: polyphase material consisting of a phases with hexagonal close-packed (hcp) and with rhombohedral structures and monophasic C₇₀ fullerite with hcp-structure. In the specimens, maximal shock pressures were reached after several reverberations of the waves between the steel walls of the recovery ampoule and were 8, 9, 14, 19, 23.5, 26, 36 and 52 GPa. With the purpose of examination of influence of a temperature schedule of shock compression on characteristics of phase transitions, experiments with thin (20 microns) specimens in massive copper plates were executed for low (up to 19 GPa) pressures. Microstructure of the material, recovered after shock-wave loading, was examined by means of X-ray diffractometry.

We have found that the results of a shock-wave compression of fullerite C₇₀ with a various initial phase composition qualitatively coincide in all explored pressure range. Rhombohedral modification of fullerite C₇₀ completely collapses already at pressure 9 GPa. At the same time, crystalline modification of fullerite C₇₀ with hcp-structure in conditions of step-like shock-wave compression does not undergo phase changes down to pressure 9 GPa and practically completely disappears from the recovered material only at pressure 23.5 GPa. Shock-induced transformation of hcp into fcc structure was fixed at pressures in the range 9 to 23.5 GPa. Depth of this transformation is increasing with growth of shock pressure. In the specimens recovered from 23.5 GPa, the only crystalline phase of fullerite C₇₀ with fcc structure is observed (about 5 %) and for the first time formation of a graphite-like carbon is fixed (about 95 %). Influence of a temperature schedule of a shock compression on phase changes in conditions of our experiments is not so great — as a rule a discrepancy of phase compositions of “thin” and “massive” recovered specimens of C₇₀ did not exceed 3 %. With growth of shock pressure up to 26 GPa and higher (up to 52 GPa),

destruction of C_{70} molecules occurs. This destruction is accompanying with a formation of graphite-like carbon.

The work was supported by RFBR.

CONDUCTIVITY OF C_{70} FULLERENE UNDER MULTI-STEP DYNAMIC COMPRESSION

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Electroconductivity is the one of the few physical properties of the substance that is accessible to direct measurements behind the front of a powerful shock wave in the area of high dynamic pressure. The achievable time resolution of such experiments at the moment allows us to make important conclusions not only about the nature of transformations of compressed substances, but also about their kinetic characteristics.

The scope of the present work is the ongoing study of the influence of carbon polymorphic modifications on electroconductivity variations under shock wave compression [1].

The behaviour of the fullerite C_{70} electric resistance under step shock wave loading up to 20 GPa was investigated. Maximum of fullerite C_{70} conductivity was observed as well as at fullerite C_{60} . That confirms the rule of strong reversible conductivity change that was discovered earlier for the case of compression of fullerite C_{60} [1,2] up to 20 GPa. At the same time the maximum value of electric conductivity for fullerite C_{70} is observed at the lesser pressures than for C_{60} . Besides, the differences between electric response of the fullerite C_{60} and the fullerite C_{70} appear in release wave.

The work is executed at financial support of the Russian Foundation for Basic Research, grant No.06-02-16552A and the program of the Presidium of Russian Academy of Sciences "Investigations of matter under extreme conditions".

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STUDY OF SHOCK COMPRESSED SiO_2 AEROGEL BY SYNCHROTRON RADIATION

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Porous materials have been found wide application in the constructions, which were working under high energy and power loading. Promising porous material is quartz SiO_2 -aerogel. In this work the possibilities of synchrotron radiation (SI) were used for investigating the behavior of aerogel under the shock-wave loading. Also its structural and quasi-static mechanical properties were determined.

The SI-application for detonation and shock-wave processes investigations were described in [1–3]. Shock wave in the studied sample was generated by the impact of the flat plate, accelerated by the products of explosive detonation through air gap. Especial compact explosive generator was developed for impactor accelerating. The diameter of cylindrical impactor was carried from 15 to 20 mm. The impactor velocities lay in the interval of 300–2200 m/s in the dependence on thickness and impactor material. The SI beam was used for measuring the current parameters of shock-compressed aerogel.

In the same experiment we measured the shock wave velocity in the target (D), the mass velocity (U), which was equal to the current flight velocity of im-pactor and the initial impactor velocity (W). Besides we directly measured width of shock wave front and compressed aerogel density. Initial aerogel densities were 0.25 g/cm³ and 0.15 g/cm³.

Obtained data made it possible to reliably build points on Hugoniot curve of aerogel target. Later these dates will be used for constructing the SiO_2 -aerogel equation of state.

Work had been done due to partial support of RAS presidium program.

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THE METALLIZATION OF ALKALI-HALIDE CRYSTALS UNDER THE HIGH PRESSURE

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Transition “dielectric–metal” takes place basically as a result of an amplifying interaction between atomic and valency orbits under action of a high pressure in crystals, which spreads power zones and finally, extremely narrows a power crack between a valency zone and a zone of conductivity. The electron-statistical model in a formalism of functional method of density is used in given work for calculation of pressure of all-round compression, at which there should be a “metallization” of dielectric. At the description of thermodynamics of an ionic crystal’s phase we shall start with model of the ideal crystal lattice having structure of type NaCl (B1-Structure), consisting of dot charges of a different sign. We shall consider the temperature equal to absolute zero.

The thermodynamic potential of an ionic lattice, constructed in view of interaction of ions of seven coordination spheres has the form

$$G_{B1}(R) = \sum_{k=1}^7 N_k U_k(a_k R) - \frac{\alpha_\mu}{R} - V \frac{\partial}{\partial V} \left[\sum_{k=1}^7 N_k U_k(a_k R) \right],$$

where $\alpha_\mu = 1,747558$ — constant Madelung B1-structures; $U_{B1}(R)$ — potential of two-factor interaction ions, a_k — the relation of radius k and the first coordination spheres, N_k — number of the nearest neighbors in k coordination sphere. We shall take the Gombash approximation as model of the metallized phase ionic crystal well describing alkaline and alkaline-ground metals. In this approximation the energy of the lattice carried to pair of particles, is equal. Thermodynamic potential of the metallized phase counting upon pair atoms enters the name in the form of

$G_m = a + E_m + pV_m$, where a — potential electronic affinities to chlorine. The pressure of “metallization” is defined, proceeding from equality of thermodynamic potentials of phases in a point phase transformation. It is shown, that the order of the pressure created in dielectric, in particular, in alkali-halogen crystals, at optical breakdown under influence of a powerful laser impulse, coincides under the order of size with pressure of all-round compression at which there is “metallization” of substances.

HEAT TRANSFER PROCESS IN ALUMINIUM–SILICON ALLOYS

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Producing materials with limited structure is not always possibly by improving the tradiational technologies. It is necessary to arrange a search for fundamentally new engineering decisions. As applied to cast alloys, first there is a need to provide a control of a heat transfer rate during crystallization of a cast, followed by its further cooling. This is a determining factor of forming a structure and, as a result, of mechanical properies. Control of the crystallization process is problematic, especially for the system of aluminium and silicon which are the most complex cast objects. Developing non-traditional procedures of casting requires a theoretical base. A solution of the nonlinear heat conduction equation [1] is derived, which is responsible for temperature distributions in the solid and liquid phase of alloy. The thermo-physical properties ρ , c_v , λ , a of an alloy are the temperature functions. Changes in the fraction of the solid phase with a growth of temperature are taken into account in this case. Boundary-value conditions are written for a semi-infinite body. To solve the nonlinear heat conduction equation for the liquid phase, use is made of the substitution $\xi = x/v^{-1} - t$, where x is the coordinate, v is the velocity, t is the time. To solve the heat conduction equation for the solid phase, use is made of the substitution $\xi = x/\sqrt{t}$ [2]. Obtaining the numerical results by the solutions derived is associated with a necessity to perform the integration operation that can be realized numerically.

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A NEW METHOD AND STANDARD FOR REPRODUCTION OF THE UNIT OF THERMAL CONDUCTIVITY

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In accordance with the general usage the unit of thermal conductivity is reproduced at individual points by means of a set of single-value measures made of standard reference materials (SRM). In the range from 0.02 to 0.2 W/(m·K) thermal insulating materials have a heterogeneous structure, in which, alongside with the conductive heat transfer mechanism, there are convective and radiation ones. It constrains the application of the Fourier law and prejudices even a possibility to use thermal insulating materials as standard measure of thermal conductivity.

The VNIIM standard, for the first time in the world, makes use of multi-value measures of thermal conductivity made of homogeneous materials. Those measures are devoid of the above drawback and present a new class of measuring instruments designed for reproduction of the unit at any point of the range from 0.02 to 0.2 W/(m·K). Their operating principle consists in the fact that a certain system of bodies, under certain conditions, by means of control action, acquires any target thermal conductivity in a certain range of values fully according to the obtained analytic dependence based on the Fourier law. Thus, the continuous scale of thermal conductivity in the range 0.02–0.2 W/(m·K) is established. It is suggested that any measuring instrument of the new class should be called “teplostat”. The new measuring method is patented.

The new set of equipment for the State primary standard of thermal conductivity of solids is designed. For the first time in the world practice, it makes it possible to reproduce the unit at any point of the range from 0.02 to 0.2 W/(m·K) according to the established analytic dependence. It realized the symmetrical stationary method for thermal conductivity measurement of guarded hot plate apparatus. The total standard measurement uncertainty is 0.3 percent.

PHASE TRANSITIONS ON A PICOSECOND TIME SCALE

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When solids and liquids are exposed to powerful laser radiation, a phase transition is preceded by a substance stay in the metastable (superheated) state. The higher the density of the energy flow into the substance and the shorter the characteristic time of heat introduction, the greater the depth of entry into the metastable region. In this case conditions that are to realizable can be simulated in a computer experiment.

We have used the method of molecular dynamics to investigate limiting superheats of the Lennard-Jones liquid and crystal at nucleation rates up to $(10^{25}\text{--}10^{27})\text{ s}^{-1}\text{ cm}^{-3}$. Thermodynamic properties (p, ρ, T — data, internal energy, isochoric heat capacity) have been calculated in stable and metastable states.

Thermal and caloric equations have been built up for the liquid and the crystal phase. The spinodals have been determined from the condition $(\partial p/\partial v)_T = 0$. The behavior of the spinodals of a superheated crystal at $T \rightarrow 0$ is discussed.

The melting line in the stable ($p > 0$) and in the metastable ($p < 0$) region has been determined from data on the thermal and the caloric equations of state for the liquid and the crystal phase. It has been found that at negative pressures a metastable extension of the melting line ends on the spinodal of a superheated (stretched) liquid. The properties of the point of meeting of the spinodal and the melting line are examined. In particular, it is shown that at this point the derivatives dp/dv and dT/dv along the melting line to zero.

The kinetics of liquid-crystal and crystal-liquid phase transitions has been investigated at positive and negative pressures. Nuclei of the crystal phase in a supercooled liquid have been localized, and their structure and topology have been studie.

This work has been supported by the Program of Basic Research of the Russian Academy of Sciences.

PREMELTING OF SOLID Fe AT THE CONTACT WITH AMORPHOUS Ar AT HIGH PRESSURE

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Experimental determination of the iron melting curve at high pressure is a long standing topic of interest. There is a considerable scatter in the experimental results obtained using diamond anvil cell (DAC) and shock-wave techniques. In order to elucidate the reasons of such an inconsistency the relevant experimental details are to be considered with special care. In this work we use molecular dynamics (MD) simulation to study the influence of the pressure medium on the surface melting of solid iron. The model under consideration is a two component system of solid Fe and amorphous Ar with a planar interface. MD simulations show that surface melting of solid Fe in contact with amorphous Ar begins at temperatures much lower than the melting temperature of the pure system. The dependence of the disordered layer thickness on temperature is obtained. A possible impact of these results on the interpretation of the DAC experiments is considered.

ELECTROSTRICION WAVES AND INSTABILITIES OF DIELECTRIC LIQUIDS IN NON-UNIFORM ELECTRIC FIELD

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Theoretical investigation of flows of dielectric liquids under action of electrostatic forces in non-uniform electric field were carried out for coaxial cylindrical and concentric spherical electrode geometries. Electric forces pull the liquid towards the inner electrode where the magnitude of electric field is higher. The flow velocity increases with time and decreases with radius. Theoretical predictions agree well with results of simulations.

Near the inner electrode, a compression wave is formed which develops to a shock wave propagating from the surface of the electrode. The density of liquid ahead of the shock wave decreases with time, and for sufficiently

strong electric field the state of a fluid moves through metastable states to an unstable state. Hence, an anisotropic decay of the liquid into a two-phase system of vapor filaments in a liquid [1] becomes possible in that region. Characteristic time of the density decrease to the minimal value for the point radius of 10 micrometers is of order of 10 nanoseconds. Such flows with shock waves and instabilities were obtained in simulations.

When the electrode surface is rough, electric field is enhanced ahead of protrusions. The electrostriction forces pull the liquid towards protrusions, and the rarefaction waves arise. If two protrusions are located sufficiently close, the interaction of rarefaction waves produces a region with low density. Interestingly, the ratio of the electric field strength to the density of a liquid E/ρ which determines the probability of electric breakdown according to the Pashen's law, takes the maximal value in this low-density region. In our simulations, the value of E/ρ increases by more than an order of magnitude. Such effect could be a new mechanism of the inception of electric breakdown of dielectric liquids.

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THERMAL LOCALLY-NONEQUILIBRIUM PROPERTIES OF AN UNDERCOOLED MELT

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Thermophysical interpretation of experimental dependences “melt undercooling–crystal growth velocity” for Ni, Cu and Ge is presented. The algorithm is based on the model of locally-nonequilibrium heat transfer at high-rate crystallization. Calculations were carried out at subcritical and supercritical undercoolings. The choice of thermodynamically admissible velocity of crystal growth is based on the account of alternating nonlinearity of the state function. The relaxation time of the heat flux on a phase boundary proved out to be an effective parameter of correlation between theory and experiments. The approach proposed is valid for not too small undercoolings. Thermophysical properties of Ni, Cu and Ge are represented by semi-empirical functions. A maximum of the entropy production as a function of a heat flux jump is present in all studied points. A dependence of the kinetic growth coefficient on melt undercooling is found.

STRENGTH AND FRACTURE OF THIN METAL PLATES UNDER CONDITIONS OF FAST HEATING BY X-RAY RADIATION

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A large number of publications were dedicated to investigation of the fracture of metals and alloys under the conditions of fast heating by penetrating radiation. In the main the fracture of thin metal plates was investigated under their irradiation by an electron beam or X-ray pulse. Results of such investigations for a lot of various metals and alloys presented in this work were shortly stated in [1–4] and several others works. In this work the uniform calculating processing was carried out for a large number of results on the fracture of samples in the form of plates made of various metals and alloys, from aluminum to tungsten, in the conditions of fast heating by X-ray radiation. The thicknesses of the plates were changed in the range from 0.05 to 2 mm. The intensity of heating and degree of its spatial nonuniformity were appreciably different for various test conditions, down to the melting and evaporation of the surface layers of the samples. Results of numerical calculation fulfilled for the determination of the thermomechanical loading conditions of the plates were compared with such results obtained with the use of simple analytic methods. Comparison of the results obtained in the work with the results obtained by other researchers in such conditions of fast heating and with the results obtained in the conditions of shock wave loading of the samples heated preliminary was made. Results of metallographic analysis fulfilled for the determination of the fracture character of investigated metals and alloys in such loading conditions are presented. Some common tendencies of the influence of loading characteristic time and temperature on the fracture conditions of samples and on the failure character of metals and alloys are noted.

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COMPUTER MODELING OF TRUE TEMPERATURE RECOVERY FROM THERMAL RADIATION SPECTRUM DURING SUBSECONDD HEATING

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In order to determine uniquely true (thermodynamic) temperature of an opaque object from the spectral intensity, we have to know the spectral emissivity, which depends on wavelength, radiation direction, surface geometry and other factors. Generally, the emissivity is unknown beforehand. As a result, the problem of contactless measurement of the temperature of a free emitting body in diathermic media is an underdetermined problem. So, we have infinitely many solutions and the problem turns out to be ill-posed. Usually, the following assumptions are a priori accepted for the problem of true temperature recovery. a) The emissivity depends only on wavelength and temperature. b) The parametric form of emissivity function is given, and the vector of unknown parameters has to be found together with the true temperature. As a rule, the error of temperature recovery is not analyzed adequately in the literature. Meanwhile, the analysis is required for such studies. One can make it easy for repeated measurements. In this report we present a numerical algorithm for the recovery both true temperature and body emissivity for each time moment during subsecond resistance heating. It is assumed that the temperature field, the optical properties of the body surface and the system geometry do not change in the measurements. For fast processes, it means that the spectral intensity must be recorded simultaneously for all wavelengths with the help of a multi-channel measuring system. The algorithm specifies sequentially the kind of the emissivity function, proceeding from the simplest linear to more complex functional dependencies. In doing so, the corresponding temperature is adjusted to every new dependence. The process stops, when the calculated model spectral intensities are adequate to the experimental spectral intensities. The algorithm was tested for a wide class of data, generated with the help of experimental emissivities. The algorithm stability was numerically estimated by means of data disturbance

with model random errors, similar to experimental ones. The accuracy of true temperature estimation are investigated by means of the “quasi-real” experiments depending on a number of unknown parameters of a body emissivity model, quantity of wavelengths and width of temperature step as well.

THE TRANSPORT COEFFICIENTS AND THE CHEMICAL COMPOSITION OF SIMPLE METALS IN LIQUID AND GASEOUS PHASES

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One of the fundamental thermophysics tasks is the calculation of transport electronic coefficients of metals for all possible densities and temperatures. (These coefficients are the conductivity, the thermoconductivity and the thermopower.) At present moment the main problems in solution of this task are located in the region of transition from the liquid state to the gaseous one [1]. There is qualitative and quantitative change in electronic transfer processes in this domain in the vicinity of the critical point, caused by ionization with the density increase. The different approaches have been used to describe this effect, such as phenomenological theories, or various forms of the generalized chemical model [2, 3]. These approaches, however, are correct only in some limited domains of the temperatures and the densities, because of the degeneracy of the electrons, which is the consequence of the ionization. So they failed at high densities without some unphysical approximations. Another approach is based on the density functional theory (DFT) [4], which is formally rigorous for any densities, although it contains ambiguous and not exact exchange-correlation interaction. The last circumstance is appeared to be the reason of incorrect description obtained by this method at low densities. It concerns the ionization degree, which must be less than unit in the gaseous phase while DFT models gives fully ionized metal. As consequence we have too exaggerated values of the transport coefficients. So, our purpose was the investigation the DFT-based models at low densities to obtain the correct limit of the ionization degree at low densities. The last value had been used for the following calculation of transport coefficients. The results were compared with the data of others researchers.

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CONDUCTIVITY OF DENSE VAPOR METAL PLASMA

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Review of experimental data on conductivity of metal vapor plasma of different elements for temperature range $8000 \leq T \leq 30000$ K and density $0,001 \leq \rho/\rho_m \leq 1$, where ρ_m — metal density, are given in work [1]. Estimation of parameters of ion-atom and an electron-ion interaction showed, that these parameters are very large (~ 10) in the mentioned range of temperature and density. The strong ion-atomic interaction results in formation of clusters which are taken into account using the Likalter fluctuation model [2]. The strong Coulomb interaction is taken into account in the nearest neighbor approximation. Calculation of metal vapor plasma composition is carried out using the modified basic chemical model [3]. Conductivity is calculated using interpolation formula of Frost. For an electron-ion transport scattering cross-section the formula of the Rutherford was used, the electron-atomic transport scattering cross-section is calculated in a quasi-classical approximation for a polarization potential. Calculations show the quite good agreement with experimental data [1] for metal vapor plasma of different elements: Al, Cu, Fe, Ni, W.

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