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EVIDENCE OF AN ANOMALOUS THOMSON EFFECT

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Research completed since the title of this paper was submitted indicates that a more correct title would have been "Evidence of an Anomalous Peltier Effect."

The anomalous Peltier effect was discovered, however, as a result of initial attempts by C. E. Canada and myself to measure Thomson coefficients through the use of an AC magnetic Wheatstone Bridge,[1] a device which senses small temperature changes in metal sample through changes in eddy-current resistance in the sample. Through the use of this device we were able to measure Thomson coefficients where the temperature at the point of measurement (T) was not greatly different from the local ambient temperature (T_o), a temperature range heretofore accessible with great difficulty for metals of low resistivity. The results of these experiments will be submitted shortly to Physical Review. Our measured Thomson coefficients showed good agreement with literature values for high resistivity metals such as nickel as can be seen in Fig. 1 where our values are compared to those of the most recent Thomson measurements, which were made by Maxwell, Lloyd and Keller,[2] and an earlier measurement by Borelius.[3] For low resistivity metals such as copper and silver, however, our measured Thomson coefficients showed trends toward infinity as the difference ($T-T_o$) decreased to zero. Possible sources of systematic and computational error did not seem to account for these latter observations. Analysis of our early copper data seemed to indicate that thermal radiation was a factor.

The system was redesigned to produce a single, stable value of T_o, and R. C. Norris and P. B. Jacovelli carried out an extensive series of measurements on a single, silver sample which are shown

Transient determinations of thermal diffusivities and emissivities of metal foils

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Diffusivities and emissivities are measured through the use of the transient technique for five metals. Diffusivity values for Al, Ag, Cu, Fe, and Ni are found to be 0.89, 1.73, 1.14, 0.216, and 0.176 cm^2/sec, and respective emissivity values are found to be 0.23, 0.031, 0.038, 0.046, and 0.054. These diffusivities agree well with other values in literature and differ from values previously obtained through use of this technique because of corrections for heat reflection and possibly better heat input techniques.

PACS numbers: 72.15.Eb, 44.40.+a

INTRODUCTION

Thermal diffusivities and emissivities of surfaces of metal foils were measured using the technique introduced by Jacovelli and Zinke.[1] The dissipation measurements of Jacovelli and Zinke were made with ambient atmosphere in contact with the foils and could not be used to determine the emissivity of the foils. Here the experiments were carried out in an evacuated region so that the emissivity could be calculated from the dissipation. The technique of injecting the heat pulse into the foil was improved, and a temperature detector with better definition was used.

Extension of the technique to measurement in evacuated regions revealed the possibility that systematic errors may have occurred in the previous measurements. Careful steps have been taken here to eliminate those systematic errors. Criteria were developed for systematic error analyses, and nomographs are presented which simplify the determination of reading error.

Measured diffusivities and emissivities are presented for foils of silver, aluminum, copper, iron, and nickel. Results seem to be in better agreement with those of previous investigators than results of Jacovelli and Zinke.

THEORY

The applied theory is relatively simple and straightforward and depends on the production in the initial instance of an instantaneous line source of heat in a metal sample where the width of the sample is much smaller than the length. The diffusing heat then produces a temperature change at some distance from the input point. The change of temperature of the metal sample is calculated through the differential equation for one-dimensional propagation of heat in a foil with surface conduction to the surrounding medium. The equation is [Carslaw and Jaeger,[2] Eq. 4.2 (2)]

$$\kappa\left(\frac{\partial^2 T}{\partial x^2}\right)-\frac{\partial T}{\partial t}-\nu(T-T_0)=0, \tag{1}$$

where κ is the diffusivity, ν is the dissipation constant, T is the temperature excursion above the ambient temperature T_0, t is the time, and x is the distance. It is assumed that temperature excursions above ambient are small enough that the rate of heat dissipated from the foil surface to the surroundings can be assumed to be a linear function of $(T-T_0)$. The solution where the injected heat can be considered to be a line source is [Carslaw and Jaeger, Eq. 10.2(9)]

$$T=\frac{Q'}{2WD\rho C(\pi\kappa t)^{1/2}}\exp\left(-\nu t-\frac{(x-x_0)^2}{4\kappa t}\right), \tag{2}$$

where

$$\nu=2H\kappa(W+D)/KWD\approx 2H\kappa/KD, \tag{3}$$

and

$$H=4e\sigma T_0^3+H'. \tag{4}$$

The heat pulse is produced at x_0 and detected a distance $(x-x_0)$ from the point of production in a foil having width W, thickness D, density ρ, specific heat C, and thermal conductivity K. The magnitude of the injected heat pulse is Q'. The quantity H corresponds to a coefficient of heat conduction perpendicular to the foil surface. This quantity can be divided into a term which depends on conduction to the surrounding gas, H', and a radiation term with e as the surface emissivity and σ as the Stefan-Boltzman constant. In these experiments it was experimentally established that H' disappeared at pressures well over an order of magnitude greater that the highest pressures used for the resulting data. Consequently,

$$H=4e\sigma T_0 \tag{5}$$

and

$$\nu=4e\sigma T_0^3/KD. \tag{6}$$

Values of κ and ν were determined by measuring T at x and t for two points on the temperature profile. The points chosen were the maximum value of temperature T_m occurring at t_m, x_m, and one of the half-maximum values of temperature, either $T_{1/2}$ or $T_{3/2}$ depending on whether the designation applies to the first or second half-maximum. Similar designations were given to x and t. The second half-maximum was usually used because of the increased reading accuracy of $T_{3/2}$ over $T_{1/2}$. The maximum temperature occurs where

$$(x-x_0)^2/4\kappa t_m^2-\nu-1/2t_m=0. \tag{7}$$

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JG 6 Self-Consistency Analysis of Optical Data: Aluminum.* E. SHILES, Virginia Commonwealth U. and Argonne Natl. Lab. and D. Y. SMITH, Argonne Natl. Lab.--The optical properties of metallic aluminum have been investigated from the infrared to the x-ray region using sum rules as a check on self-consistency of the optical constants. Published compilations of data for aluminum by Ehrenreich, et al., Sasaki and Inokuti, and Hagemann, et al., all show violations of one or more rules exceeding experimental or computational error. Re-analysis of the most reliable experiments indicates that available optical constants for aluminum below the $L_{II,III}$ edge are consistent with the partial f sum of 3.1 - 3.2 electrons per atom predicted for the three conduction electrons per atom from Pauli principle redistribution of oscillator strength. However, the currently accepted values for absorption above the $L_{II,III}$ edges show an unexplained excess oscillator strength of approximately 1.5 electrons per atom. The possibility of systematic errors in experiment or oversimplifications in currently accepted theory will be discussed.

*Work performed under the auspices of the USERDA.

JG 7 Transverse Magnetoresistivity of Antimony Single Crystals at Low Temperature and High Magnetic Field. C. L. TSAI,* D. WALDORF, K. TANAKA,** and C. G. GRENIER, Louisiana State University. -- The anomalous field and size dependence of the transverse isothermal magneto- of Sb single crystals below 4.2 K and magnetic fields up to 24 kG is attributed to the surface current which is influenced by the condition of the surface. The surprising discontinuity of magnetoresistivity which appeared at the superfluid phase transition (measured with the sample in contact with the He bath) and the weak temperature dependence of magnetoresistivity are explained by the electron-phonon mutual drag effect[1] which dramatically decreases the effective electron-phonon resistive scattering. The magnetoresistivities were measured in two distinct ways: with the sample (1) in a vacuum chamber and (2) in contact with the liquid He bath, to unambiguously distinguish between the isothermal and adiabatic cases.

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[1] L. E. Gurevich and I. Ya. Koreblit, Sov. Phys.--Solid State 9, 932 (1967). Yu. Kagan and Y. N. Flerov, JETP Lett. 20, 384 (1974).

JG 8 The Fermi Surface of Platinum.* D. H. DYE, Northwestern U., J. B. KETTERSON, Northwestern U. and Argonne Natl. Lab., and G. W. CRABTREE, Argonne Natl. Lab.--The two high mass (ε,β) orbits on the open hole surface of platinum predicted by band structure calculations[1] but not observed in previous dHvA studies[2] have now been measured, providing a complete set of area data for this transition metal. Phase shift fits using a non muffin tin relativistic KKR formalism at two values of the Fermi energy parameter have been calculated, with RMS errors of about 0.3%. From these fits the Fermi radii have been determined for all surfaces. A preliminary inversion of effective mass data to determine Fermi velocities has also been carried out. The density of states has been calculated for each surface, and the total of all sheets has been compared with that deduced from the electronic heat capacity measurements.

*Work supported by the NSF under grant #DMR72-03019 and the USERDA.

[1] O. K. Andersen and A. R. Mackintosh, Solid State Commun. 6, 285 (1968); F. M. Mueller (unpublished.)

[2] J. B. Ketterson and L. R. Windmiller, Phys. Rev. B2, 4813 (1970).

JG 9 Fermi Surface and Magnetic Breakdown in Niobium.* D. P. KARIM and J. B. KETTERSON, Northwestern U. and Argonne Natl. Lab and G. W. CRABTREE, Argonne Natl Lab.—We have made a de Haas van Alphen study of the Fermi surface of niobium. Data were taken at temperatures as low as .3 K and in fields as high as 130 kG. Area data has been taken on several previously unobserved orbits including second zone octahedron and the third zone jungle gym. The area data has been used to parameterize the Fermi surface in terms of non muffin tin KKR scattering phase shifts. New cyclotron effective mass data will also be presented and discussed in terms of electron-phonon enhancement.

JG 10 Inflection Points in Seebeck Potentials. P.B. Jacovelli and O.H. Zinke, Univ. Ark.Fayetteville.--Pronounced inflection points appear in measured Seebeck potentials obtained from a copper-iron thermocouple where the conductors of the thermocouple were disposed asymmetrically with respect to surface temperatures. The inflection points were shown to shift with respect to the temperature of the conductor with a well-defined surface temperature. The effect is shown to be in qualitative agreement with previously reported Thomson effect measurements[1].

[1] O.H. Zinke, J.B. Sawyer, R.C. Norris, and C.E. Canada, Bull. Am. Phys. Soc. 20,645 (1975).

JG 11 Low Temperature Electron Transport Properties of Pd-Ru Alloys. C. UHER and P.A. SCHROEDER, Michigan State U.*--Measurements of electrical (σ) and thermal (κ) conductivities, thermoelectric power (S) and thermoelectric ratio (G) have been made on 0.1,0.5,1, and 5 at.% alloys of Ru in Pd** from 4.2K down to about 50mK. A high sensitivity superconducting quantum interference device (SQUID) has been used as a null detector. In general the transport properties behave as predicted from conventional theory. σ is essentially temperature independent and the Lorenz number calculated from σ and κ and also from S and G are in accord with each other and with the theoretical value. S and κ both vary linearly with T. However a small departure from linear dependence is observed on S at the lowest temperatures. This anomaly appears more clearly in the temperature dependence of G which can be measured very precisely. Small steps observed in σ at around .5K may be associated with precipitates of superconducting ruthenium or ruthenium rich alloys.

*Supported by N.S.F. grant

**Same alloy samples as used in work of D. Greig, T.K. Brunk, and P.A. Schroeder, Phil. Mag. 25, 1009, 1972.

JG 12 Positron Studies of Liquid Hg-In Alloys. W.F. HUANG, Y.C.LEUNG and T.B. LIN*, Univ. of Louisville. --Liquid Hg-In alloys of 5,7.5,10,15,20,25,30,35,40, 44,45,50,55,57.5 and 60 atomic percentages of In were studied by positron annihilation. Coincidence rates were measured at 0 and 10 milliradians, i.e. N(0) and N(10) respectively, for each concentration. The parameter, $f = N(0)/N(10)$, of each alloy was compared with that of pure Hg. It was found that the f values continuously increased while N(10) values decreased until the In concentration reached 60%, indicating a diminishing portion of positrons annihilating with core electrons. The final results were analyzed in terms of two positron trapping centers of vacancy-solute complexes and solute atom sites. To the extent that the concentration of vacancy-solute complexes was negligible, the concentration of annihilation sites created by In atoms was found to be 10^{-4} of the total solute concentration.

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JG 13 Temperature Dependence Studies of the Electric Field Gradient at Cd Impurities in Heavy Rare Earth Metals*. S. A. LIS and R. A. NAUMANN, Princeton U.--Using the 84 nsec, ^{111m}Cd, the temperature dependence of the EFG has been studied by the method of Time-Differential-Perturbed Angular Correlations in the rare earth metals Gd, Tb, Dy, Ho and Er. The measured elec-

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Snowplowing in a Plasma Rail Gun

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(Received 4 September 1969; final manuscript received 4 May 1970)

Agreement between data from a plasma rail gun as analyzed by a time-of-flight technique and predicted by snowplow theory indicates that there is no necessity for any theory of drag force in the gun and seems to indicate that one theory for drag force which also accounts for the conduction of electrical current into a moving plasma should be re-examined.

INTRODUCTION

One possible technique for studying the manner in which electric current is conducted into a plasma from conducting walls is to determine the behavior of the plasma as it moves with respect to the walls in a device such as a plasma gun. It has been noted by Thom, Norwood, and Jalufka[1] that moving plasmas never achieve expected flow velocities in such devices. In the same article it has been postulated that a moving plasma may be slowed if the conduction of electric current into the plasma from the walls occurs through the positive ions of the plasma. The effect has been called drag force.[1] Lovberg[2] has offered a postulate which depends on "whether the current front in the gun acts as a tight piston or whether it displays permeability." Apparently technical literature by Lovberg, Gooding, and Hayworth[3] as quoted by Thom, Norwood, and Jalufka[1] attribute the difficulty to the "mass-loading problem" which, according to the latter authors, "describes the technical problem of matching the inertia of the mass of the plasma to the inertia of the electrical circuitry which powers the gun."

In any event, the energy lost to drag force is experimentally of the same order of magnitude of the flow energy and the various theories would apparently have to predict losses of like order of magnitude. It is the purpose here to report that if plasma drag occurs with a simple rail gun, the energy transferred to the drag mechanism must be at least an order of magnitude less than the plasma flow energy. Indeed, simple snowplowing seems to account for all aspects of plasma behavior observed. Therefore, the various theories for plasma drag should be re-examined and, in particular, the theory of Thom, Norwood, and Jalufka[1] which accounts for the flow of electric current into the plasma should be reviewed.

Measurements of plasma characteristics were made through the time-of-flight technique which has been described in some detail by Manka[4] and Ross[5] and used by Manka, Crawford, and Zinke[6] and Ross and Zinke.[7] The technique yields the temperature (T) of the positive ions of the plasma, the flow velocity (V) of the plasma as it exits the rails, the ion population of the plasma (N), and the time the plasma is released from the rails. Manka[4] estimates that oscilloscope reading errors, the principal source of error, give a 50% variation in the measured temperature and a 15% variation in the measured flow velocity. Reading errors may cause plasma release times to be off in these data by as much as several microseconds. For similar reasons the ion population may be off by a factor of 2 and is, additionally, subject to the assumption of a fully ionized plasma being present. Snowplow theory is modified here to predict, in addition to the flow velocity of the plasma, the temperature, the ion population, and the plasma release time.

SNOWPLOW THEORY

The theory will assume that a plasma of initial positive ion population n_0 originates at one end of a rail gun and is accelerated to the other through a neutral gas of n_1 atoms or molecules per unit length. The point of plasma initiation will be taken as $x = 0$. The plasma is assumed created in a breakdown of neutral gas caused by the discharge of an energy storage capacitor. The plasma forms one component of a simple series circuit. The snowplow equation derived here will be similar to that derived by Hart.[8] However, the notation of Mostev, Neuringer, and Rigney[9] will be used. Kirchoff's law for a plasma driven by a discharging capacitor is [see, e.g., Eq. (1) of Ref. 9]

$$\frac{d(L_0 I + L_r I)}{dt} + (R_0 + R_r + R_p)I + \frac{1}{C}\int_0^t I\,dt = V_0. \qquad (1)$$

The inductance L_0 is associated with the circuit

[1] K. Denbigh, *The Principles of Chemical Equilibrium* (Cambridge University Press, Cambridge, England, 1966), p. 397 *et seq.*

[2] T. L. Hill, *Introduction to Statistical Thermodynamics* (Addison-Wesley Publ. Co., Inc., Reading, Mass., 1960), p. 86 *et seq.*

[3] See Ref. 2, p. 490 *et seq.*

[4] M. Born and T. von Karman, Physik. Z. **13**, 297 (1912).

[5] L. B. W. Jolley, *Summation of Series* (Dover Publications, Inc., New York, 1961), p. 78.

[6] H. Wergeland in *Proceedings of the NUFFIC International Summer Course in Science*, compiled by E. G. D. Cohen (North-Holland Publ. Co., Amsterdam), p. 58.

[7] *Webster's New International Dictionary* (G. & C. Merriam Co., Springfield, Mass.), 2nd ed., unabridged (scales).

[8] Lord Rayleigh, *Theory of Sound* (Dover Publications, Inc., New York, 1945), p. 16.

[9] M. Born, Proc. Phys. Soc. (London) **54**, 362 (1942).

AMERICAN JOURNAL OF PHYSICS VOLUME 38, NUMBER 2 FEBRUARY 1970

Bose–Einstein Condensation of Noninteracting Particles

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The chemical potential is determined for a Bose–Einstein gas of noninteracting particles in a closed system. The calculation is done in a manner which shows dependence on an energy gap $(\epsilon_1-\epsilon_0)$, limits of application of the results, and behavior through the transition temperature.

The usual approaches to Bose–Einstein condensation for noninteracting particles are typified by those of London,[1] Wilson,[2] Landau and Lifschitz,[3] and Jackson.[4] The chemical potential is obtained from an expression involving a summation [see Eq. (2) below] which must be divided for evaluation into a single term involving the lowest energy level and a new summation [see Eq. (9) below]. London[1] has shown the dominant role of the lowest energy level which leads rather naturally to this division. Objections can be made with respect to the evaluation of the new summation, which is inevitably integrated [see, e.g., Eq. (4) of Ref. 1 or Eq. (6.42.4) of Ref. 2] in such a way that the limits of application of the result with respect to temperature variation are not immediately apparent. In particular, it is not apparent whether the derived expression is applicable *through the transition temperature.* It will be shown below that the limits of application of the result are also dependent on the energy difference $(\epsilon_1-\epsilon_0)$. This dependence is not shown in existing derivations. Since the ϵ_0 term must be separated from the series of energies representing the levels for the noninteracting particles in a box, in principle, the ϵ_0 level need not be such a level, and the energy difference $(\epsilon_1-\epsilon_0)$ could have any value. For this reason, the energy difference between the lowest and the next level is called a "gap" here.

The approach below seems to meet the above objections. The calculations are started from their beginning to avoid the difficulty of correlation with the various energy normalizations used by other authors.

The average population of the jth level of a collection of noninteracting Bose–Einstein particles is

$$\langle N_j\rangle = g_j/[\exp\{(\epsilon_j-\zeta)/kT\}-1], \qquad (1)$$

where g_j is the statistical weight of the energy state E_j; ζ is the chemical potential; and all other symbols have their usual meanings. The chemical potential is found as a function of N, V, T from

$$N=\sum_{j\geq 0} 1/[\exp\{(\epsilon_j-\zeta)/kT\}-1]. \qquad (2)$$

However, the range of values available to the chemical potential are restricted. If $\epsilon_i\leq\zeta\leq\epsilon_{i+1}$ for some set of the macroscopic variables and some value of $j=i$, then for every $j\leq i$ we have $\langle N_j\rangle<0$, a statement which has no physical interpretation. Therefore, it can be concluded that $\zeta\leq\epsilon_0$. For the closed system considered here,

$$\lim_{T\to 0}\langle N_0\rangle = 1/[\exp\{(\epsilon_0-\zeta)/kT\}-1]=N \qquad (3)$$

AMERICAN JOURNAL OF PHYSICS VOLUME 36, NUMBER 6 JUNE 1968

NOTES AND DISCUSSION

Elimination of the Monopole Term in the Expansion of the Magnetic Vector Potential

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(Received 6 February 1968)

Perusal of sections of 15 modern electricity and magnetism texts concerning the magnetic field from an arbitrary charge distribution finds the integral

$$\int \mathbf{J}d\tau,$$

where mentioned, dismissed as zero for one of two reasons. Panofsky and Phillips,[1] Owen[2], Cheston,[3] and others indicate that the current density J can be divided into filamentary current paths which integrate to zero. Jackson[4] reasons that "For a localized steady-state current distribution the volume integral of J vanishes because $\nabla\cdot\mathbf{J}=0$."

It is not easy for students to accept that the conditions on the current distribution allow the distribution to be divided into filamentary circuits. Criteria for such a division are not discussed. Nor is it easy for them to

the first integral on the right. The last integral becomes

$$\mathbf{n}\cdot\int \mathbf{J}d\tau=0.$$

Since n is an arbitrary vector in magnitude and direction, it must be concluded that

$$\int \mathbf{J}d\tau=0.$$

Note that both conditions on the current distribution are used explicitly.

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[1] W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism* (Addison-Wesley Publ. Co., Reading, Mass., 1962).

[2] G. E. Owen, *Electromagnetic Theory* (Allyn and Bacon, Boston, Mass., 1963).

[3] W. B. Cheston, *Elementary Theory of Electric and Magnetic Fields* (John Wiley & Sons, Inc., New York, 1964).

[4] J. D. Jackson, *Classical Electrodynamics* (John Wiley & Sons, Inc., New York, 1962).

Conical Pendulum Experiment

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ture is wide, the corrected resistivity is indeed proportional to T except for small effects. The thermal expansion should also contribute to the deviation from Matthiessen's rule. The effect will be most pronounced for solids of high melting temperature and should also apply to other transport properties, including the lattice thermal conductivity.

*Supported by the U. S. Army Research Office - Durham.

EP 8 Electronic Properties of Metals at Low but Finite Temperatures* David Y. Kojima (introduced by Isihara) and A. Isihara, State U. of N. Y. at Buffalo.--Based on a grand ensemble method, the electronic internal energy, specific heat and susceptibility have been evaluated most accurately for low but finite temperatures. The density dependence of the correlation energy has been determined in two different ways, one iterative and the other direct. The ring diagram contribution has also been determined with and without an r_s expansion. The failure of the well-known r_s series of the correlation energy will be pointed out. The temperature and density variations of the specific heat, the correlation energy and the para- and dia-magnetic susceptibilities and the field dependence of the Fermi momentum will be discussed.

* Work supported by N.S.F.

EP 9 Temperature Dependence of the Nuclear Relaxation of ^{69}Ge in Copper Metal* G.SCHATZ†, M.RAFAILOVICH, and G.D.SPROUSE, SUNY-Stony Brook.--In order to study the effects of radiation damage on an implanted impurity, we have used the reaction ^{65}Cu(^{7}Li,3n)^{69}Ge to populate the $9/2^+$, τ=4 μsec level in ^{69}Ge. An external field of 8 kG was applied and the perturbed angular distribution of the 398 keV decay γ-ray was measured at target temperatures varying from 320K to 720K. At the highest temperature, no relaxation of the initial anisotropy (A_2=0.13(1)) was observed. At a temperature of 320K the initial anisotropy was slightly reduced (A_2=0.10(1)) and a relaxation time of 8±3 μsec was observed. A preliminary interpretation of the relaxation times is made by considering the interaction of the impurity atom with mobile defects introduced into the solid by radiation damage. Further experiments with extended ranges of temperature and magnetic field are in progress.

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†Max Kade Fellow, Univ. of Erlangen-Nürnberg, Germany.

EP 10 Anomalous Behavior of Thomson Coefficients. O.H. ZINKE and J.B. SAWYER, Univ. Ark., R.C. NORRIS, Texas Inst., and C.E.CANADA, Mason and Hanger--Thomson coefficients directly measured in this laboratory show a strong dependence on ambient temperature. The dependence would have escaped thermocouple detection. Direct measurements by other investigators show the same dependence although there has apparently been no previous effort to interpet it. The effect seems to be associated with thermal radiation.

EP 11 Electrical Properties of Carbonized Microcrystalline Cellulose.* R. P. LYONS, JR. and J. J. SANTIAGO, Aerospace Research Laboratories, WPAFB, Ohio 45433, and F. DIAZ, University of Puerto Rico, Rio Piedras, Puerto Rico 00931.--High purity microcrystalline cellulose was carbonized under partial vacuum at temperatures from 600°C isochronally for 30 minutes. Electrical contacts were placed on carefully cut samples. Both conventional Hall effect and Van der Pauw configurations were used, depending on the size of the sample. Resistivity and Hall voltages were measured from 77°K to 298°K. After the electronic transport measurements were done the same samples were ground in an agate mortar, and magnetic susceptibility by the Faraday method was measured in the same temperature range. The resistivity decreased with carbonization temperature suggesting the coalescence of carbon atoms into clusters and the disappearance of the volatiles such as hydrogen. The diamagnetic susceptibility remained constant with carbonization temperature (χ = -0.40 ± .03 X 10^{-6} emu/g) and its value is close to the carbon ion core susceptibility, suggesting the absence of aromatic ring formation with its large Landau-Peierls type diamagnetism. Measurements of dielectric losses and permittivity as functions of frequency were performed.

*Submitted by J.M. Meese

EP 12 Soft Recovery of Shocked Specimens for Dynamic Fracture Studies. W. H. HOLT and W. MOCK, JR., Naval Surface Weapons Center, Dahlgren Laboratory, Dahlgren, Virginia.--A system that permits the soft recovery of specimens shock loaded with a gas gun has been designed for use in dynamic fracture studies. Thin flyer plates carried on flat-faced projectiles impact the specimens which are soft recovered and examined metallographically for microscopic spall fractures. The function of the recovery system is to separate the impacting projectile and flyer plate from the impacted specimen to prevent subsequent unintentional specimen damage. This separation is accomplished via the in-flight capture of the projectile and flyer plate. The specimen moves unhindered after impact until it is soft recovered in a separate area. The system has been successfully tested for projectile velocities up to 1050 ft/sec; this velocity range has been adequate for studies of microscopic spall fracture.

EP 13 Ultrasonic Studies of In-Tl Alloys at Low Temperatures. G.A. SAUNDERS, D.J. GUNTON and D.Y. CHUNG*, The Univ. of Durham,England. --The indium-thallium alloys in the composition range 16-31 at.% Tl undergo a martensitic phase transformation from higher temperature f.c.c. form to the lower temperature f.c.t. modification- a transformation which is well suited to ultrasonic studies. Here we report the ultrasonic velocity and attenuation measurements near the transition for a number of alloy compositions at low temperatures. It is shown that the onset of instability of the f.c.c. and f.t.c. structures is directly associated with the approach of $(C_{11}-C_{12})/2$ towards zero.

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SUPPLEMENTARY PROGRAM

EP 14 Acoustic Mode Softening and the Melting in In-Tl Alloys. G.A. Saunders, D.J. Gunton and D.Y. Chung*, The Univ. of Durham, England. -- The ultrasonic velocities and attenuation in several In-Tl alloys have been measured very close to the melting point T_m (to within $0.99T_m$). These alloys showed acoustic mode softening and lattice instability near their martensitic transition temperatures T_f. The purpose of this experiment is to correlate the acoustic properties near the melt to that near T_f. In all the alloys measured (including pure indium),no apparent phonon softing due to the melting was observed. The results will be presented.

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device using a short pulse Nd: glass laser is proposed. A light pulse propagates in a plasma with group velocity $c(1 - \omega_p^2/\omega^2)^{1/2}$ and the ponderomotive force of the photons leaves behind a train of plasma waves as a wake with phase velocity same as the photon group velocity. Such plasma waves trap electrons and are efficient accelerators of electrons to high energy. Either by preacceleration or by density gradient it might also be possible to accelerate ions. The maximum energy electrons can gain is $W = 2mc^2\omega^2/\omega_p^2$ $\{W = (\omega/\omega_p)Mc^2[1 + (2\omega/\omega_p)^{1/2}(m/M)^{1/2}]$ for ions$\}$. Wave breaking sets a limit on the electrostatic field at $E = mc\omega_p/e$. With a laser light focused to 10^{18} W/cm^2 and plasma of density 10^{18}cm^{-3}, it will take 1 cm to accelerate electrons to 1 GeV with electrostatic field of 10^9 V/cm through this mechanism. Computer simulations on the 1-2/2 D relativistic electromagnetic code have demonstrated this concept and confirm the scaling law for W at least up to $(\omega/\omega_p)^2 = 40$. Applications to pulsars and cosmic rays are also suggested.

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HI 3 Transport Coefficients in Halogen-Nitrogen and Halogen-Rare Gas Mixtures*. K.J. NYGAARD, S.R. HUNTER†, H.L. BROOKS, S.R. FOLTYN, and R.A. SIERRA, University of Missouri-Rolla.--Using the method developed by Grunberg[1], we have measured the attachment coefficient and electron drift velocities for several halogen-containing gas mixtures. Specifically, results have been in I_2-N_2, NF_3-Ar, F_2-Ar and CCl_4-Ar, for the range of E/N from 1 to 40 Td (1 Td = 10^{-17} V cm^2). Halogen concentrations were varied from 0.1% to 1.0%, with total gas pressures of 10 Torr to 100 Torr. Calculations of the rate coefficient have been made from our data and compared to the results of other researchers.

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[1] Grunberg, R., Z. Naturforsch. 24a, 1039 (1969).

HI 4 Electron Transport Coefficients in CO_2 and CO_2-N_2-H_e Mixtures of Laser Interest.* R.A. SIERRA and K.J. NYGAARD, University of Missouri-Rolla.-- Transport coefficients for electrons in CO_2 and CO_2-N_2-H_e mixtures have been measured at total pressures ranging from 10 torr to 200 torr and over an E/N range of 40 Td to 220 Td (1 Td = 10^{-17} volt-cm^2). At low E/N where ionization in pure CO_2 is very small the attachment coefficient (η/N) has been measured using an integrated charge method. At higher E/N the spatial current growth has been monitored to obtain both attachement and ionization (α/N) coefficients. In addition, temporal analysis of the electron transient wave form has yielded drift velocities in these gases. The results are compared with theoretical calculations and with existing experimental data.

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HI 5 Time-of-Flight Analyses of Magnetically-Separated Charge States of Ions from Laser Blowoffs. C.K. MANKA, Sam Houston State U. and M.R. CARRUTH*, L.G. GRAY, R.H. HUGHES, R.J. ANDERSON, and O.H. ZINKE, Uof Arkansas**--Plasma produced from blowoff by 25-MW, Q-switched YAG laser bursts on C, Al, Cu, and Pb was allowed to drift, and the ions were then extracted and focussed by an Einzel lens onto a magnetic analyzer which produced charge-state separation. Each charge state was analyzed by the time-of-flight technique[1,2]. Excellent fits to Maxwell-Boltzmann distributions were observed and the plasma temperature and flow velocities were calculated. Non-common temperatures for ions of different charge states from single plasmas are indicated.

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1. C.K. Manka, J.R. Crawford, and O.H. Zinke, Phys. Fluids 10, 767 (1967).
2. D.P. Ross and O.H. Zinke, Exploding Wires Vol. IV, edited by H.K. Moore and W.G. Chace, Plenum Press (1968).

HI 6 Finite-Length Theory of Collective Free-Electron Lasers. S. JOHNSTON, Columbia U.* The small-signal gain of a free-electron laser operated in the stimulated Compton mode is derived without limitation on the density of the electron beam employed. Expansion of the exact result in powers of the linear susceptibility $|\chi|$ reproduces the vacuum gain formula[1], and shows that the leading plasma correction causes a slight enhancement (not reduction!) of the vacuum gain. The theory also generalizes past work by including a static guide magnetic field and an arbitrary distribution of beam momenta; the principal assumption is small gain in the available length (i.e., a recycled system). For denser beams ($|\chi|>1$), it is shown that stimulated Compton scattering persists in a finite-length system, and that the Compton gain can easily rival the finite-length Raman gain which is derived for comparison. The possibility of an x-ray laser operated in this new regime (plasma-modified Compton effect) is discussed.

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[1] F.A. Hopf, P. Meystre, M.O. Scully and W.H. Louisell, Opt. Commun. 18, 413 (1976).

HI 7 Ablative accelerator designs for light ion beams.* J.H. GARDNER and J.P. BORIS, U.S. Naval Research Laboratory. Light ion beams are of interest as an energy source for ablatively driven pellets for inertial confinement fusion. The ion beam deposits its energy in a much thicker region of the ablator material resulting in more ablator material being blown off at a lower velocity and hence a lower efficiency of transfer of energy to the payload. One way to overcome this is to put a heavy tamping material at the outer edge of the ablator. The mass of this tamping material must be chosen so that the Bragg peaks for a given ion beam will occurr in the ablator material. A quasi-Lagrangian one dimensional hydrodynamics code has been developed which allows as to treat interfaces of materials while maintaining the desirable features of Flux-Corrected Transport in semi-Eulerian mode. We present results for calculations of proton beams absorbed in a sandwich layer of gold and plastic. We investigate the optimum thicknesses of the gold and plastic layers in terms of energy transfer and maximum velocity obtained for the accelerated payload.
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HI 8 Intense Relativistic Electron Beam Expanding into a Field-Free Vacuum*. F. MURRAY**, D. PERSHING, J. SMITH, and W. O. DOGGETT, North Carolina State Univ., Raleigh, N. C.--An intense relativistic electron beam produced in NCSU's 7 ohm diode (0.5 MeV, 70 kA) is fired through a hole in the anode plate into a field-free vacuum. The transmitted portion of the beam expands as a result of its own self fields. A principle diagnostic employed is blue cellophane film which is calibrated to give current density as a function of change in transmission coefficient for red light. The transmission coefficient is determined on an optical microdensitometer which has been modified to accommodate He-Ne laser as its light source. The calibration constant which relates the current density to the change in transmission agrees within experimental error with a previously published value at much lower dose deposition rate.[1] Preliminary results will be presented which show the radial beam profile as a function of axial position.

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[1] E. J. Henley and D. Richman, Anal. Chem. 28, 1580 (1956).