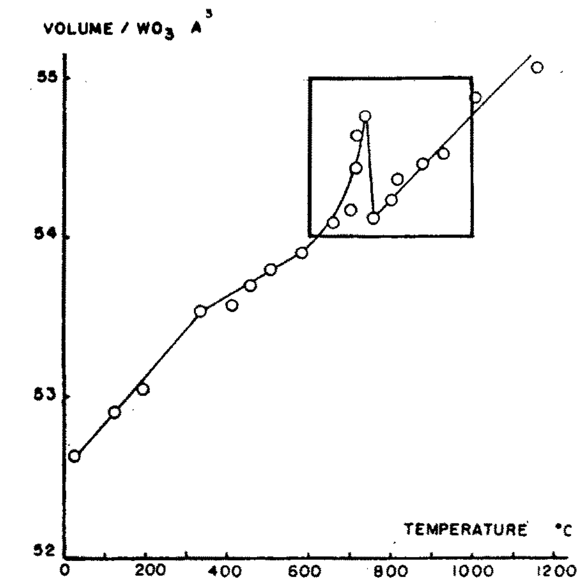

FIG. 2. Volume expansion of WO_3 (Perri–Banks–Post, 1957).

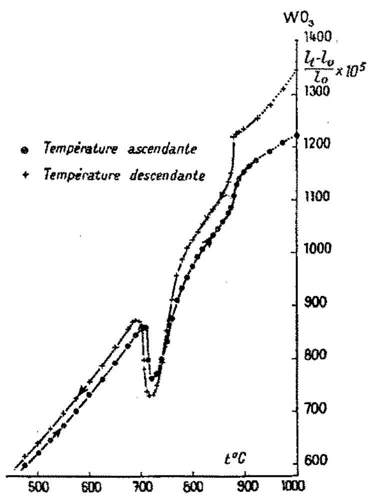

FIG. 3. Dilatometric anomalies of WO_3 (Foëx, 1945).

The author believes that these dilatometric indications have been erroneously assumed a measure of unit-cell volume. At this 712°C transition the unit cell undergoes a basal contraction and a somewhat larger axial expansion, giving a small but definite increase in the volume of the cell. The Foëx curves illustrate that in an interlocked crystallite "web" these normally concurrent processes may take place with temperature lags, resulting in the image of a unit-cell decrease within the temperature interval.

The 845°C expansion in the lattice-cell volume denotes a phase change marked by a corresponding basal expansion and a very slight axial contraction, with otherwise no indications observed of changes in the tetragonal–pyramidal structure.[2] In the Foëx curves this transition seems to show up with some +35°C displacement.

With this 845°C transition, the number of published WO_3 modifications has risen to six, all of them having essentially the same structural configuration as described in the author's trioxide communication of 1931.[4]

More detailed communications are forthcoming.

[1] J. A. Perri, E. Banks, and B. Post, J. Appl. Phys. **28**, 1272 (1957).
[2] H. Brækken, thesis (NTH, Trondheim, 1936) (unpublished).
[3] M. Foëx, Compt. Rend. **220**, 917 (1945).
[4] H. Brækken, Z. Krist. **78**, 487 (1931).

Comment on the Paper, "Complex Modulus of a Cohesive Soil from Stress Relaxation Response using the One-Sided Fourier Transform"

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In a recent paper,[1] Kondner and Ho determined the storage and dissipation resistance to deformation of a cohesive soil by applying a simple linear theory of stress relaxation.[2] Such a theory is based on the superposition integral, which holds only when two separate stimuli applied together lead to a response which is the sum of the responses of the two stimuli applied individually. A nonlinear system cannot be analyzed correctly using this approach, yet that of Kondner and Ho is admitted by them to be nonlinear. Its measured relaxation modulus *versus* time is a strong function of strain level. The stress relaxation response at a given constant strain level cannot, therefore, be validly used in a linear theory as Kondner and Ho have done. Their derived results are therefore suspect. For a nonlinear system with time-invariant material characterization parameters, as that of Kondner and Ho is probably likely to be, some such complicated analysis would be required as that presented by Nakada,[3] and Okano and Nakada.[4] In any event, linear analysis is inadequate for a nonlinear system, and it becomes less and less applicable the stronger the nonlinearity.

[1] R. L. Kondner and M. M. K. Ho, J. Appl. Phys. **36**, 2119 (1965).
[2] J. R. Macdonald and C. A. Barlow, Jr., Rev. Mod. Phys. **35**, 940 (1963), and references given therein.
[3] O. Nakada, J. Phys. Soc. Japan **15**, 2280 (1960).
[4] K. Okano and O. Nakada, J. Phys. Soc. Japan **16**, 2071 (1961).

Complex Modulus of a Cohesive Soil from Stress Relaxation Response using the One-Sided Fourier Transform

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The authors agree with Macdonald's comments that the superposition integral holds only when the response of two separate stimuli applied together lead to the sum of responses as obtained by applying the stimuli individually, and that a nonlinear system cannot be analyzed rigorously using such an

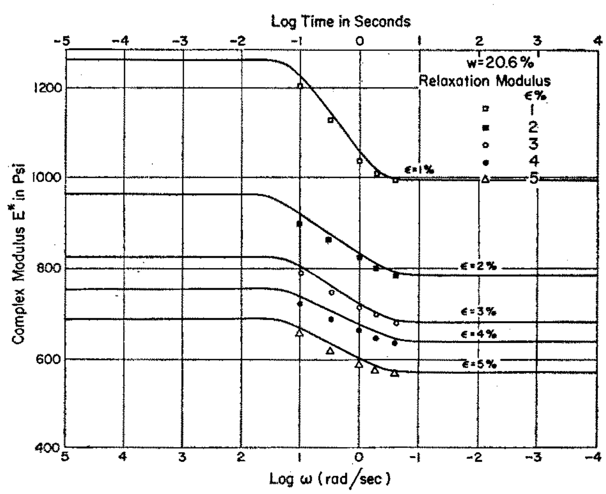

FIG. 1. Comparison of derived dynamic modulus in frequency domain and experimental modulus in time domain: different strain levels.

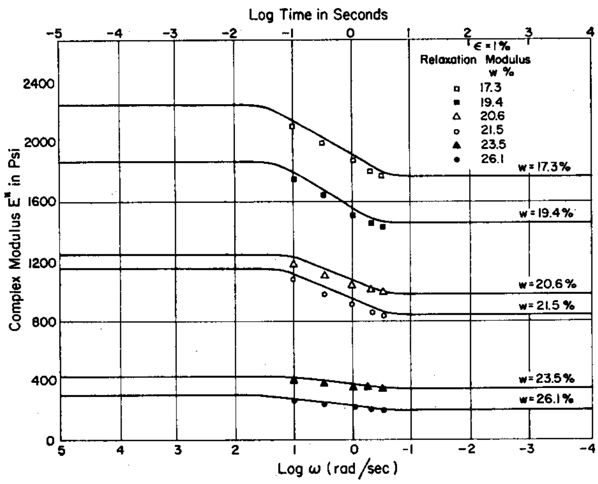

FIG. 2. Comparison of derived dynamic modulus in frequency domain and experimental modulus in time domain: different moisture contents.

approach. However, such techniques can be quite useful as expedient first-order approximations in situations where inordinately more difficult, if not impossible, techniques would be necessary for completely rigorous analysis. It was with such a viewpoint that the paper was prepared in order that much needed quantitative information on energy dissipation and storage of a cohesive soil be made available. Thus, to evaluate the applicability of such approximations, it is necessary to compare the derived results with experimental response. Such results are given in Figs. 1 and 2 which show experimentally determined moduli in the time domain for comparison with the derived results previously given in Figs. 5 and 6 of Ref. 1. The higher values of the derived dynamic complex moduli magnitudes at comparable strains for corresponding times or frequencies are in general agreement with the response characteristics prevalent in work on the mechanical properties of polymeric materials where comparison is made on the basis of the approximation that time t is the reciprocal of frequency ω. The authors conclude that such techniques as presented are useful approximations in determining soil response characteristics.

[1] R. L. Kondner and M. M. K. Ho, J. Appl. Phys. 36, 2119 (1965).

Pyrometric Measurements of Si, Ge, and GaAs Wafers Between 100° and 700°C*

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AT temperatures between 700°C and the melting point, the temperature of Si and Ge samples can be measured by means of optical pyrometers operating in the wavelength range around 0.65 μ, the emissivity correction being available from Allen's work.[1] Below 700°C the temperature measurement becomes very difficult if the samples to be tested are in a vacuum, because thermal contact is notoriously unsatisfactory when the sensing element (e.g., thermocouple) cannot be welded reliably to the sample, as is the case for Si and Ge. We have therefore calibrated the response of a radiation pyrometer for a number of wafers of Si, Ge, and GaAs. The radiation pyrometer used operates in a wavelength band (2.0–2.6 μ) that is actually not very suited to the optical properties of these semiconductors, but has the advantage of being available commercially (Ircon, Inc., model 300). Since at, and close to, room temperature Si, Ge, and GaAs are all quite transparent to radiation in the range between 2.0 and 2.6 μ, the spectral emissivities are expected to be very low[2] and very sensitive to changes in sample thickness, surface conditions, and sighting angle.

The materials tested had the following characteristics: Si, 12 $\Omega\cdot$cm, p type, orientation 6° off [211]; Ge, 0.015 $\Omega\cdot$cm, p type, orientation (110); GaAs, 0.10 $\Omega\cdot$cm, n type, orientation (110). The samples were 5 cm long and 1.2 cm wide, with thicknesses ranging between 0.4 and 1.5 mm. They were heated by sending an electric current through them, the surrounding atmosphere being mostly forming gas (10% H_2+90% N_2) and occasionally argon. Before each run, a small drop of a suspension of a material with suitable melting point was allowed to dry to a small dot in the middle of the sample surface. These suspensions of materials with calibrated melting point are also available commercially (Tempil Corporation). The radiometer was focused to sight an area of approximately 3 mm^2 immediately adjacent to the dot. During the run, the temperature of the sample was increased gradually and the dot observed with a suitable microscope. The melting of the dot defined the true temperature of the sample, while the radiometer reading at the same moment defined the brightness temperature. For Si and Ge, the measurements were extended to the temperature range above 700°C: In this case, the sample chamber was evacuated and the true temperature determined with an optical pyrometer corrected for Allen's emissivity data.[1]

Three main effects were investigated: (1) *Effect of the sighting angle.* In general, for the same true temperature, the brightness temperature was found to be lower when the sample surface was perpendicular to the axis of the radiometer lens than otherwise. A change of 50° in the sighting angle resulted in a change in brightness temperature of about 15°C for Si, 5°C for Ge, and 10°C for GaAs. (2) *Effect of sample thickness.* For Si, samples 1.5 mm

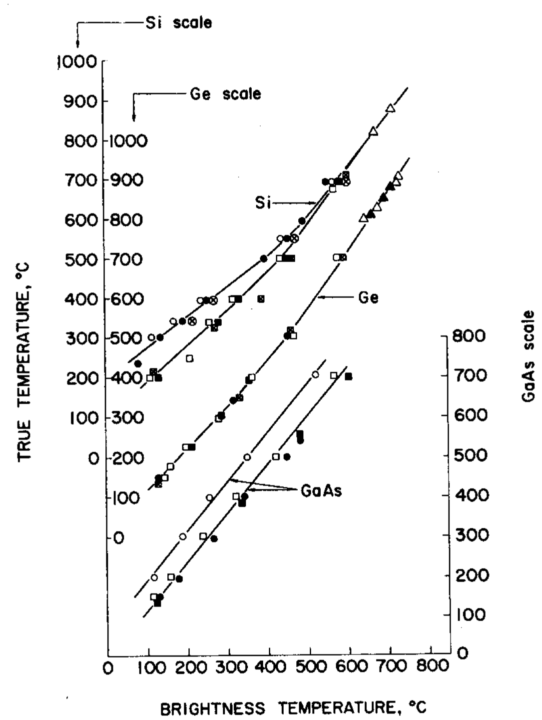

FIG. 1. True vs brightness temperature (2.0–2.6 μ). Circles refer to samples polished on both sides, squares to samples lapped on one or both sides, squares to samples lapped on one or both sides, triangles to measurements of samples with different thicknesses using an optical pyrometer (0.65 μ). Si—○: 0.4 mm thick; ●: 0.7 mm thick; ⊗: 1.5 mm thick. □: polished surface sighted (0.7 mm thick); ■: lapped surface sighted; ⊠: both sides lapped. Ge—●: 1.5 mm thick; □: polished surface sighted (0.4 mm thick); ■: lapped surface sighted; ⊠: both sides lapped (1.4-mm thick). GaAs—○: 0.5-mm thick. □: polished surface sighted (0.5-mm thick); ■: lapped surface sighted; ⊠ both sides lapped.