TABLE I

Sample orientation	(1 0 0)	(0 1 0)	(0 0 1)
ϵ (at 1.6 kHz)	10.67	10.71	10.13
	10.61	8.30	
ρ(at 1.6 kHz, Ω cm)	2.9×10^9	7.4×10^8	3.9×10^9
	3.5×10^9	3.6×10^9	
Loss tangent (tan 8 at 1.6 kHz)	0.037	0.143	0.029
	0.031	0.038	
Pyroelectric coefficient (C cm^{-2} ° C^{-1})	0	$\gtrsim 4.3 \times 10^{-10}$	0
Pyroelectric coefficient (after attempts to pole)	2.3×10^{-10}	1.8×10^{-10}	0
Hysteresis at 50 Hz	None	None	None

and spectrographic analysis [3] confirmed the formula (as $Na_2CO_3 2CaCO_3$) and the impurity content, except in the latter case some silicon and boron were present at a minimum level of 1000 p.p.m. by weight for the former and 10 p.p.m. by weight for the latter.

Evidence for pyroelectricity was sought by means of the charge integration technique and for ferroelectricity by seeking for dielectric hysteresis using a Sawyer–Tower circuit [4] modified to compensate for the saturation value of the sample capacitance [5]. The results of the measurements made at 20° C are as given in Table I.

These results indicate that the crystals exhibit only a weak pyroelectric effect if they exhibit the effect at all. The mineral has been assigned the acentric space group C2mm on the basis of previous data [1] but on present data this cannot be supported. An explanation of this discrepancy could be that the mineral is a solid solution between sodium carbonate and calcium carbonate. The relevant phase diagram between the two carbonates [6, 7], shows the solid forming as a double salt plus calcite. If this is the case small differences in composition between crystals and in a given crystal are likely to result. These can lead to differences in crystal structure [8] and hence differences in physical properties which are sensitive to structure such as the pyroelectric effect. Thus some samples of the mineral could have shown the pyroelectric effect, whereas others would not do so.

Acknowledgement

This article is printed with the permission of the Controller, HMSO.

References

1. J. J. FAHEY, US Geol. Prof. Paper **40** (1962) 22.
2. Courtesy of the Keeper, Dept of Minerology, British Museum.
3. Analytical Dept, BDH Ltd, Poole, Dorset.
4. A. M. Glass, *J Appl Phys* **46** (1969) 4699.
5. C. B. SAWYER and C. H. TOWER, *Phys Rev* **35** (1930) 269.
6. P. NIGGLI, *Zeit Anorg. Chem.* **98** (1916) 241.
7. *Idem, ibid.* **106** (1919) 126.
8. M. Y. KHAN, *J. Appl. Cryst.* **10** (1977) 70.

Received 13 February
and accepted 20 March 1978.

D. S. ROBERTSON
N. SHAW
I. M. YOUNG
Royal Signals and Radar Establishment,
Great Malvern,
Worcs., UK

Fatigue crack tip displacement observations

The continuing study of fatigue crack propagation mechanisms has brought about the need for measurements within the plastic zone at the crack tip. Plastic zone size and shape have been measured with electron channelling [1, 2], etching [3], interferometry [4], and several other techniques, and positive replies have been used to measure slip offsets, and therefore strains, very near the crack tip [5]. This note describes another technique for visualizing and measuring these crack tip displacements using a stereo viewer.

The technique was discovered during the analysis of photographs made during propagation of a fatigue crack within the scanning electron microscope, utilizing an especially designed cyclic loading stage [6]. Photographs of the crack tip

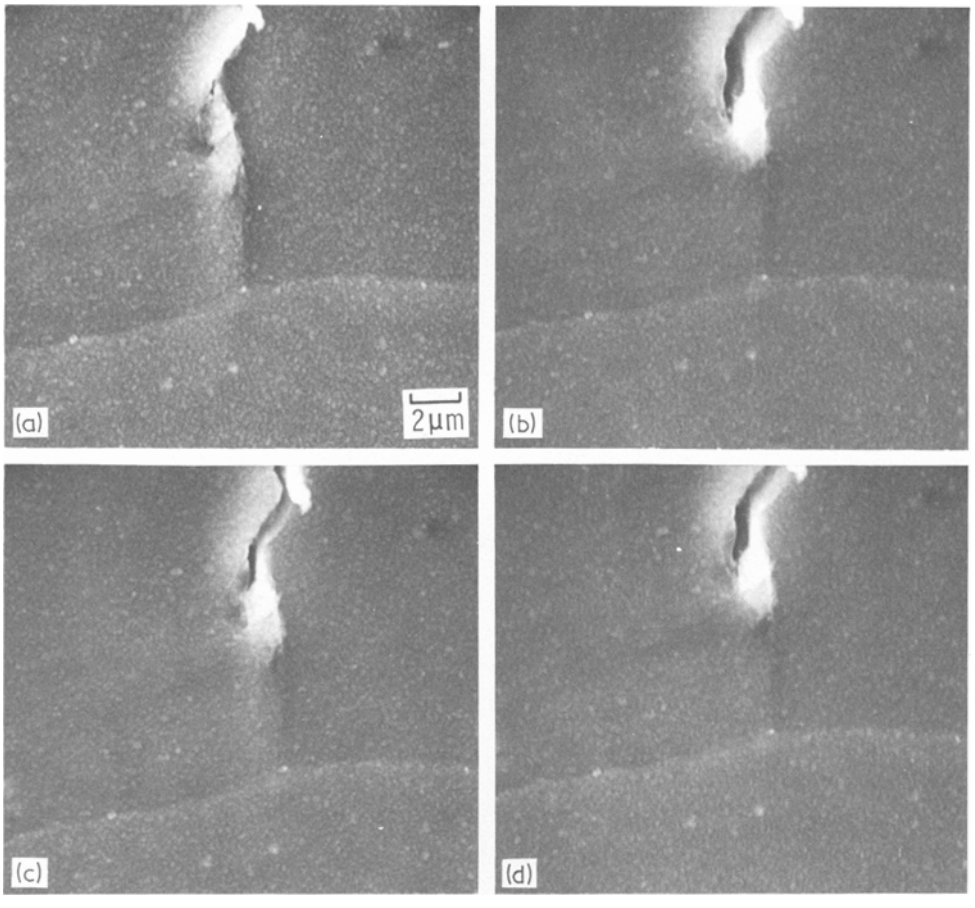

Figure 1 Stepped loading sequence for 2024-T4 aluminium alloy. (a) $K = 2\,MN\,m^{-3/2}$ (b) $K = 9.66\,MN\,m^{-3/2}$ (c) $K = 7.5\,MN\,m^{-3/2}$ load increasing (d) $K = 7.5\,MN\,m^{-3/2}$, load decreasing. All photographs at the same magnification and taken on the same load cycle.

made at different loads, such as shown in Fig. 1, may then be used to measure displacements in the crack tip region. Photographs have been made up to a magnification of 10 000 times, giving a resolution of better than 500 Å. Lower magnification photographs covering a larger area, while decreasing the usable resolution, give necessary additional spatial information and are most often used. The displacement field at the crack tip is visualized by placing photographs taken at two loading conditions in a stereo viewer. Displacements are visualized as changes in the third (z-axis) dimension, and may be measured using stereographic mapping techniques, such as are used in aerial photography. From this measurement of displacements, the spatial differential may be taken, giving strain.

The eyes see depth by detecting changes in perspective and changes in focal point. For stereo microscopy, the eyes detect depth through a change in focal position, with the larger angle between the eyes showing up as height ($+z$) in the stereo imaging of the two photographs. A convention must be adopted when using this method, and the convention used so far has been to put the condition producing the smaller displacement, usually the lowest load, on the left. The increased displacement, seen by the right eye then, will appear as a change in height, either $+z$ or $-z$, depending on the motion of sides of the crack and the orientation of the photographs. The stereo viewing technique visualizes displacements only along an axis described by the eyes, so measurements must be made on two axes, by reorienting

the photographs 90°, and then drawing the resultant total displacement. The axes may be chosen so that displacements perpendicular to (Mode I) and parallel to (Mode II) the crack direction may be directly resolved, with the resultant giving the weighting of the combination of the two opening modes and the material rotations which occur as the crack tip opens. The displacements associated with hysteresis (using two photographs made at the same load magnitude, but one made during loading, and the other during unloading) may also be measured using this stereo viewing technique. The reader is encouraged to reproduce Fig. 1, cut out the photographs and try the stereo viewing technique for himself to see the effects described above.

In summary, the simple technique described for observing displacements at crack tips by stereo viewing offers the following possibilities:

(1) Measurement of displacements at high resolution very close to the crack tip;

(2) Derivation of crack tip strain magnitudes;

(3) Division of displacements into those related to Mode I and Mode II loading;

(4) Measurement of hysteretic displacements due to cyclic loading;

(5) Measurement of the hysteretic, or cyclic, and total plastic zone size and shape due to cyclic loading with and without hold times.

All the above information may also be derived from replicas, either positive or negative as made by a variety of techniques, and photographed in the transmission or scanning electron microscopes, or it may be determined by directly loading the specimen in the SEM. The only limitation now known for the technique is that it allows crack tip deformation information to be determined only at the specimen surface, which is a limitation of most other techniques as well. Electron channelling and etching, however, may be used to measure interior plastic zone parameters, for some materials, on metallographic cross-sections [3, 7].

References

1. J. LANKFORD and D. L. DAVIDSON, *J. Eng. Mater. Technol. (ASME)* 98 (1976) 17.
2. D. L. DAVIDSON and J. LANKFORD, *ibid.* 98 (1976) 24.
3. G. T. HAHN, R. G. HOAGLAND and A. R. ROSENFIELD, *Met. Trans.* 3 (1972) 1189
4. G. R. CHANANI, Air Force Materials Laboratory Report AFML-TR-76 (1976).
5. J. LANKFORD and J. G. BARBEE, *J. Mater. Sci.* 9 (1974) 1906.
6. D. L. DAVIDSON and A. NAGY, *J. Phys. E: Sci. Instrum.* **11** (1978) 207.
7. D. L. DAVIDSON, *Int. J. Fracture* **11** (1975) 1047.

Received 11 April
and accepted 12 May 1978.

DAVID L. DAVIDSON
Southwest Research Institute,
San Antonio,
Texas 78284, USA

Experiments on the stoichiometry of UCo_2

Several preparations of this cubic Laves phase have been made in the course of investigations principally concerned with measurements at low temperatures. The physical property data obtained are presented and discussed elsewhere [1]. The purpose of this note is simply to record some interesting features of their preparation and characterization. The experimental variable was the Co/U ratio. The values of the ratio quoted below are probably not of fundamental significance since the true stoichiometric ratio will probably differ slightly from nominal owing to impurities in the source metals and losses in preparation. However, special care was taken to keep preparation conditions constant as far as possible, so that *relative* values of Co/U are significant.

Samples weighing approximately 1.5 g were made by arc-melting together high-purity cobalt and uranium (Johnson Matthey "Specpure" grade), and casting attempted by the suction-casting process [2, 3], using a mould with cylindrical cavity 1.6 mm in diameter and 18 mm high. At this point, marked variability in fluidity was noticed, such that casting was difficult or impossible near a Co/U ratio of 1.98. Further observations of partial running of the alloy (Fig. 1) indicated that a critical composition occurred at a Co/U ratio between 1.97(5) and 1.98(0). This ratio coincided, within the limits of experimental error, with a