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Detection of dislocation by the moiré pattern in electron micrographs.

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By using an electron microscope of the highest resolution, Menter (1956) observed dislocations in direct images of 12 Å net spacings in crystal lattice of platinum and copper phthalocyanine. The present note deals with the detection of dislocations by the moiré pattern which can be observed by electron microscopes of lower resolution.

A moiré pattern is a coarse mesh pattern which is produced when two fine mesh are superimposed. The one-dimensional moiré pattern is easily demonstrated: draw two sets of equally spaced parallel lines on separate sheets of transparent paper, place one on the other and slowly rotate one with respect to the other; a changing moiré pattern is obtained. Moiré spacing s is given approximately by

$$s = d/\theta\,, \qquad (1)$$

where d is the spacing of the parallel lines and θ the angle of rotation. Moiré patterns are produced not only by rotating but also by inclining the meshes towards each other.

Moiré patterns on superposed atomic lattices were first reported by Mitsuishi, Nagasaki & Uyeda (1951), who observed moiré patterns on thin sheets of graphite crystal by an electron microscope.

Recently we found dislocations in moiré patterns on thin cupric sulphide crystals. Fig. 1(*a*) shows a region wherein the crystal lattice is almost perfect and Fig. 1(*b*) a region containing several dislocations. Figs. 1(*c*), (*d*) and (*e*) show highly magnified pictures of isolated and coupled dislocations. It is interesting that a single dislocation in a moiré pattern corresponds to a single dislocation in an atomic lattice. This fact is proved by the following demonstration: Fig. 2(*a*) is a model of net planes having a dislocation near its centre and in Fig. 2(*b*) there is no dislocation. Superpose these figures and slowly rotate one with respect to the other. Then a single dislocation is observed in the moiré pattern independent of the angle of rotation, i.e. independent of the moiré spacing (Fig. 2(*c*) and (*d*)). Coupled dislocations (Fig. 1(*d*) and (*e*)) are also demonstrated by suitable models (Fig. 2(*e*) and (*f*)). In Fig. 3 many moiré dislocations of the same sign are appearing along a curve, indicating a small-angle tilt boundary (Burgers, 1939). It is most interesting that atomic dislocations which are too fine to be observed by present-day electron microscopes can be detected through the moiré pattern.

It was pointed out by Kainuma (1956) that if a moiré pattern is produced by two inclined crystal sheets, a screw dislocation nearly normal to the sheets produces a moiré dislocation also. By the selected-area diffraction method, however, it was proved that the present moiré pattern was caused by rotated crystal sheets, as was studied by Seki (1953) for a moiré pattern on sericite. The measured angle of rotation is $\theta = 0{\cdot}018$ rad. and the observed moiré spacing is $s = 100$ Å. The net plane causing the moiré pattern is (11.0) of the cupric sulphide crystal and the spacing is $d = 1{\cdot}88$ Å. These values satisfy equation (1). Thus the moiré dislocations in Fig. 1 are without doubt caused by edge dislocations nearly normal to the crystal sheets.

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Unit-cell parameters and space group of bisacetylacetoneberyllium.

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Bisacetylacetoneberyllium, $Be(C_5H_7O_2)_2$, was reported by Jaeger (1914) to be monoclinic prismatic with

$$a:b:c = 1{\cdot}4765:1:1{\cdot}3592;\ \beta = 52^\circ\ 20'\,.$$

From Weissenberg photographs taken using Cu $K\alpha$ radiation a different unit cell has now been chosen as preferable. This cell has the dimensions

$$a = 13{\cdot}45\pm0{\cdot}06,\ b = 11{\cdot}30\pm0{\cdot}04,\ c = 7{\cdot}74\pm0{\cdot}05\ \text{Å};\ \beta = 100{\cdot}8\pm0{\cdot}1^\circ\,,$$

a and c being the two shortest distances between lattice points in the (010) plane. Jaeger's c is double the new c and his a is the new $[\bar{1}01]$. Calculating from the new cell dimensions, we get

$$[\bar{1}01]:b:2c = 1{\cdot}48:1:1{\cdot}37$$

and the angle between $[\bar{1}01]$ and c is 52·2°, agreeing well with Jaeger's determination.

The only systematically absent X-ray reflexions are ($0k0$) with k odd. The space group is therefore $P2_1$ or $P2_1/m$. Since the density is 1·164 g.cm.$^{-3}$ (Jaeger, 1914), there are four molecules in the unit cell ($\varrho_{\text{calc.}} = 1{\cdot}19 \pm 0{\cdot}02$ g.cm.$^{-3}$).

I do not intend to proceed with analysis of the structure of this compound. I thank Prof. W. Wardlaw for the gift of a specimen of bisacetylacetoneberyllium.

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The crystal structures of PuAs, PuTe, PuP and PuOSe.*

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Compounds of the MX type containing plutonium and the metalloid elements arsenic, tellurium, and phosphorus have been prepared, and their common crystal structure has been identified. These compounds are of the NaCl type, isostructural with the analogous uranium compounds (Ferro, 1954; Iandelli, 1952; Zumbusch, 1941).

Preparation of the compounds was carried out by induction heating of small samples (5–10 g.) under vacuum or in a helium atmosphere of slightly less than atmospheric pressure. Attempts to prepare compounds containing some atomic percentage of plutonium other than 50 were not successful. The combination of the constituents on heating resulted in every case in a strongly exothermic reaction. It is concluded, therefore, that the MX compounds are quite stable. They appear to undergo decomposition, rather than melting, in the neighborhood of 2000° C. If other compounds of plutonium with the same metalloid elements exist, it seems likely that they are less stable than the MX compounds and would, therefore, have been decomposed at the temperature of the strongly exothermic reactions that in every case resulted in the formation of an MX compound only.

The unit-cell dimensions (Cu rays, resolved doublets, $\alpha_1 = 1{\cdot}54051$, $\alpha_2 = 1{\cdot}54433$ Å) and calculated densities for the MX compounds are

	a_0 (Å)	ϱ (g.cm.$^{-3}$)
PuAs	5·855±0·004	10·39
PuTe	6·183±0·004	10·33
PuP	5·644±0·004	9·87

It was not found possible by the method employed to prepare an MX compound with selenium; the Debye pattern of a plutonium–selenium product indicated, however, the presence of a new phase that was not immediately identified. This product was subsequently found by W. H. Zachariasen (unpublished) to be PuOSe, which has the tetragonal PbFCl structure with unit cell dimensions

$$a_1 = 4{\cdot}151 \pm 0{\cdot}003,\quad a_3 = 8{\cdot}369 \pm 0{\cdot}005 \text{ Å}$$
$$(\text{Cu } K\alpha = 1{\cdot}5418 \text{ Å})\,.$$

The calculated density is 7·69 g.cm.$^{-3}$.

The diffraction data for PuOSe appear in Table 1. No further work on this compound is contemplated.

Table 1. *Diffraction data for* PuOSe

hkl	$(\sin^2\theta)_o$	$(\sin^2\theta)_c$	I_o
002	0·0347	0·0339	*w*−
101	0·0439	0·0430	*m*+
102	0·0702	0·0684	*w*
110		0·0690	
003	0·0785	0·0762	*w*
111		0·0775	
112	0·1044	0·1029	*s*
103	0·1122	0·1107	*m*
004	0·1397	0·1355	*wm*
200		0·1380	
113	0·1471	0·1452	*vw*
201		0·1465	
104	0·1730	0·1700	*w*
202			
211	0·1827	0·1810	*m*−
203	0·2162	0·2142	*w*
105	0·2509	0·2462	*ms*
213		0·2487	
204	0·2782	0·2735	*w*
220		0·2760	
115	0·2829	0·2807	*vw*
214	0·3104	0·3080	*w*−
301	0·3198	0·3190	*vw*
106	0·3411	0·3394	*w*
302	0·3478	0·3444	*vw*
310		0·3450	
205	0·3544	0·3497	*w*
223		0·3522	
311		0·3535	
116	0·3759	0·3739	*vvw*
312	0·3810	0·3789	*w*
215	0·3869	0·3842	*w*
303		0·3867	
224	0·4139	0·4115	*vw*
313	0·4238	0·4212	*vw*
321	0·4589	0·4570	*w*−
216	0·4790	0·4774	*m*
323	0·5257	0·5247	*m*
207	0·5557	0·5529	*w*
108	0·5778	0·5766	*w*−
308	0·8537	0·8526	—
431, 501	0·8709	0·8710	—
1,0,10	0·8815	0·8815	—
416	0·8929	0·8914	—
336	0·9261	0·9259	—
433, 503	0·9373	0·9387	—

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