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NOTE

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Hardness anisotropy of L-arginine phosphate monohydrate (LAP) crystal

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Abstract : Deformation characteristics of an important non-linear material, L-arginine phosphate monohydrate (LAP) was studied by measuring the anisotropy of Knoop microhardness on (100) cleaved plate of LAP for various loads It was found that the low load deformation is mainly due to the slip system {100} <011> whereas the higher load deformation is dominated by twinning

Keywords : L-arginine phosphate monohydrate, Knoop microhardness

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L-arginine phosphate monohydrate (LAP) with the chemical formula $[H_2N]^+CNH(CH_2)_3$ $CH[NH_3]^+COO^-H_2PO_4^-H_2O$, is a promising nonlinear optical (NLO) material discovered by Chinese scientists Xu *et al* [1]. The attractive features of this material are its high damage threshold ($\geq$ 15 J/cm^2 at 20 ns), large nonlinearity ($\geq$ 1 pm/V) and the ease with which large crystals of high optical quality can be grown [2,3]. So, it has the potential to replace potassium dihydrogen phosphate (KDP), the material most commonly used for frequency conversion of infrared lasers in the harmonic frequency generation for laser fusion experiments. As a part of our project work on this important NLO crystal, we have already reported the growth and characterization of LAP [4]. In the present note, we report the anisotropy of Knoop microhardness on (100) cleaved plate of LAP.

For these studies, a (100) cleaved plate of LAP grown in this laboratory, was taken and polished with water to make the test face flat. A mhp 160 microhardness tester, fitted with a Knoop indentor and attached to a Carl-Zeiss (Jenavert) incident light research microscope, was used for the measurement of microhardness. The hardness anisotropy was measured by applying a minimum of five indentations for each load at an interval of 15° and over the range of 0–165°. The zero degree orientation of the long Knoop indentor diagonal is parallel to [010] and was established by the macrosteps that form along the direction [010] [5]. The load was varied from 10 gm to 50 gm and the indentation period was kept constant at 10 S. Owing to the microcracks at the corners of the impression, the maximum load applied was 50 gm. The Knoop hardness was calculated from the usual formula [6]

$$H_K = 0.014228 \times P/d^2 \text{ gm mm}^{-2}$$

using the known test load P (gm) and the measured length d (mm) of the long diagonal of the indentation

Figure 1 shows the Knoop microhardness (H_K) measured on the cleavage (100) plane of LAP with 10 gm normal load in air at different orientations of the indentor. Rotating the crystal from 0° to 165°, hardness was found to decrease from a high of 66.40 at 0° to a low of 31.31 at 45° and then there is a further increase in hardness upto 150°, though no sharp maximum is found in between.

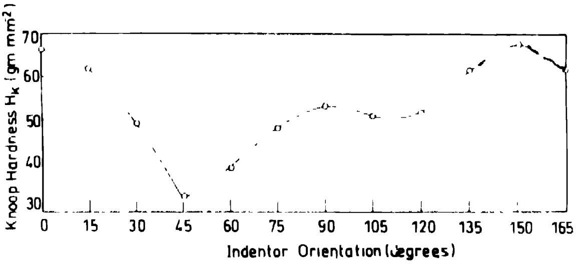

Figure 1. Variation of Knoop microhardness (H_K) with indentor orientation on the (100) cleavage plane of L-arginine phosphate monohydrate (LAP) at 10 gm load

Figure 2 shows the load dependence of the Knoop microhardness for the two indentor orientations [010] and [011] on the (100) plane. Initially, the hardness number (H_K) decreases with load for both indentor orientations and maintains a constant ratio upto P = 20 gm, that is the relative microhardness apparently is independent of load in this range. But in the high load region above P = 20 gm, the difference in hardness number (H_K) between the two orientations becomes more pronounced and also the hardness number increases for [011] orientation upto a load P = 50 gm, but for [010] orientation the variation of H_K is slightly different from that of [011] orientation. The result is found disputable with the observations made by different investigators on different crystals which generally have shown that the microhardness either increase or decrease with load at low loads and subsequently attains a fixed value at higher loads. The explanation for this type of behaviour observed here is due to the different types of slip systems that are operative with increase in load. To get a clear understanding of this behaviour, an additional study of hardness anisotropy at 50 gm load was undertaken and it was observed that the variation in hardness at this test load is somewhat different from that with load 10 gm (Figure 1) The variation of Knoop microhardness (H_K) at different orientations of the indentor on cleavage

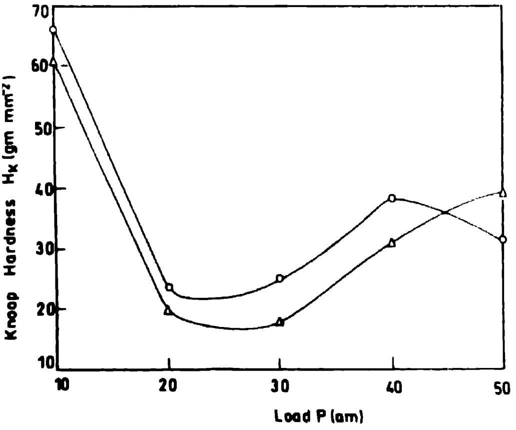

Figure 2. Variation of Knoop microhardness (H_K) with load (P) on the (100) cleavage plane of L-arginine phosphate monohydrate (LAP) for two different orientations of indentor 0°–O, 135°–Δ

(100) plane of LAP for these two loads 10 gm and 50 gm is presented in Figure 3. This shows different degrees of plastic deformation by twinning and slip at the two loads. The

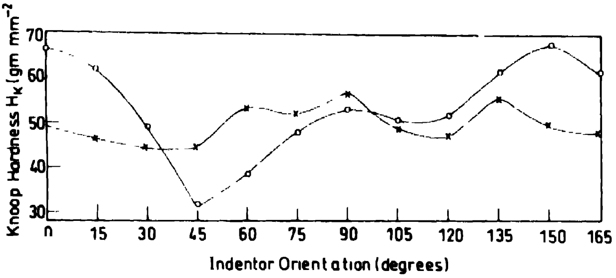

Figure 3. Variation of Knoop microhardness (H_K) with indentor orientation on the (100) cleavage plane of L-arginine phosphate monohydrate (LAP) at 10 gm (O) and 50 gm (x) loads

low load deformation is mainly caused by slip where as the higher load deformation is dominated by twinning. The low load hardness anisotropy could be explained by slip on the (100) [011] system.

In conclusion, plastic deformation in organic nonlinear optical crystal LAP occurs as a result of either slip or twinning and the relative contribution depends on the magnitude of load.

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