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**NOTE**

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# Knoop hardness studies on benzoic acid crystals

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**Abstract** : Knoop microhardness studies were carried out on benzoic acid single crystals. The hardness *versus* load plot shows two peaks at 3 gm and 6 gm loads having hardness value of 6.2 kg/mm$^2$ each. This corresponds to the first peak at 20 gm load observed with pyramidal hardness studies. The peak was due to the slip plane in the (100) [010] direction. The present observation suggests that the (100) [010] dislocations split into partials.

**Keywords** : Knoop indentation, microhardness, benzoic acid

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Molecular solids are divided into two broad categories, the plastic and the non-plastic. Plastic crystals have nearly spherical molecules forming a cubic or a highly symmetric crystal structure [1]. The non-plastic crystals consist in general of non-spherically symmetric molecules which pack together as closely as the geometry allows to define a crystallographic structure. These solids are difficult to deform plastically at normal ambient temperatures and pressures in the bulk. For these materials, the study of plastic deformation produced by point loading is of practical importance as the results can be related to mechanical properties.

Single crystals of benzoic acid were grown from the melt by the Bridgemann method. The starting material was column chromatographed, twice vacuum sublimed and zone-refined. The material was transferred to the crystal growth tubes without exposure to the atmosphere [2]. The crystals were cleaved in the usual manner using a sharp blade.

Smooth (001) cleavages were selected after optical examination. The crystals were indented on a Carl Zeiss NU2 Universal Research Microscope.

Indents were made with a Knoop Indenter. Loads ($P$) varied from 1.25 gm to 17.5 gm in small steps. A number of indents were made at each load. The long diagonal length was used in calculating the Knoop Hardness Number (KHN) using the formula

$$\mathrm{KHN} = 14228.8 \times P/d^2, \quad (1)$$

where $P$ is the applied load in gm and $d$ the mean long diagonal length in μm. The indentation time of 10 s was kept constant. The crystal size was much larger than the indentation sizes, thus eliminating the boundary effects on the results. The distance between the indents was five times the size of the largest indentation mark. The crystal thickness was relatively more such that the indenter did not sense the lower surface [3]. A number of crystals were studied.

Figure 1 shows the hardness variations with load for benzoic acid. The plot exhibits two peaks very close to one another and having the same hardness value at loads around 3 gm and 6 gm.

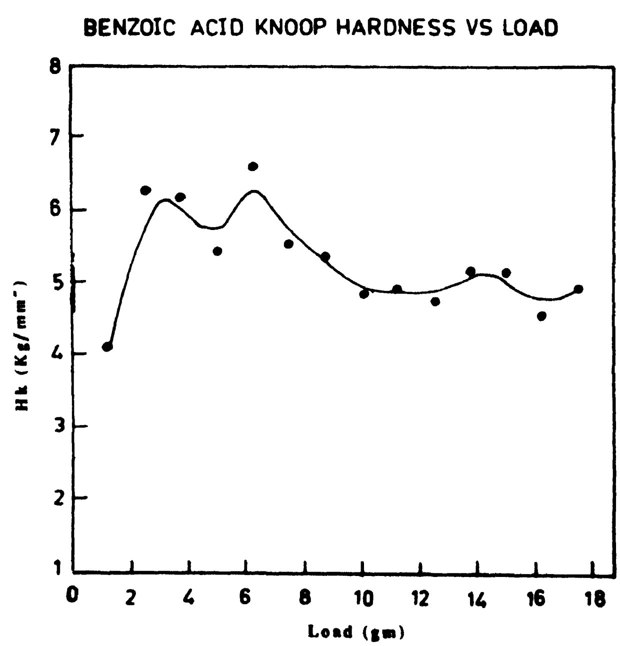


**Figure 1.** Hardness variation with load.

There are a few papers on the pyramidal hardness of some organic and inorganic molecular solids [4–6]. In all these studies one observes that the load variation has been studied using the standard set of weights available in the weight box. Some detailed studies have been done using weights having small differences [7]. These studies show that the plots of hardness variation with load is just not a curve which decreases or increases at low loads and then remains steady but exhibits two and sometimes three peaks. These peaks have been accounted for slip taking place on different planes slipping in a common direction.

There are no studies on the hardness variation with load using a Knoop Indenter in organic molecular solids to the best of the authors knowledge.

The hardness of a material depends on its plastic and elastic properties. For Knoop indentation, elastic recovery takes place in the short diagonal only and the long diagonal does not change when the load is removed. When a loaded indenter penetrates a material, the depth of penetration increases until the condition of the lattice immediately below the indenter has the same characteristics as that of a specimen in which saturation value of the compressive strain has been attained. The strain becomes progressively smaller with increasing distance from the center of the material to a distance equal to the length of the long diagonal.

Pyramidal indentation studies on the (001) cleavages of benzoic acid single crystals show two peaks in the plot of the hardness with load at 20 gm and 80 gm with the Vicker's Hardness values being 6.02 kg/mm$^2$ and 5.70 kg/mm$^2$ respectively [8]. These two peaks have been assigned due to the dislocation of the type (100) [010] and (010) [100].

Knoop indentation studies could be carried out only for load upto 20 gm at small intervals. Studies at higher loads caused the length of the long diagonal to become large and out of the measuring view. When the Knoop hardness values are plotted against these loads, two peaks very close to each other at 3 gm and 6 gm load are observed with a hardness value of 6.2 kg/mm$^2$ for each peak.

The first peak in the pyramidal hardness studies has been assigned to dislocations of the type (100) [010] which occurs at 20 gm load having a hardness value of 6.2 kg/mm$^2$. As the hardness value is the same as that in the pyramidal hardness studies and the peaks occur at lower loads than that of the pyramidal hardness curve of hardness against load, it is conjectured that the dislocation (100) [010] splits into partials as has been said to occur in anthracene [9].

The conclusions are :

1. The Knoop hardness variation with load gives rise to two peaks very close at 3 gm and 6 gm load with a hardness value of 6.2 kg/mm$^2$.
2. These two peaks are caused due to the splitting of the (100) [010] dislocation into partials.

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