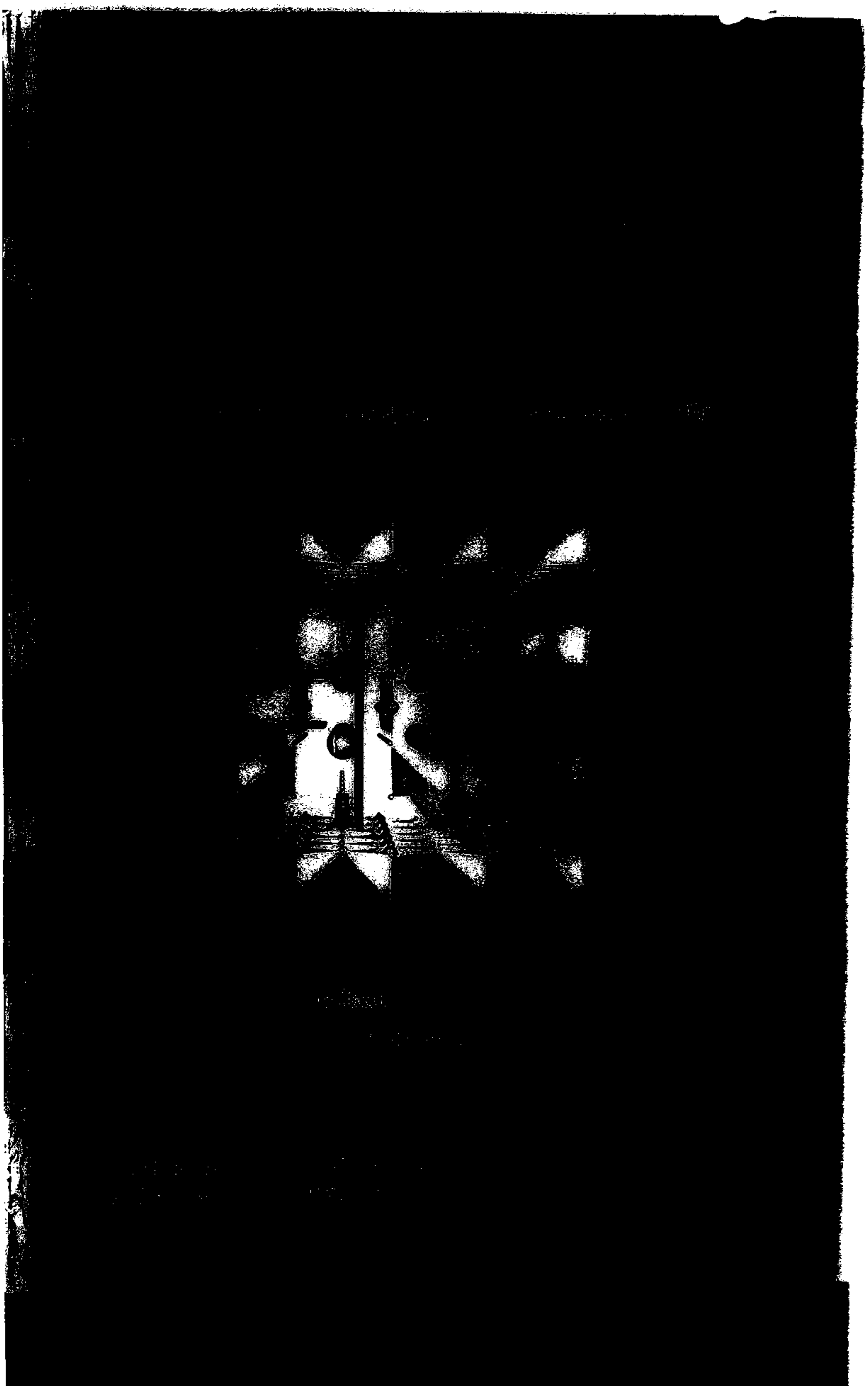

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Low Field and Deformation Effects on T_c and Crystal Structure of BSCCO Superconductors

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High temperature superconductors of Bi–Sr–Ca–Cu–O compounds have been prepared alone or substituted [illegible] and Al. The solid state reaction method is used for sample preparation. At no f[illegible] the influence of three different deformation levels (below [illegible]Pa, 44-[illegible]MPa and [illegible]100 MPa) on T_c (onset) and T_c (zero) and crystal structure have been investigated. The best effect of deformation level is found to be at [illegible]MPa. This leads to an increase on T_c (onset) to 135K. No effect of magnetic field has been detected on T_c (onset). Higher magnetic field, however, reduces T_c(zero) values.

I. INTRODUCTION

When a material is stressed below its elastic limits, the resulting deformation or strain is temporary. The removal of the applied stress returns the specimen gradually to its original dimensions. On the other hand if a material is stressed beyond its elastic limits, plastic deformation takes place, and it will not return to its original shape by the application of force alone [1].

A mechanical deformation may depress the distance between the Bi-O layers, leading to a decrease in the distance of Cu-O planes, for a stress applied in the c-direction, a decrease in the buckling of [illegible]-O layers in c-axis will occur. Changes in lengths along a and b axes are also expected. Accordingly, one may observe a change in the properties of the sample such as T_c (onset), T_c (zero), energy gap and electrical resistivity of the superconductor. Additionally the coefficient of thermal expansion and bulk modulus of elasticity may be changed due to the influence of deformation [2].

II. EXPERIMENTAL TECHNIQUES

A. Sample Preparation

The samples were prepared by the solid state reaction method using highly pure powders of $(BiO)_2$ CO3, Sr CO_3, CaO, CuO, PbO, and Al_2O_3 with 99.9% purity. Three types of superconductor systems were obtained, namely:

Bi-Sr-Ca-Cu-O, Bi-Pb-Sr-Ca-Cu-O, and Bi-Al-Sr-Ca-Cu-O.

The methods have been described elsewhere [3].

B. Deformation Technique

By using a hydraulic press from SPECEC Ltd., U.K., the influence of pressure on Tc(onset) and Tc(offset) was investigated. Three ranges of hydrostatic pressures were applied on the superconducting pellets : (a) low level ($P<20$ MPa), (b) medium level ($P<40<50$ MPa), and (c) high level ($60<P<100$ MPa).

C. Resistivty Measurement

The resistivity of superconducting samples [cut as pellets into 10 mm x5mm rectangular shape] was measured by using four-probe technique as described in Ref. [3,4].

D. X-Ray Diffraction

The structure of the prepared sample was obtained by using x-ray diffraction for ground pieces of the sample adhered to glass substance. The x-ray diffractometer type (Philips) has been used (see ref. [4]).

III. RESULTS

A. Effect on T_c and Crystal Structure

The low level of deformation did not affect the T_c and the crystal structure of 2223 samples. The structure of such compounds was strong enough against low level of deformation. At medium level, a deformation caused by 44 MPa for 5hr shows the following behaviours:

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A. Effect on T_c and Crystal Structure

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1) The 2223-Bi sample showed on increase in T_c (onset) for both phases from (90-110K) to (115-135K) as in (Fig. 1). This is attributed to the change in the lattice parameters. Using X-ray diffraction (Fig. 2) a, b and c parameters were calculated. The a and b lattice parameters were changed from a = 5.394 Å to 5.214 Å and b = 5.346 Å to 5.679 Å, the c-parameter was kept constant at 35.146 Å. The increase in b-axis increases the flatting state of Cu-O layers which in turn leads to an increase of T_c (onset). The increase in peak intensity is due to a rotation of unit cell, which again increases the degree of crystallization. While the appearance of the two new peaks in XRD pattern due to this deformation indicates another phase caused by the twinned structure. This twinning is formed during the time under which the pressure was applied. That could somewhat divide the ordered structure into two types because of the arrangement of atomic position repeated in every unit cell length. The first affected atoms in structure are oxygen atoms which depress their positions inwards. This mechanism may somewhat form the domains of oxygen vacant twin boundary which represents a cleavage or a road to Cooper pairs. We can, therefore, conclude that b-axis in 2223-Bi system plays an important role in increasing T_c (onset) as in c-axis suggested by Tarascon [3].

2) The 2223-Pb 0.35 system under deformation by 44 MPa for 5hr has sharper drop with transition width (10 K) (Fig. 3). The lattice parameter, however, is unchanged. This is attributed to the influence of deformation [4]. In doped samples with Pb, it is assumed that Bi-O layers are more flat which lead to higher strength against the deformation. The increase in T_c (zero) by (10K) is due to increase the crystallization level exhibited as an increase in intensity of XRD peaks (Fig. 4).

3) In 2223-Pb 0.4 system, the deformation on T_c(onset) [not on T_c(zero)] decreases the T_c(onset) from 125 K to 120 K (Fig. 5). This phase is unsuitable with this doping. Also the magnetic field affects T_c(zero) of this compound to lower temperature range but the strong shift to 35 K occurs at 0.9 Tesla. As explained above, the XRD pattern [Fig. 6] is used to indicate the effect of deformation on a,b and c axis. The results show a decrease in c-axis from 35 Å to 33.379 Å.

4) In Al-doped system, we see a different influence with higher or low doping rate. At higher doping rate (0.8 Al) for 2223-Bi system, deformed by 44 MPa for 5hr leads to disappearance of the super- conducting to semiconductor-state (Fig. 7). An explanation of these changes may come from the localization of charge carriers due to distortion in crystal structure by deformation.

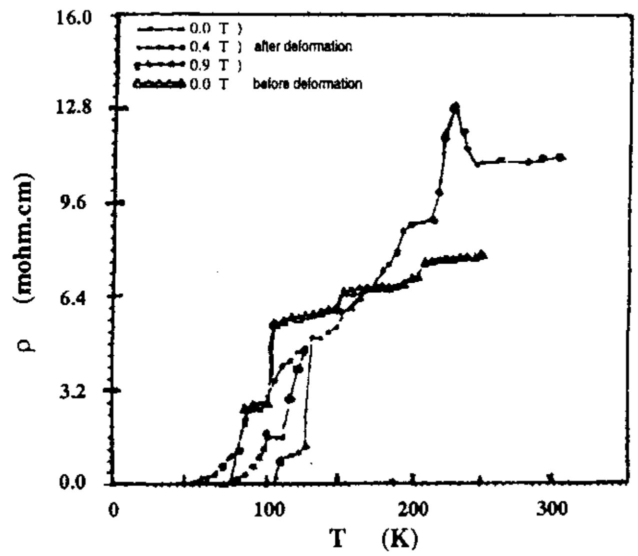

Fig. 1. The resistivity vs temperature for $Bi_2Sr_2Ca_2Cu_3O_{10}$ deformed by 44 MPa with different magnetic fields.

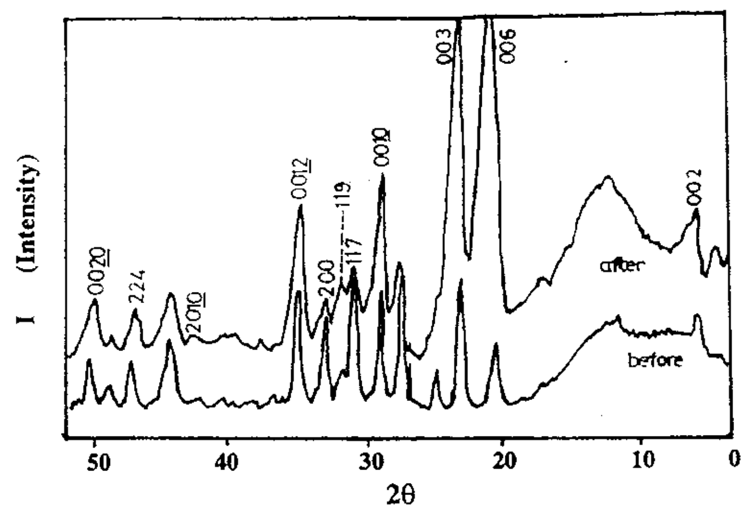

Fig. 2. XRD pattern of 2223-Bi sample deformed by 44 MPa for 5h.

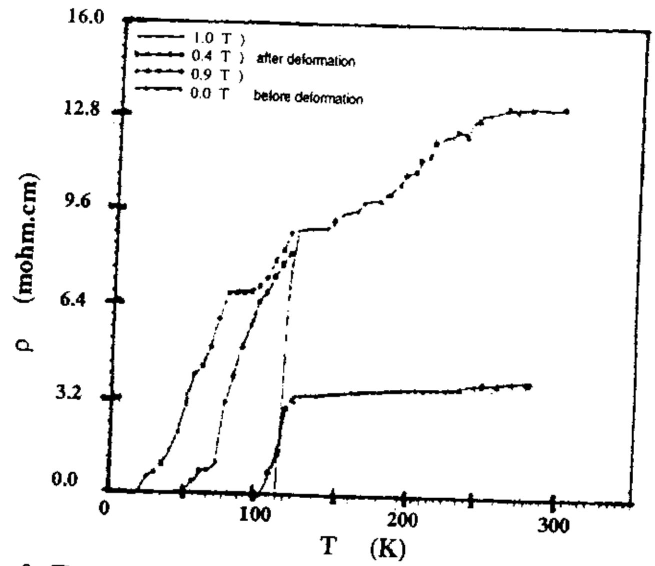

Fig. 3. The resistivity vs temperature for $Bi_{1.65}Sr_2Ca_2Cu_2O_{10}$ deformed by 44 MPa with different magnetic fields.

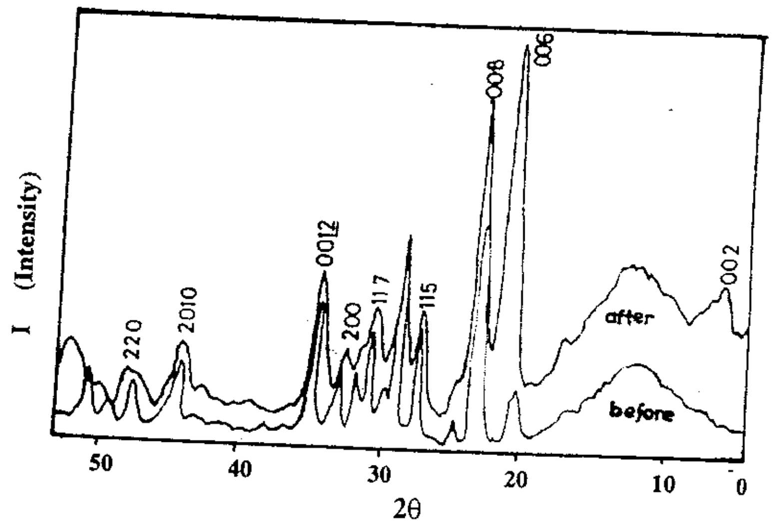

Fig. 4. XRD pattern of (2223-Bi) doped with $Pb_{0.35}$ and deformed by 44 MPa for 5h.

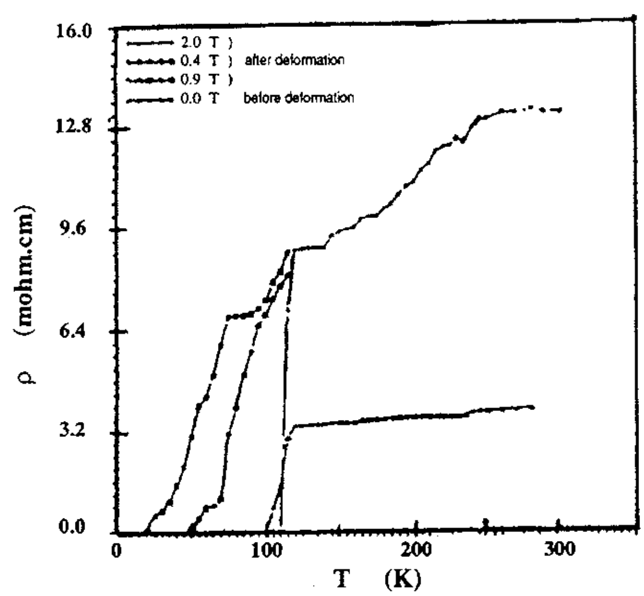

Fig. 5. The resistivity vs temperature for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10}$ deformed by 44 MPa with different magnetic field.

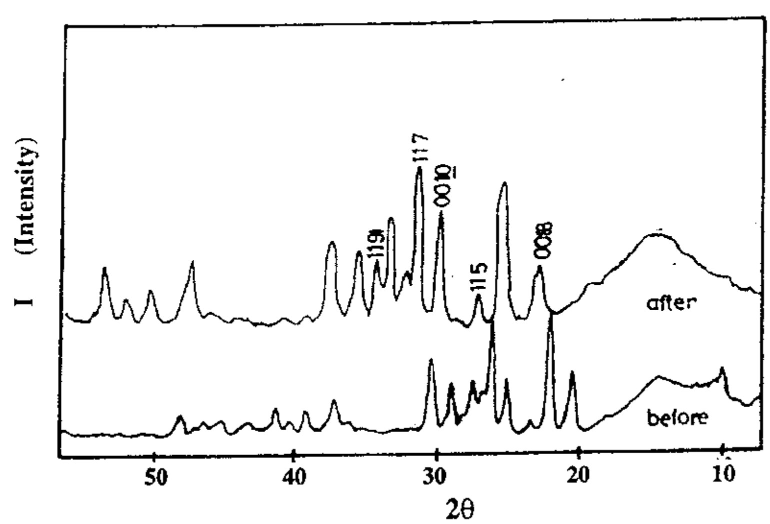

Fig. 6. XRD pattern of (2223-Bi) doped with $Al_{0.8}$ and deformed by 44 MPa for 5h.

For low Al-doped Bi_2-$Al_{0.1}$-Sr_2-Ca_2-Cu_3-O_{10} system an increase in the T_c (zero) from 60 to 80K occurs and then a sharper drop (Fig. 8). This is indicated by the increase in peak intensity of XRD pattern (Fig. 9). This is explained by the tendency for localization of carriers, which are stimulated by disorder introduced as a result of deformation. Such static defects predominate in Cu-O and Bi-O layers because this layers are sensitive to produce the super- conducting properties. Table I summarizes the effect of medium deformation on superconducting properties of the above samples.

Table I. T_c (onset) and T_c (offset) for medium deformation of different systems.

Sample	Pressure level MPa	T_c (on) – T_c (off) Undeformed (K)	T_c (on) – T_c (off) Deformed (K)
2223-Bi	44	110, 90 - 75	115, 135 - 105
2223-$Pb_{0.35}$	-	120 - 100	120 - 110
2223-$Pb_{0.4}$	-	125 - 105	120 - 105
2223-$Al_{0.1}$	-	110 - 60	115 - 85
2223-$Al_{0.2}$	-	80 - 50	-
2223-$Al_{0.8}$	-	100 - 80	-

As the level ofdeformation is gradually increased (i.e. to 68, 78, 88, 98 MPa) both T_c (onset) and T_c (zero) of 2223-Bi system decreases. The transition temperature goes down as in Fig. 10, which can be explained as follows:

The deformation level beyond 50 MPa produces a damage in the weak links, between grains, due to displacement of light atoms, i.e., oxygen. Such atoms has a weak bonds in crystal which lead to a change or distortion in the arrangement of atoms.It thus introduces interplanar defects in such away that the d-spacing between layers is buckled.

On the other hand, the long time of deformation (5hr) leads to a shift the in the peaks of XRD pattern. It results in the variation of the lattice constant which means that shift the atoms with long bond in the deformation direction.

This then minimizes or buckles the bond such as Sr-O bond which is 2.739 Ålong [4]. This volume variation leads to closer atoms and increases the link between the atoms. It thus increases T_c (zero). Zeng et al [5] believe

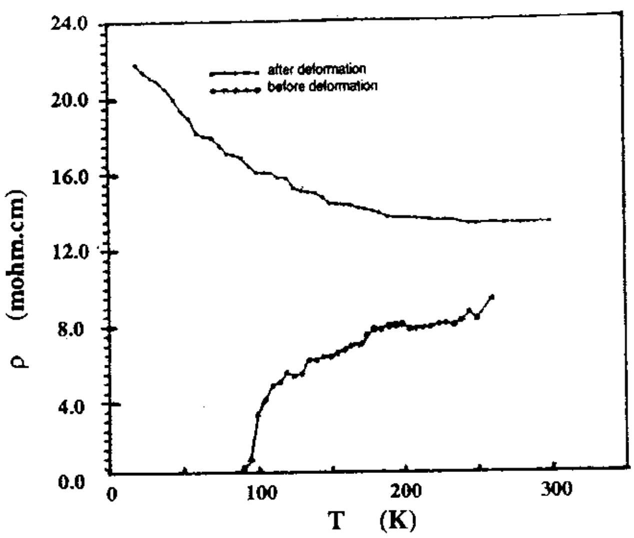

Fig. 7. The resistivity vs temperature for $Bi_2Al_{0.8}Sr_2Ca_2Cu_3O_{10}$ deformed by 44 MPa.

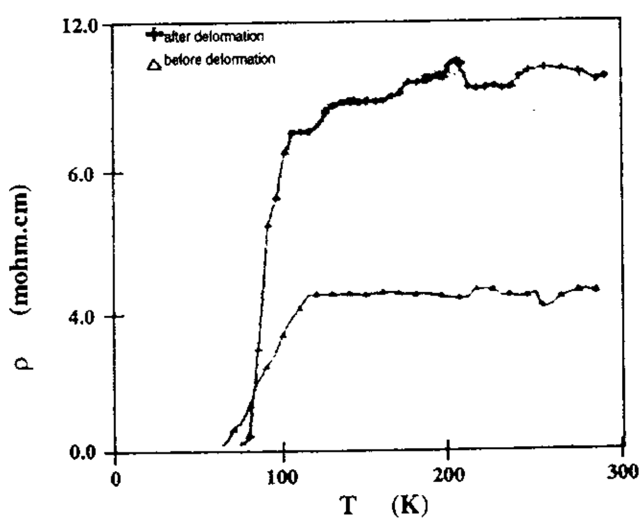

Fig. 8. The resistivity vs temperature for $Bi_2Al_{0.1}Sr_2Ca_2Cu_3O_{10}$ deformed by 44 MPa.

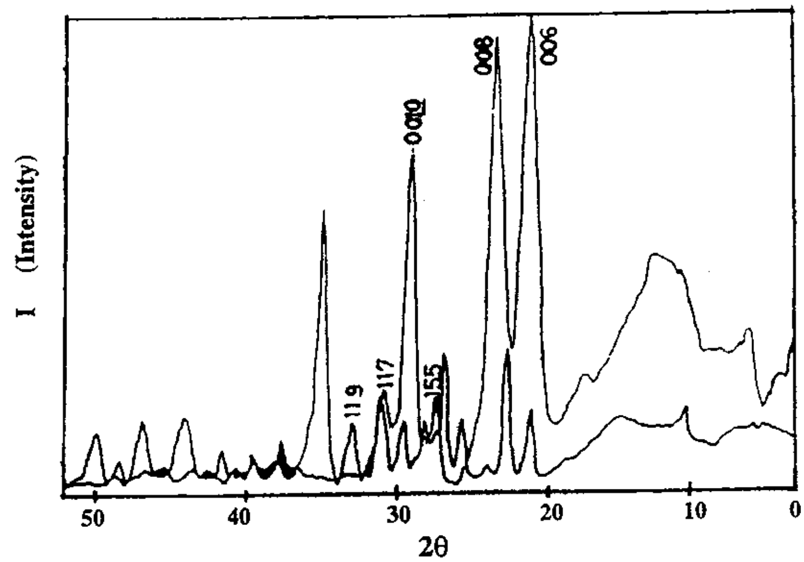

Fig. 9. XRD pattern of (2223-Bi) doped with $Al_{0.1}$ and deformed by 44 MPa for 5h.

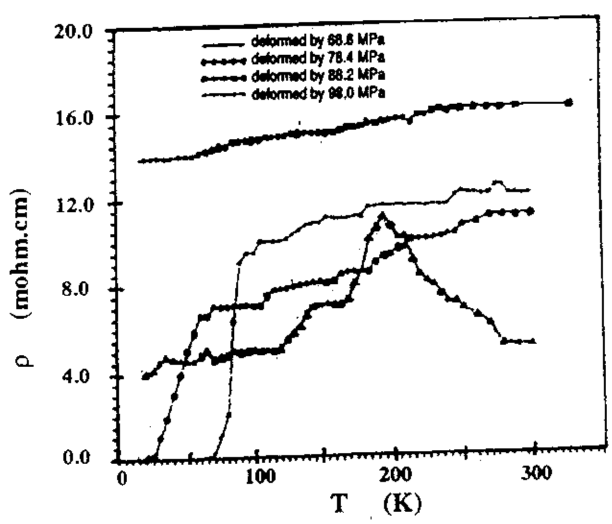

Fig. 10. The resistivity vs temperaure for $Bi_2Sr_2Ca_2Cu_3O_{10}$ deformed by higher level of deformation.

Cu_3O_{10}

300

$_2Ca_2Cu_3O_{10}$

that relaxation process loads to ordering of crystal composition in BSCCO sample.

IV. CONCLUSION

The following conclusion can be inferred from the study:

1. The increase in the b-axis from 5.346 A to 5.679 Å plays an important role in increasing T_c of 2223-Bi system.
2. The magnetic field affects T_c (zero) only and shifts it to lower temperature.
3. The mechanical deformation has different influence on super-conducting properties depending on the doping state. Deformation depressed T_c values in doped samples.

REFERENCE

1. Avner, *Introduction to Physical Metallurgy* (Academic Press, New York, 1978).
2. E.A. Lynaon, *Superconductivity* (Methuem, London, 1964).
3. S.K. Al-ani, R.H. Yousif and G.A. Al-Dahash, in *High-T_c Superconductors: Proceedings of the 12th Anniversary HTS Workshop*, edited by A K M A Islam (Rajshahi, 1998).
4. Galib Abd Al Wahab Al-Dahash. PhD Thesis submitted to College of Science, Baghdad University (1998) - unpublished.
5. J.M. Tarascon, W.R. Mckiunon, Y. Lepage, N. Stffel and M. Grroud , Phys. Rev. B **38**, 8885 (1988).
6. P. Bordetm, Physica C **153-155**, 623 (1988).
7. W.G. Zeng, J.X. Zhang, G.M. Lin, C.L. du, P.C.W. Fung, O.G. Siu, Solid State Commun., **70**, 333 (1989)