FINAL TECHNICAL REPORT

ELECTRICAL CONDUCTIVITY OF SOME SOLIDS AT AND BELOW ROOM TEMPERATURE

Principal Investigator

Professor S.M.A.Tirmizi
Department of Physics
University of Karachi

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SUMMARY

Gray Iron samples alloyed with tin in small proportions have been studied for their electrical resistivity properties. The Tin content were varied in steps of 0.05% within a total range of 0.00-0.35% Tin. Three independent sets of samples were prepared. Measurements were made on each set of samples in the temperature range from 85-1173K. In general each sample shows positive value of $d\rho/dT$ over a very wide temperature range, from 85 to 773K(measurements below 85K have not yet been done). The numerical values of $d\rho/dT$ for the different samples of the same series of alloy, however, differ substantially. A graphical plot of $d\rho/dT$ against % of Tin shows a significant inflexion at about 0.1% Tin for each of the three sets of samples. This is suggestive of some ordering effect in the composition range of 0.1-0.15% Tin. Interestingly The British cast and Iron Research Association has also reported a definite magnetic transition in similar alloys at a composition of about 0.1% Tin.For an understanding of the Physics of this transition, a good deal of further investigations would be required.

Magnetoresistance measurements of these materials were also undertaken at room temperature. These are very preliminary measurements, and are only significant in so far as that they do indicate significant magnetoresistance effects. These measurements need to be followed up further, and one may expect to observe some significant effect in the composition range of 0.1-0.15% Tin.There is very little information available in literature on this material, and so the present study is useful in its own right.

INTRODUCTION

Electrical properties of solids have always been the subject of great interest in Physics.The electrical conductivity measurements provide the data necessary for undertaking the machanism of electrical conduetion in Solids which ultimately leads to their new technological applications. Metallic solids are generally good conductors and their alloys have found applications as resistive heating materials as also for making highly conducting materials at low temperatures.

Gray Iron alloy with Tin in small proportions were taken up for studying their electrical resistivities over a wide temperature range, beginning from 85 to 1173 K. Magnetoresistance measurements of these materials were also undertaken at room temperature.There is very little published information available on this material, and so the present study is useful in its own right.

RESULTS, DISCUSSIONS AND CONCLUSIONS:

The work on the electrical resistivity measurements has been reported as a research paper in Karachi University Journal of Scince. A copy of the paper is attached herewith which gives the details of the results of the investigation, their discussion, and the conclusions.

Preliminary measurements on magnetoresistive properties of the same samples were also undertaken at room temperature. The results are presented as graphs in Figs.10,11 & 12 also attached herewith.As these are very preliminary measurements they need to be followed up by more careful measurements at different temperatures before their results could be considered more meaningful for any serious discussion.

NEED FOR ADDITIONAL RESEARCH:

The measurements need to be extended below Liquid Nitrogen temperature, preferably down to 4K.For this purpose the Cryo-tip has to made operational for which purpose a project proposal has already been submitted to Pakistan Science Foundation (P.S.F.reference No.S.KU/PHY(41)).

LIST OF PUBLICATIONS,PATENTS AND PATENT APPLICATION:

Study of Electrical Resistivity of Gray Iron with Tin Impurities in the temperature range from 85 to 1173K

S.M.A.Tirmizi, S.M.M.R.Naqvi,S.Ziaul Hasan,Irfan Ahmed

Karachi University Journal of Science,Vol9(1&2),pp.41-54(1981).

GRADUATE STUDENTS

Number of post graduate students: One

Name of the student: SYED ZIAUL HASAN

LIST OF SCIENTISTS

Principal Investigator:	Prof.S.M.A.Tirmizi.
Research Officer:	Syed Ziaul Hasan(Full Time)

Kar. Univ. J. Sc. 9(1 & 2): 41–54/1981

STUDY OF ELECTRICAL RESISTIVITY OF GRAY IRON WITH TIN IMPURITIES IN THE TEMPERATURE RANGE FROM 85 TO 1173K

S. M. A. TIRMIZI, S.M.M.R. NAQVI, S. ZIAUL HASAN and IRFAN AHMED*

Pure and Applied Physics Research Centre,
Department of Physics, University of Karachi, Karachi–32, Pakistan.

ABSTRACT

The present work is based on the measurement of electrical resistivity of 20 samples of gray iron with varying percentage of tin impurities in the temperature range from 85 to 1173 K.

These measurements show some sign of ordering at 0.1-0.15% of tin impurity.

Introduction

Electrical resistivity measurements are important in many respects. On the one hand, the data help us to understand the mechanism of electrical conduction, and on the other hand, they lead to new applications in Solid State Physics. Metallic solids are generally good conductors, and metal alloys have been found to be useful in applications as resistive heating materials and also for making highly conducting materials at low temperature.

Gray iron samples alloyed with tin (Sn) in small proportions have been the subject of the present study, and some interesting observations were made at low and high temperatures. At present, there is very little information available in published literature on the electrical properties of the alloys under investigation.

Preparation of the Samples and Composition:

Materials were prepared at the Department of Metallurgical Engineering, University of Engineering and Technology, Lahore. Three independent sets of materials of comparative compositions were prepared. For each set of_materials, the starting gray iron (1) materials were taken independently, as such the three sets differed slightly in composi-

*Department of Physics, University of Surey, England.

tion in respect of C,Mn,S,P,Si. Each set consisted of a series of different samples, differing in Sn content, successive samples differing in Sn contents by 0.05% within a total range of 0.35% Sn. The compositions of these samples as given by the suppliers are given in Tables (a) and (b): these are the compositions of the mixture before alloying, and have note been analysed after the final alloys were prepared because of lack of analytical facilities.

TABLE (a)

Variation in the Composition of the starting Material of the three series.

Impurities	Series 20–27	Series 40–47	Series 70–77
Carbon	3.22	3.13	3.18
Manganese	0.58	0.58	0.60
Silicon	2.06	1.97	1.92
Sulphur	0.042	0.043	0.041
Phosphorous	0.28	0.26	0.27

TABLE (b)

Variations in the 'Sn' Contents of Sample in each series

Samples			Percentage of Tin
20	40	70	0.00
21	41	71	0.05
22	42	72	0.10
23	43	73	0.15
24	44	74	0.20
25	45	75	0.25
26	46	76	0.30
27	47	77	0.35

STYDY OF ELECTRICAL RESISTIVITY OF GRAY IRON

Experimental set up:

For building up the actual set-up for resistivity measurements of gray iron, a four probe method was adopted. Each sample of gray iron was cut in the shape of parallelopiped with dimensions $4x4x25mm^3$. Contacts were made using spot welding technique and were checked to ensure that they were ohmic. For low temperature studies down to 85K, a sample holder and cryostat were designed as described in an earlier paper (2). For high temperature measurement upto 1200K another sample holder was designed in the following way. The sample with the four leads was placed in a glass tube, keeping the two pairs of lead at the opposite ends of the tube. The wire leads were insulated with the help of glass beads. The sample was then covered with burned asbestos and it was then inserted in another glass tube. In order to keep the sample in place, the outer tube was heated to form constriction at the two ends, in this way the exposure of the sample to atmospheric air was also minimized. An electric furnace based on resistive heating (allowing controllable rate of rise of temperature) designed in these laboratories was used in this study. A theremocouple, placed underneath the sample, electrically insulated with the help of a sleeve, was used to record the temperature of the sample.

The potentiometer measuring set-up was the same as described in an earlier paper (3). While the measuring accuracy of the instruments was better than one part per million, the overall precision of individual measurements reported in this work has been one part in 10^4

Results and Discussion

The electrical resistivities of three series of samples (identified as 20, 40, 70 series) have been undertaken for measurements in the low and high temperature range. These measurements have been reasonably precise for they have been checked for reproducibility.

The results can be discussed under two headings;

(a) Low temperature and (b) High temperature.

(a) Low Temperature: The results of the measurements of 20 series at low temperature are shown graphically in Fig. 1. The graph shows that each sample of the series gives a positive value of $d\rho/dT$ and the curves are reasonably linear. What is disturbing, however, is the difference in the slopes of individual curves, so much so that some of the curves do in fact intersect with each other (Fig. 1).

The measured values of resistivity for 40 and 70 series of samples, at low temperature are given in Figs. 2 and 3 respectively. A comparison of the corresponding curves for the three series do not apparently show any relationship except that all curves are linear and have positive slope of resistivity with respect to temperature, i. e. $d\rho/dT$ is positve. One would normally expect that the numerical values of resistivity of corresponding samples at corresponding temperatures should be identical, but the experimental values do not bear this out. This is rather unexpected: one may attempt to explain this in terms of small variations in the concentration of the impurity elements in the different series of samples, and also perhaps in the possible differences in the microstructure of the individual samples. The contributions of these factors to resistivity would be an interesting study by itself (Figs. 2 and 3).

A graph of slope of the different samples drawn against % of Tin is shown in Fig.4. It is significant to note that all the curves show a marked inflexion at about 0.15% tin content, and furthermore the numerical values of $d\rho$ / dT at this concentration for the three series are also very close to each other. This observation seems to suggest that, while the contribution to electrical resistivity from the different impurity elements (C,Si,Mn,S,P) and other variables such as microstructure must have been present, the contribution from Sn far outweighs the other contributions at this composition. This would also, therefore, support the view that at this composition some transition also takes place. Interestingly, the British Cast Iron Research Association (4) has reported a definite magnetic transition in similar alloys at a composition of about 0.1% Tin. (Fig. 4).

(b) High Temperature: The resistivity versus temperature relationship for the three series (20s,40s,70s) are shown graphically in Figs. 5 to 9. The graphs for series 20s and 40s have been split up into two groups only in order to avoid crowding.

In the low temperature range, observations were taken at large intervals because of experimental difficulties. As the number of observational points were very limited it has only been possible to draw straight lines through these points. But in the case of high temperature measurements, it has been possible to make observations at rather much closer intervals, and so it has been possible to draw the graphs with greater reliability. As such, the high temperature measurements can be discussed with a little more confidence.

In the 20s series (Figs. 5,6) the nature of the curves of samples 21 and 22 follows almost the same pattern: the curve is non-linear and shows a positive curvature. Also, the corresponding values of resistivities for sample 22 (.1%Sn) are always lower than those of 21. The curve for sample 23 onwards shows a marked change in that the curvature has significantly changed. The transition in the nature of curves from sample 21 to 23 confirms some transition in the composition range 0.1- 0.15% Sn (Figs. 5 and 6).

In the 40s series (Figs. 7,8) there appears a change in the nature of curves for samples 40 and 41, suggesting that the introduction of Sn even in as small a quantity as 0.05% makes a significant impression on the resistivity behaviour of gray iron. Furthermore, the curve for sample 42 is very much different from that of curve 41, showing a hump at around 750K. The resistivities for sample 43 show a significantly different pattern than those of 42, consistent with the observations made in the case of series 20. This, therefore, further supports the view that some transition is taking place around 0.1-0.15% Sn composition. Also it is observed that the curves corresponding to the different samples fan out as the temperature increases, which means that in general $d\rho/dT$ is not only different for different samples of the same series but also progressively changes as one goes to higher temperatures (Figs. 7 and 8).

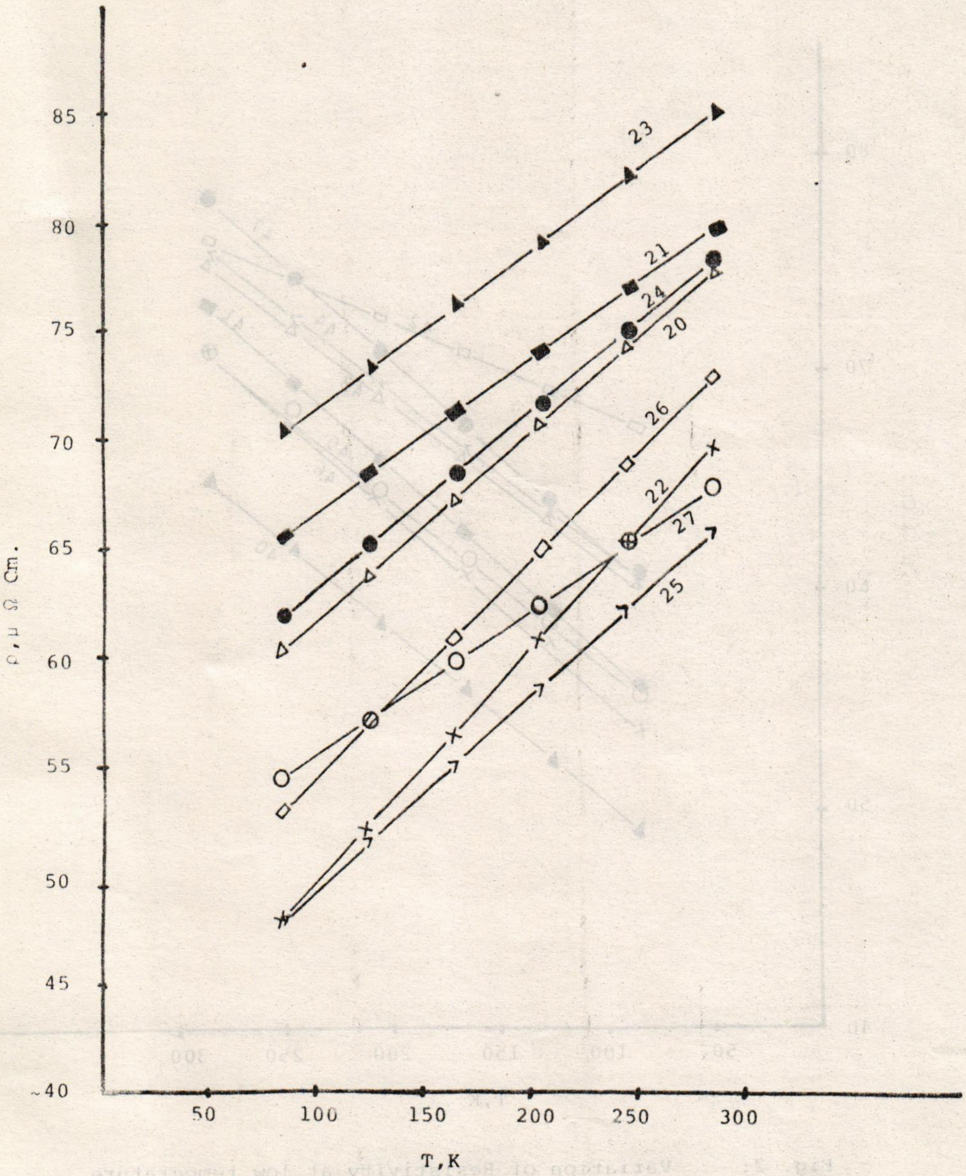

Fig. 1: Variation of Resistivity at low temperature for various Samples.

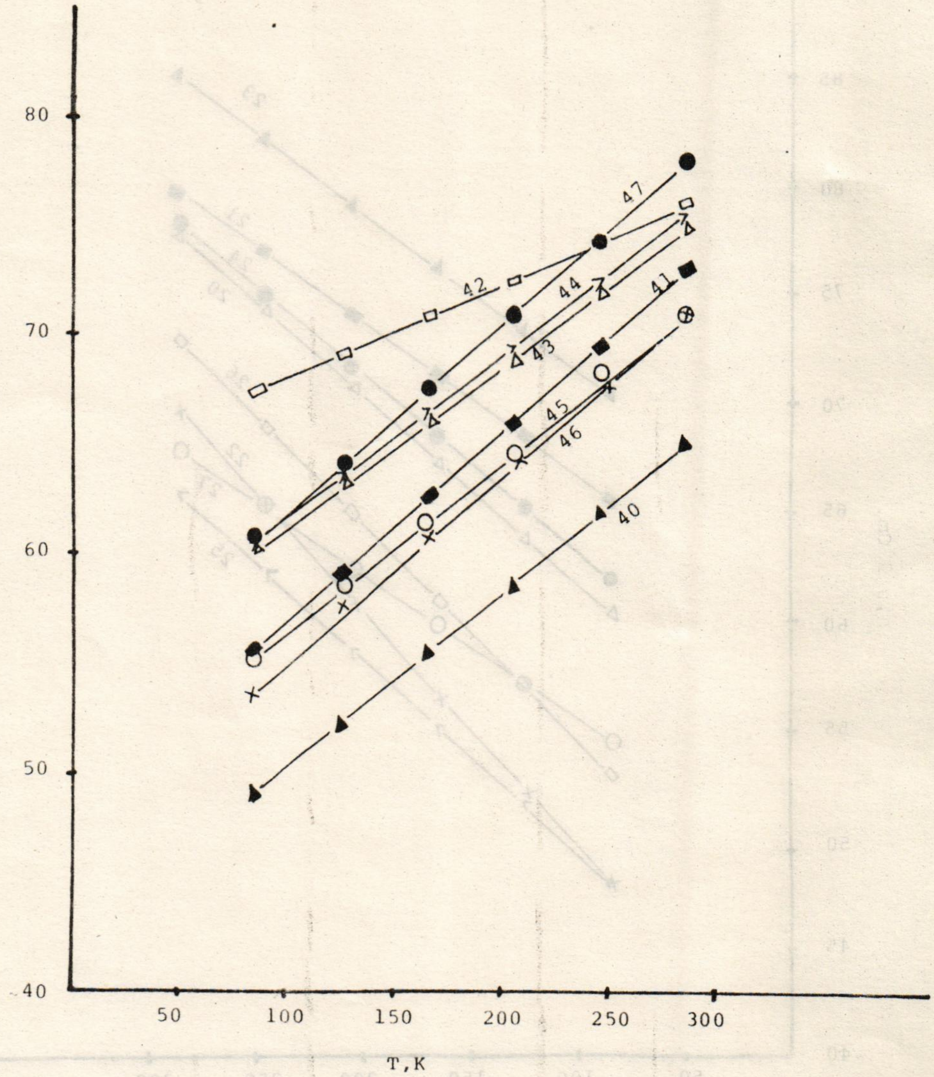

Fig. 2: Variation of Resistivity at low temperature for various Samples.

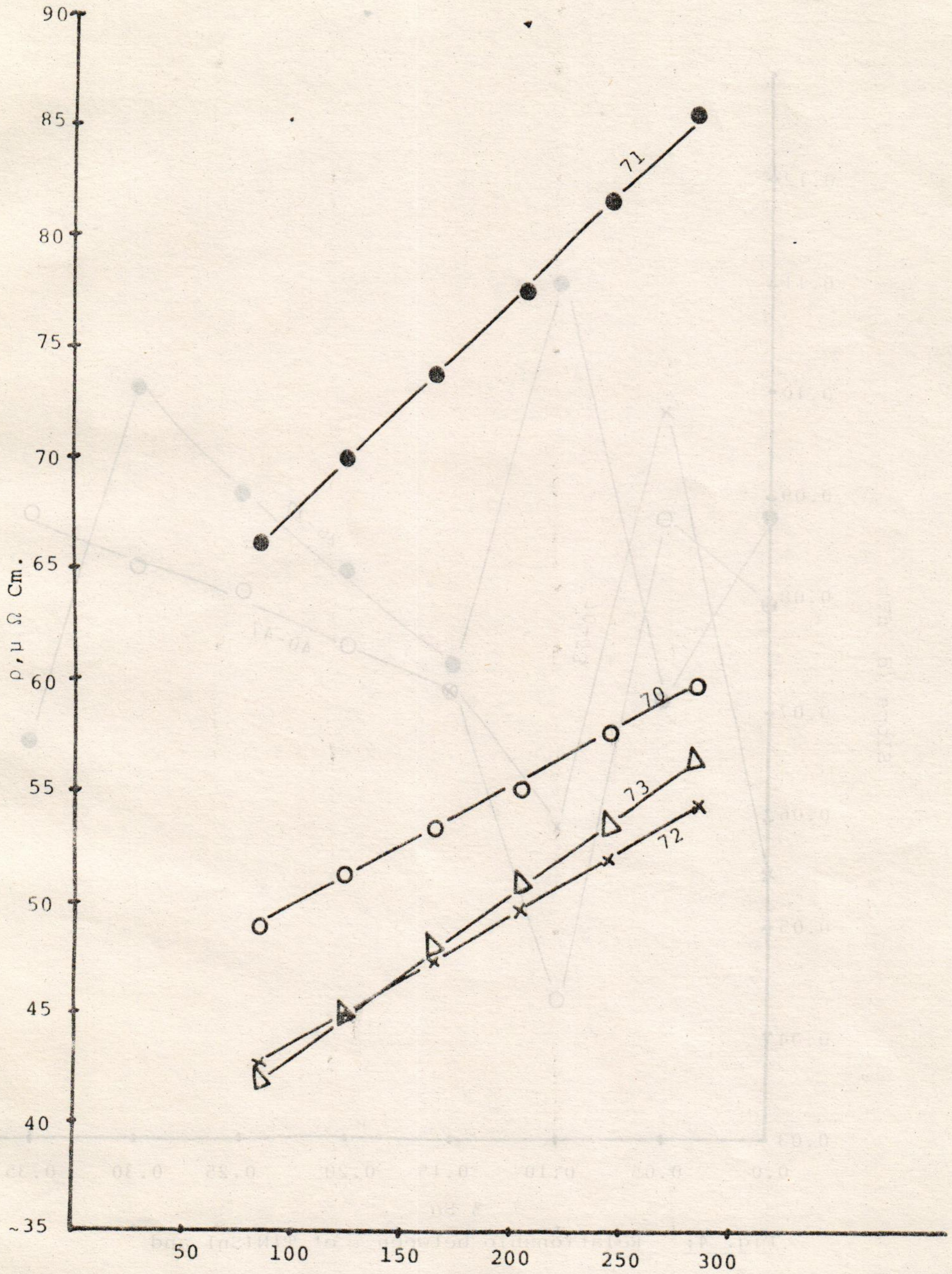

Fig. 3: Variation of Resistivity at low temperature for various Samples.

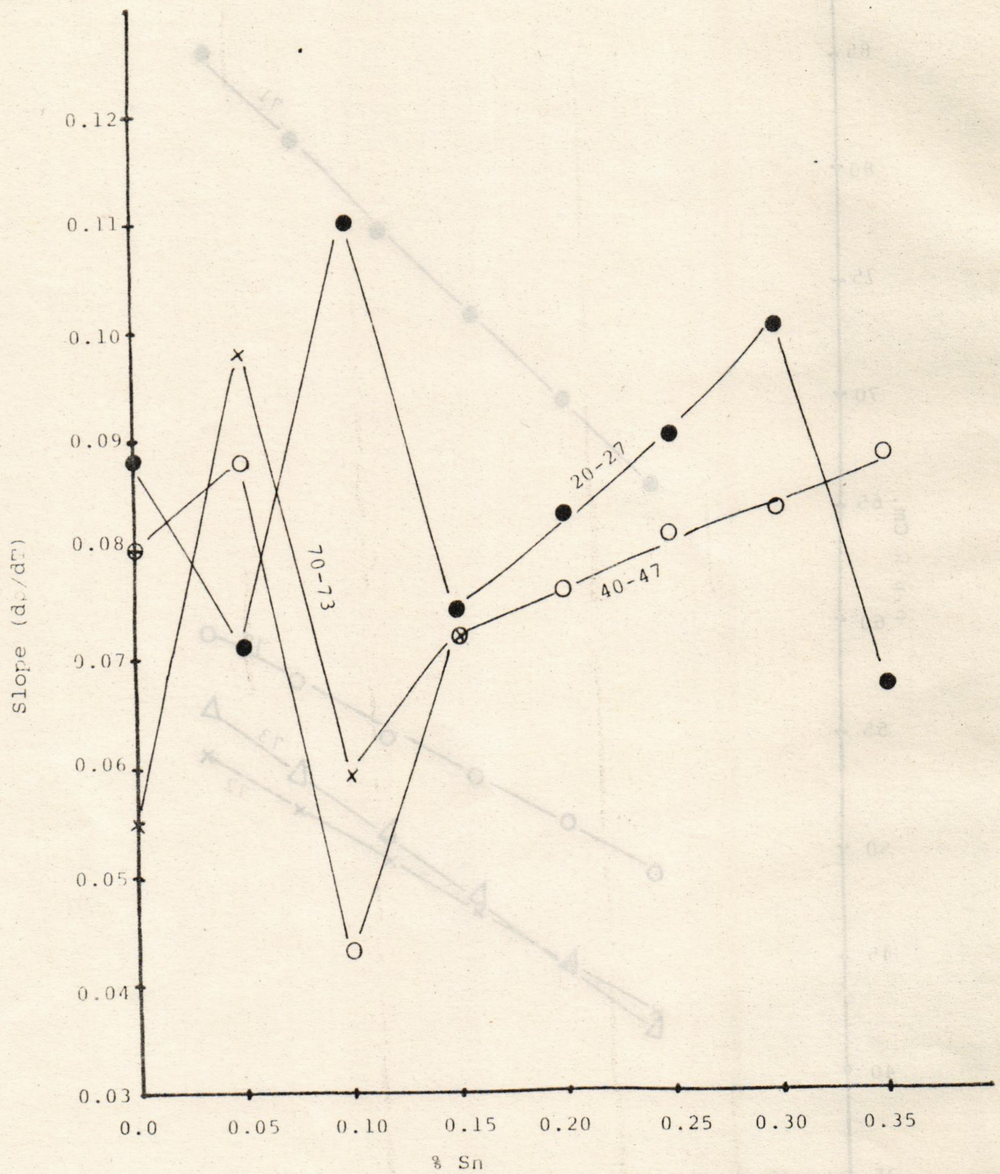

Fig. 4: Relationship between % of TIN(Sn) and slope (dρ/dT) of different series

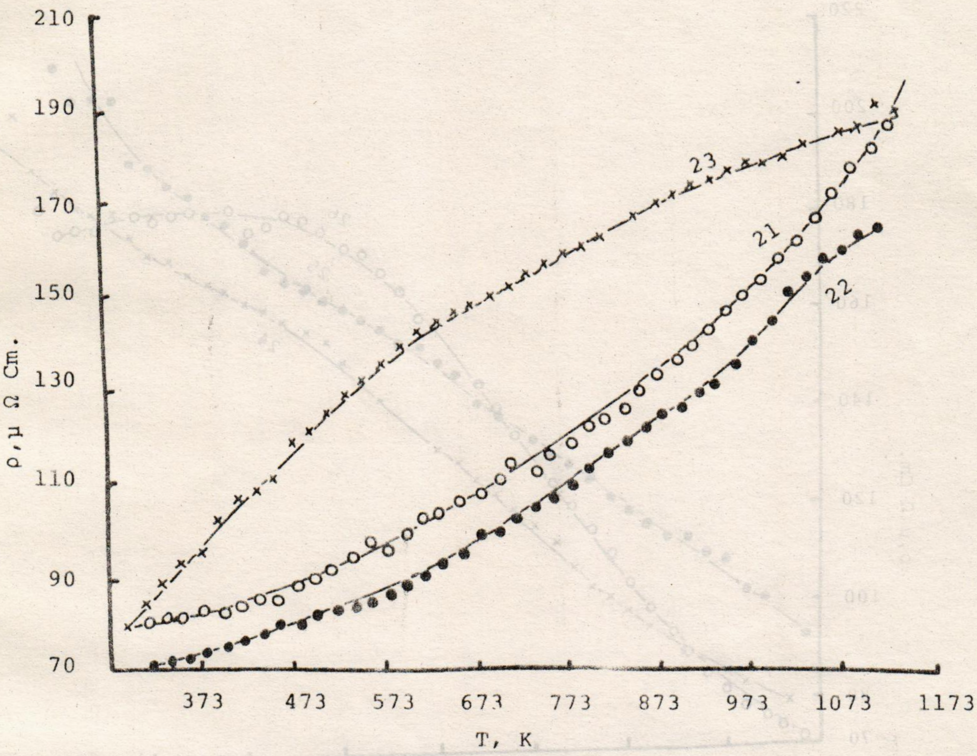

Fig.5: Variation of Resistivity at high temperature for various samples.

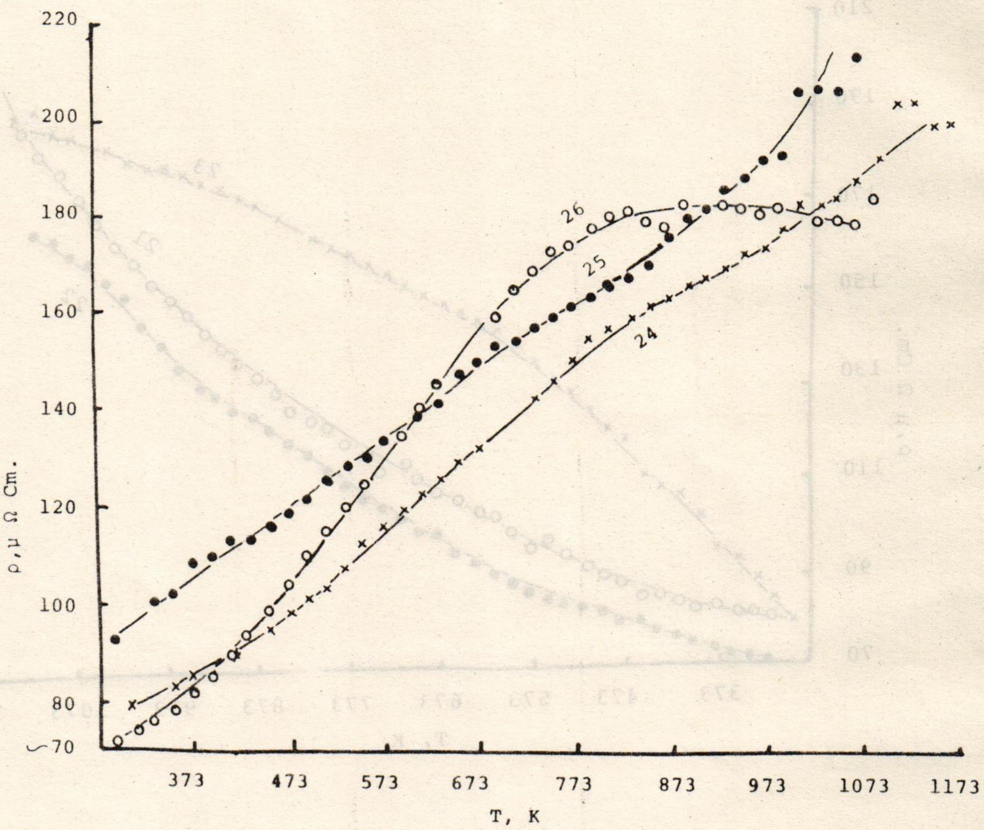

Fig.6: Variation of Resistivity at high temperature for various samples.

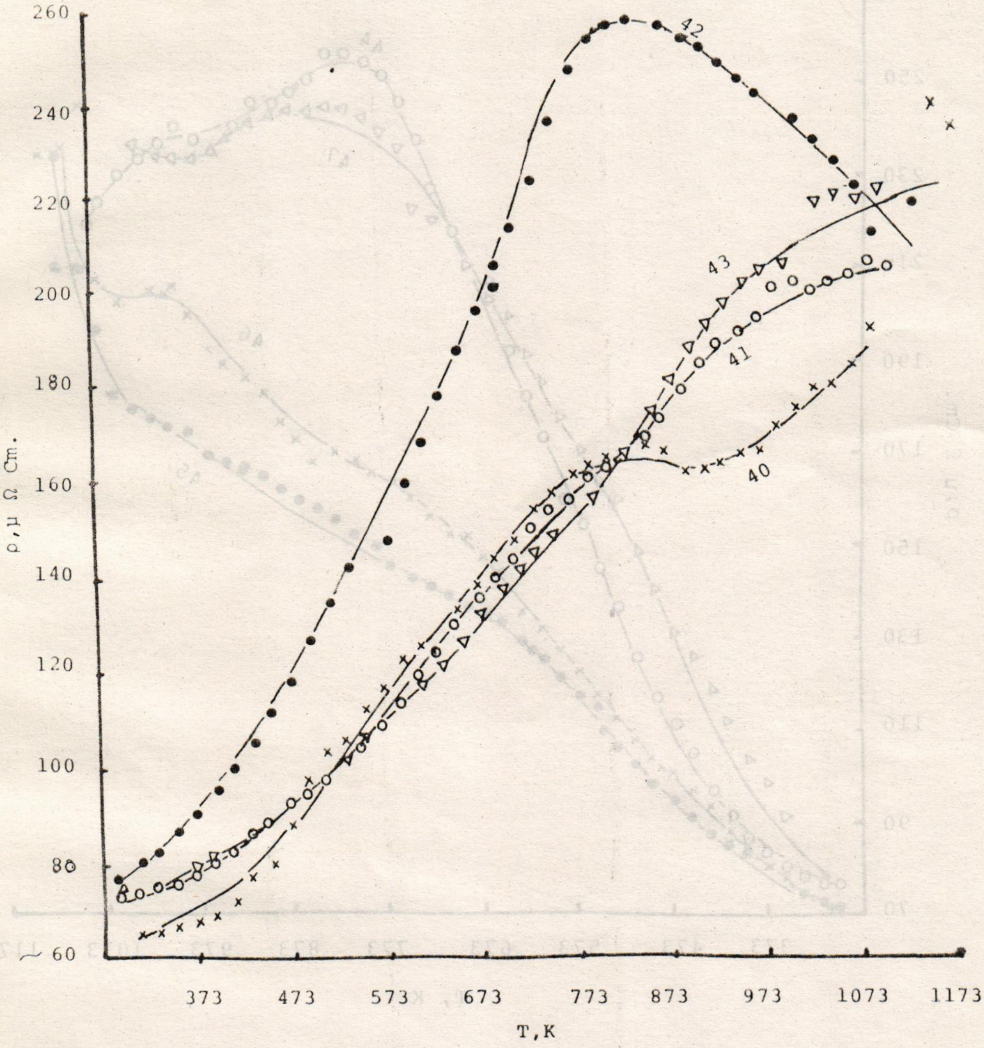

Fig.7: Variation of Resistivity at high temperature for various samples.

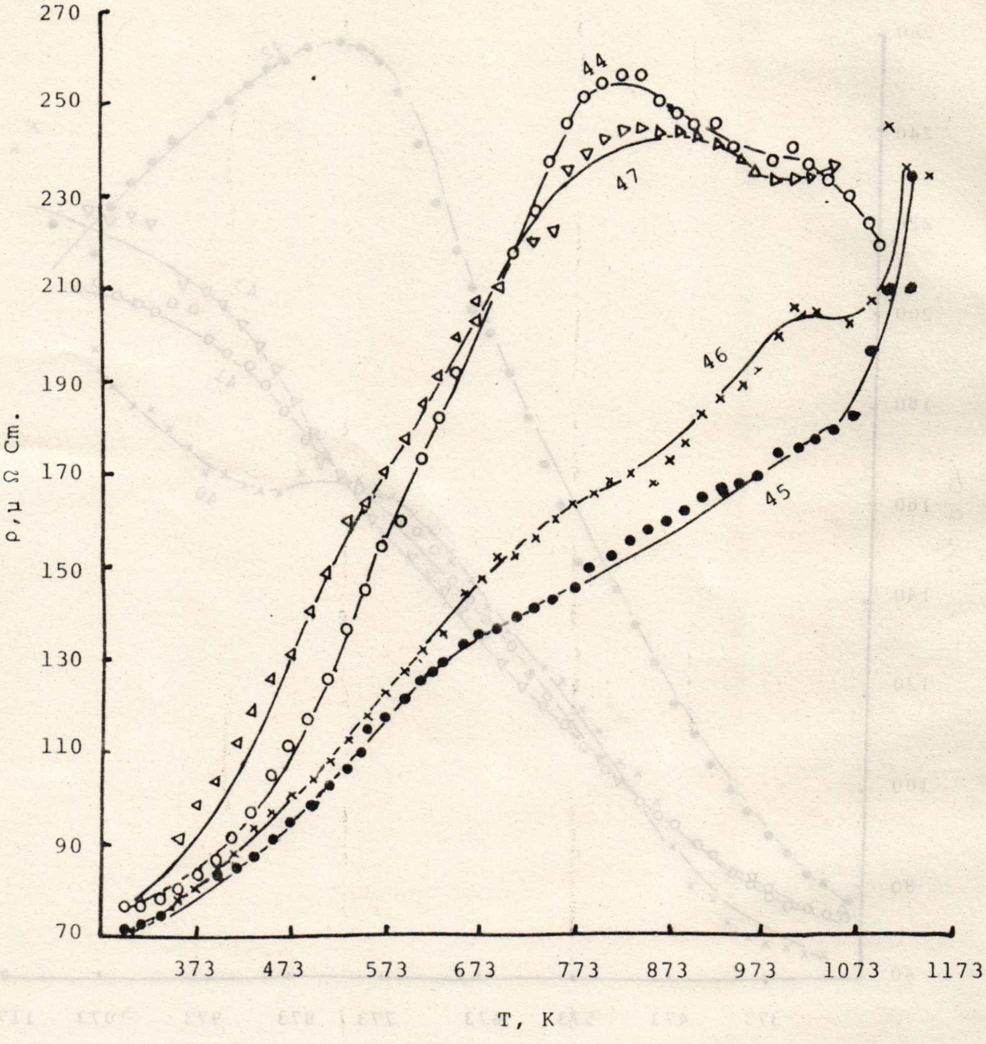

Fig.8: Variation of Resistivity at high temperature for various samples.

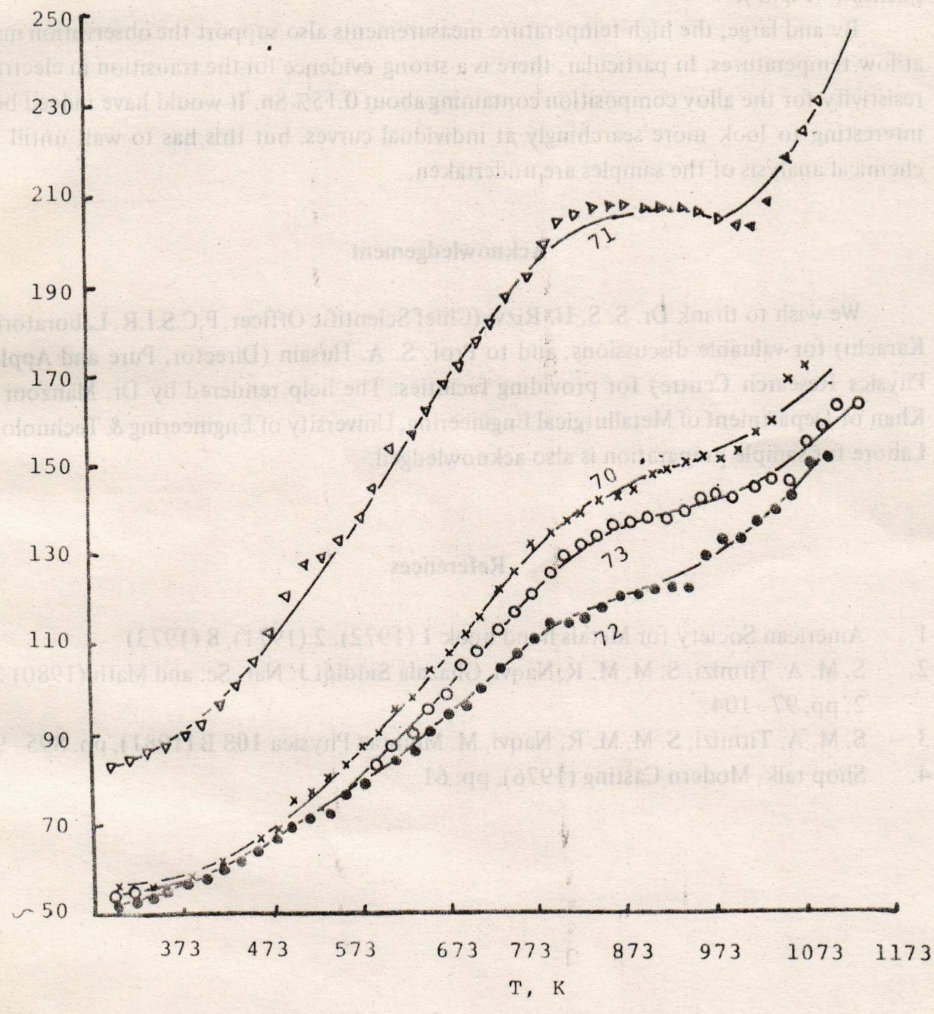

Fig.9: Variation of Resistivity at high temperature for various samples.

The curves for all the samples of series 70 (Fig. 9) show some amount of similarities, but even in this series a visible variation in the pattern of curves for samples 72 and 73 are observed, supporting again the occurrence of some transition in this range of composition (Fig. 9).

By and large, the high temperature measurements also support the observation made at low temperatures. In particular, there is a strong evidence for the transition in electrical resistivity for the alloy composition containing about 0.15% Sn. It would have indeed been interesting to look more searchingly at individual curves, but this has to wait untill the chemical analysis of the samples are undertaken.

Acknowledgement

We wish to thank Dr. S. S. H. Rizvi (Chief Scientific Officer, P.C.S.I.R. Laboratories, Karachi) for valuable discussions, and to Prof. S. A. Husain (Director, Pure and Applied Physics Research Centre) for providing facilities. The help rendered by Dr. Manzoor H. Khan of Department of Metallurgical Engineering, University of Engineering & Technology, Lahore for sample preparation is also acknowledged.

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2. S. M. A. Tirmizi, S. M. M. R. Naqvi, Ghazala Siddiqi J. Nat. Sc. and Math (1980) **20**, 2, pp. 97–104.
3. S. M. A. Tirmizi, S. M. M. R. Naqvi, M. Mumtaz Physica **108** B (1981), pp. 895–96.
4. Shop talk, Modern Casting (1976), pp. 61

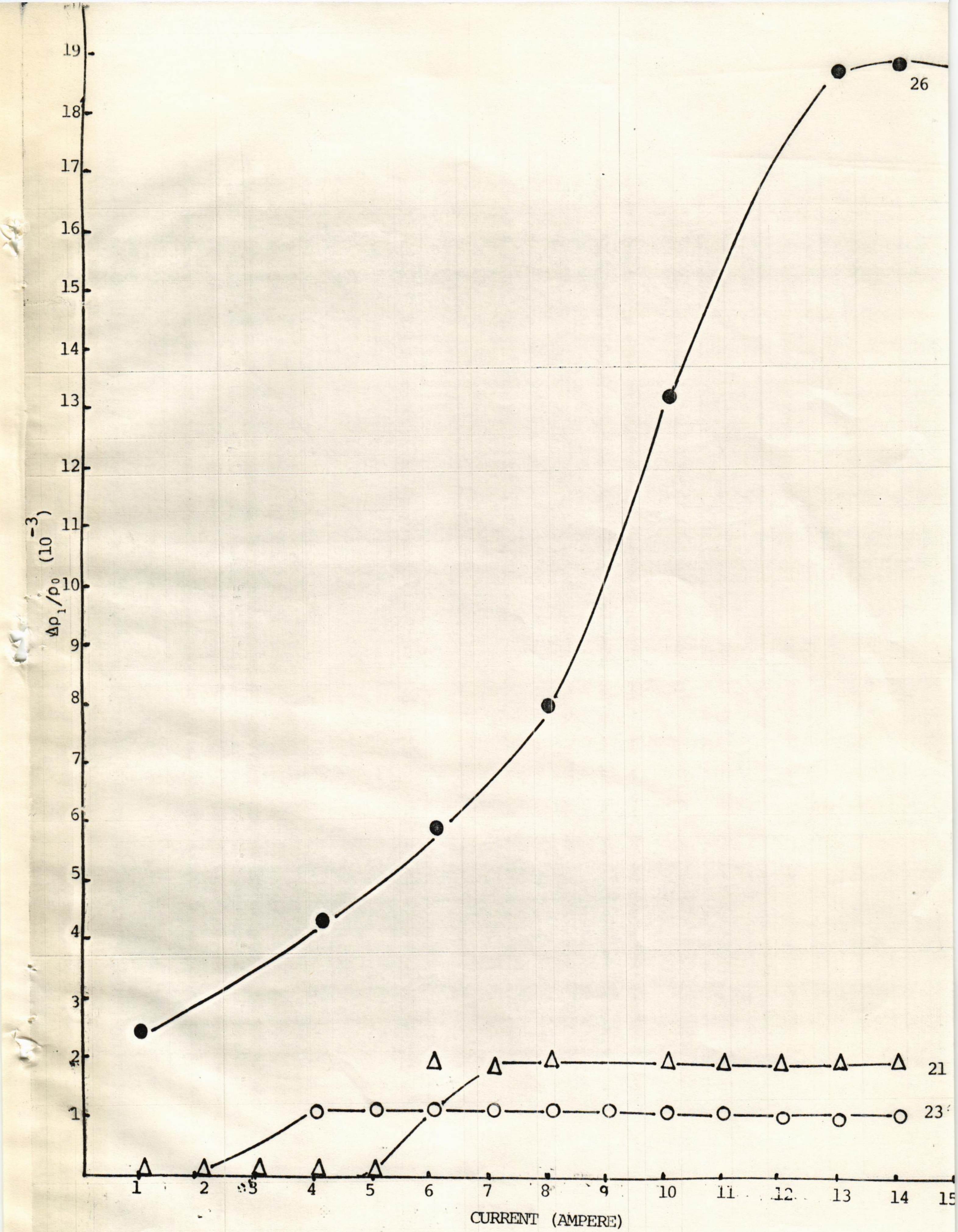
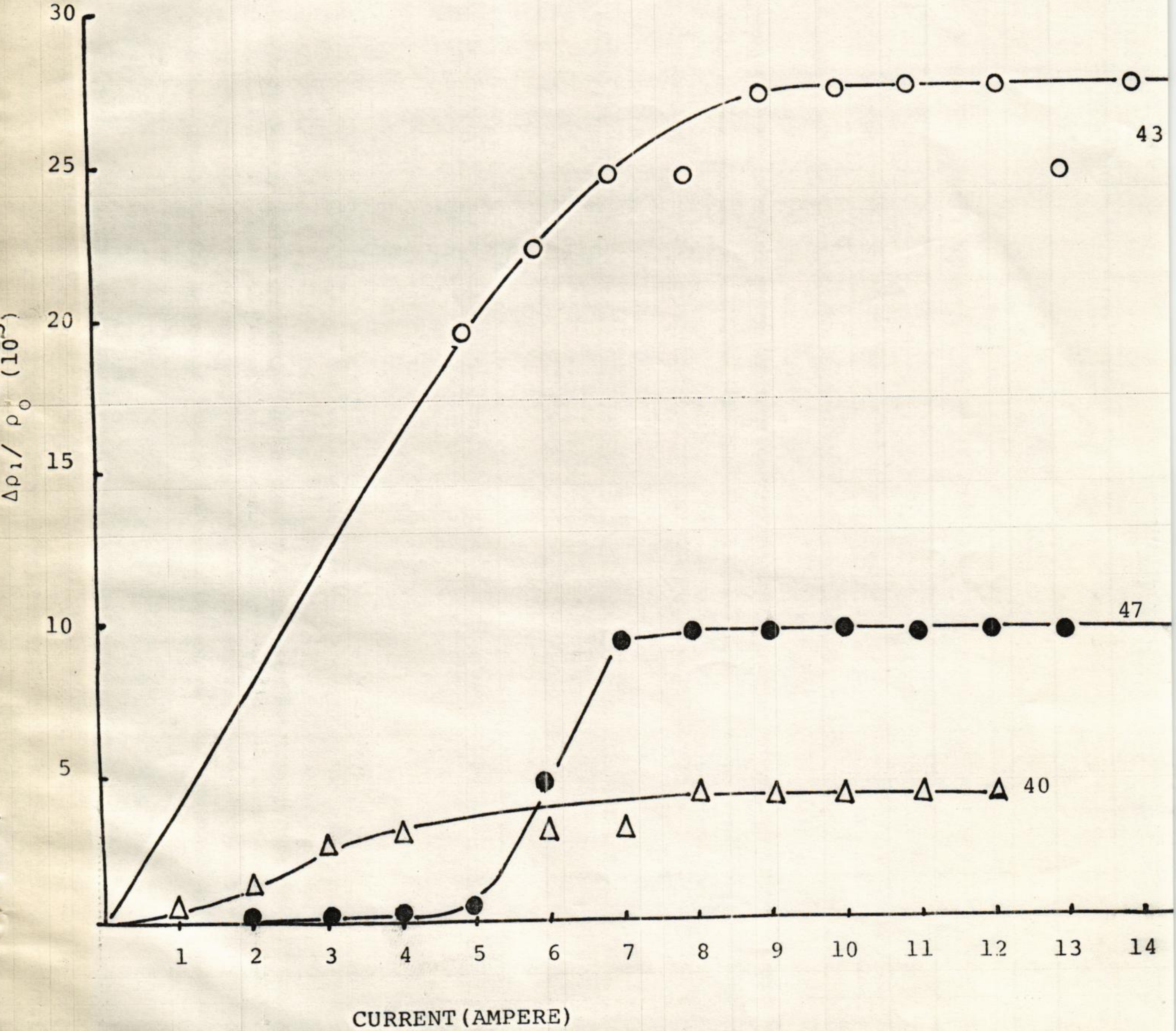


Fig.10.Variation of ratio of Magneto-resistivity at room temperature for various samples



ratio of
Fig.11.Variation of/Magneto-resistivity at room temperature for various samples.

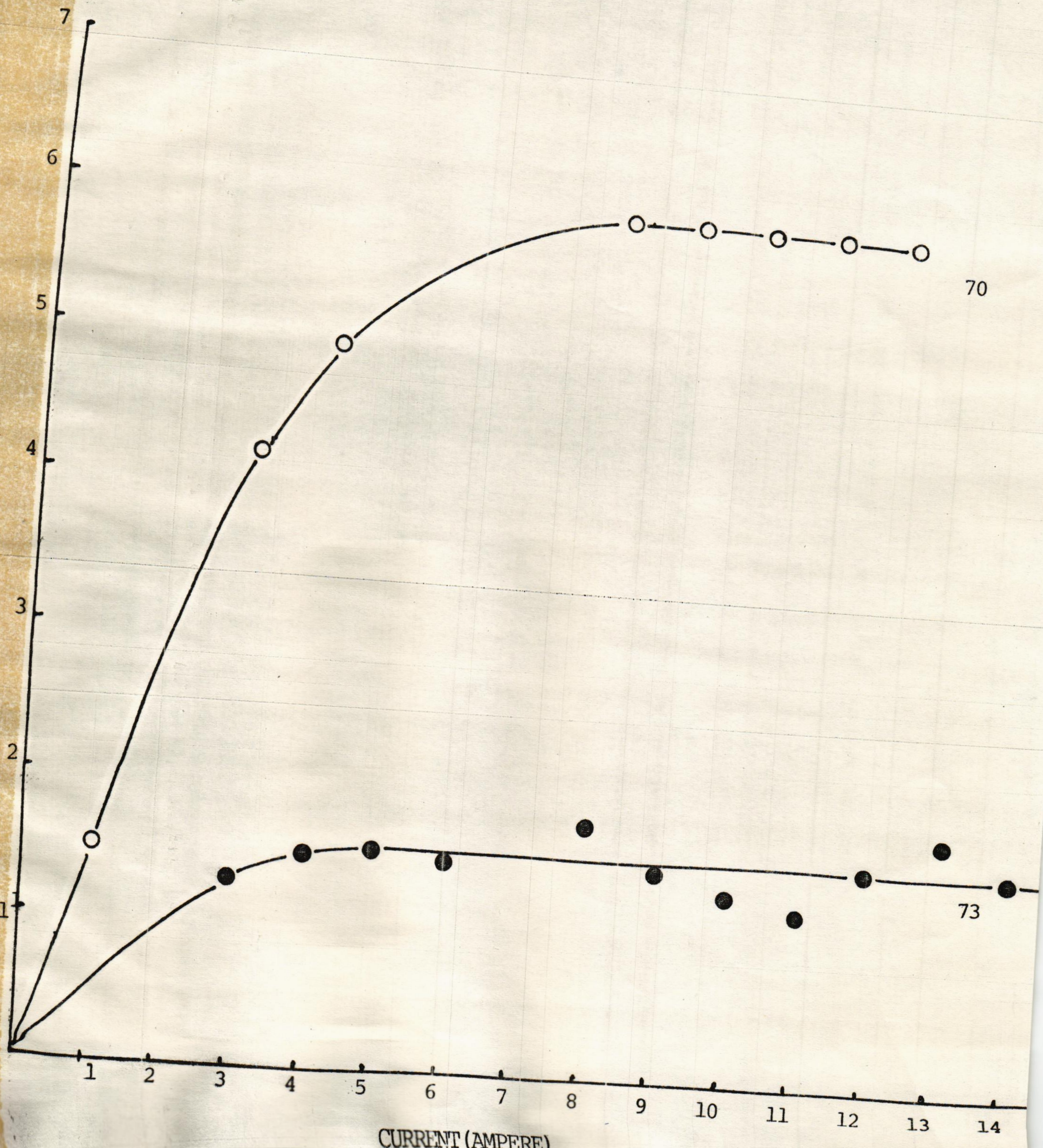


Fig.12. Variation of ratio of Magneto-resistivity at room temperature for various samples