

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

METALLURGICAL FACTORS CONTROLLING IMPACT PROPERTIES OF TWO PHASE STEELS

### Permalink

<https://escholarship.org/uc/item/4k90r7wq>

### Author

Koo, J.Y.

### Publication Date

1979-09-01



# Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

## Materials & Molecular Research Division

Submitted to Scripta Metallurgica

METALLURGICAL FACTORS CONTROLLING  
IMPACT PROPERTIES OF TWO PHASE STEELS

J. Y. Koo and G. Thomas

September 1979

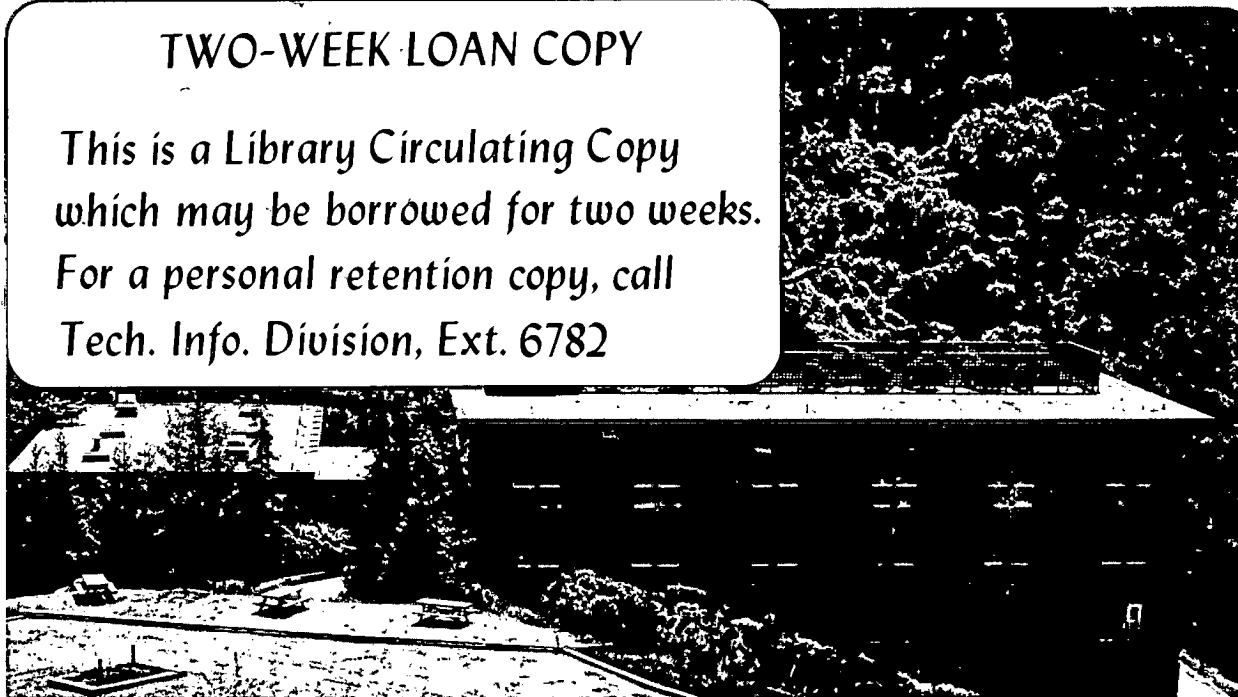
RECEIVED  
LAWRENCE  
BERKELEY LABORATORY

OCT 15 1979

LIBRARY AND  
DOCUMENTS SECTION

### TWO-WEEK LOAN COPY

*This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 6782*



LBL-9535 c. 2

## DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

METALLURGICAL FACTORS CONTROLLING  
IMPACT PROPERTIES OF TWO PHASE STEELS

J.Y. Koo\* and G. Thomas\*\*

\*Department of Mechanics and Materials Science,  
Rutgers University, NJ 08854

\*\*Department of Materials Science and Mineral Engineering  
University of California, Berkeley, CA 94720

## INTRODUCTION

There has been a growing interest in recent years in low carbon steels heat-treated to produce a mixed structure of ferrite and martensite (1,2). The new class of HSLA steels, now known as dual-phase (DP) steels, combines high strength and good formability, which are superior to those of comparable commercial HSLA steels. The current interest in DP steels has been largely concentrated on the superior tensile properties, which find important applications for weight reduction and fuel savings in automobile industries. Consequently, the major emphasis on the dual phase microstructure - property relations has been placed specifically on the stress-strain behavior, while the other important mechanical properties, e.g. impact energy, have not been well characterized. The purpose of this paper is, therefore, to identify and characterize those microstructural elements which have a significant influence on the impact properties of DP alloys.

## EXPERIMENTAL

The compositions of the alloys used in this investigation are listed in Table I. The alloys were melted in a vacuum induction furnace, homogenized, and furnace-cooled. The heat treatment to produce controlled DP structures consists of austenitizing and quenching to 100% martensite, followed by annealing in the ( $\alpha+\gamma$ ) range and subsequent quenching to room temperature. The volume fraction of martensite was controlled by choosing appropriate temperatures in the two phase range, and was determined by quantitative optical metallography. Experimental details of heat treating conditions are described elsewhere(3,4). The specific heat treatment and alloy compositions were chosen so as to control the morphology of the dual phase microstructural constituents, which is strongly influenced by the substitutional solute, as will be shown later.

The standard and 3/4 subsize Charpy V-notch specimens(5) were used for

the Charpy tests. The impact tests were conducted on a Universal Impact Machine with a 120 ft-lb capacity. Low temperature tests were performed following the ASTM 23-72 specifications(5). The data reported represent an average of at least three tests.

## RESULTS

Marked differences are developed in the morphology of the DP structures depending on the amount and type of alloying element X present in the Fe/X/0.1C ternary system(6,7). These are illustrated in the optical micrographs, Figs. 1 and 2. Fig. 1 shows the DP structure developed in the alloy #1. As can be seen in this figure, martensite particles occur in a continuous network along the prior austenite grain boundaries with an acicular morphology in the interior of the prior austenite grains. In sharp contrast, a discontinuous, fibrous morphology was developed in the 2% Si-containing DP steel, Fig. 2.

The results of impact test data are plotted in Figs. 3 through 5. Fig. 3 shows the impact energy curves of the 0.5Cr DP steels with two different volume fractions of martensite. The curve with 35% volume fraction of martensite does not exhibit a definite DBTT, while the one with 90% martensite volume fraction apparently does. The similar variations of DBTT with volume percent martensite in Si-containing DP steels are illustrated in Fig. 4. The apparent DBTT was lowered by increasing volume percent martensite from 30% to 60% in the case of the 0.5% Si DP alloy, whereas the 2% Si steel (alloy #3) showed no apparent DBTT and no significant difference in the impact energy as the volume percent martensite was varied.

Fig. 5 compares the impact energy curves of the DP alloys 1 and 3, both having 35% martensite volume fraction.

The fracture surface of all the broken subsized CVN impact specimens, regardless of alloy composition and martensite volume fractions, exhibited

mainly quasi-cleavage like morphology, Fig. 6, with a small quantity of ductile rupture the proportion of which depended on the testing temperature and the relative amount of each constituent phase in the DP steels. The mode of fracture changed significantly with the size of the impact specimen. Isolated experiments showed that when standard specimens were used, a large proportion of dimpled rupture features were associated with the fracture appearance.

#### DISCUSSION

From Figs. 1-5, one notes that the impact properties of the DP steels are strongly affected by the three major structural factors: morphology (shape, size and distribution) of DFM structure, volume fraction of martensite, and toughness (carbon content) of the martensite particles. The last two factors are correlated to each other since the carbon content is a linear function of the volume fraction of martensite.

As the volume fraction decreases it is expected:

- (1) The connectivity of martensite will decrease, thus resulting in better impact properties.
- (2) Concurrently, toughness of the martensite will decrease due to increased carbon enrichment, thereby decreasing impact properties since the carbon level has a drastic effect on reducing notched impact energy and DBTT(3).

Therefore, for a given morphology of DFM structure, the observed effect of volume fraction on the impact properties will be determined by the balance between the two opposing factors.

For the 0.5 Cr DP structure tested up to room temperature, the energy curve with higher volume fraction (90% Ms, 0.07wt.%C in the martensite) exhibited better impact energy, and showed an apparent DBTT, while no DBTT was present in the one with the lower volume fraction (35% Ms, 0.17wt.%C in the

martensite). This result may be due to the fact that the toughness factor has an overwhelming influence on the notched impact toughness compared to the connectivity factors, since in both cases the martensite phase was interconnected along the prior austenite grain boundaries (Fig. 1).

In contrast, the 2% Si DP structure yielded essentially identical energy curves for two different volume fractions of martensite, as is seen from Fig. 4. This indicates that toughness and connectivity factors counterbalanced each other to result in no variations in the curves. The individual martensite particles are still separated and surrounded by the ferrite matrix at 60% martensite, maintaining the same fibrous morphology as that of 30% martensite, thereby resulting in identical energy curves for the two volume fractions. On the other hand, the martensite particles in the 0.5% Si DP steel revealed a high degree of connectivity at all volume fractions of martensite ( $\geq 20\%$ ). The impact energy curves thus show similar behavior to those of 0.5% Cr DP steels, Fig. 4.

Silicon is known as a very detrimental alloying element in lowering impact toughness properties in carbon steels. Nevertheless, the impact properties of 2% Si DP steel are as good as those of 0.5% Si DP steel at 35% martensite volume fraction. This indicates that the connectivity of martensite constituents at a given volume fraction is an important factor in controlling impact properties, as can also be seen from Fig. 5. In general, it appears from the present study that the toughness or carbon content in the martensite is the single most important parameter in determining impact toughness, as has also been substantiated by Young(9). It is therefore essential to limit the initial carbon content in the alloys to less than 0.1 wt. % for optimum impact toughness and tensile properties(4). The influence of the prior austenite grain size and interparticle spacing on the impact properties of



DP alloys is being investigated, and the results will be presented in a subsequent paper.

ACKNOWLEDGEMENTS

This work was supported by the Division of Materials Science, Office of Basic Energy Services, U.S. Department of Energy under Contract No. W-7405-Eng-48.

We wish to thank Daido Steel Corporation (Japan) for providing the steels used in this investigation.

TABLE I. Alloy Compositions (wt. %)

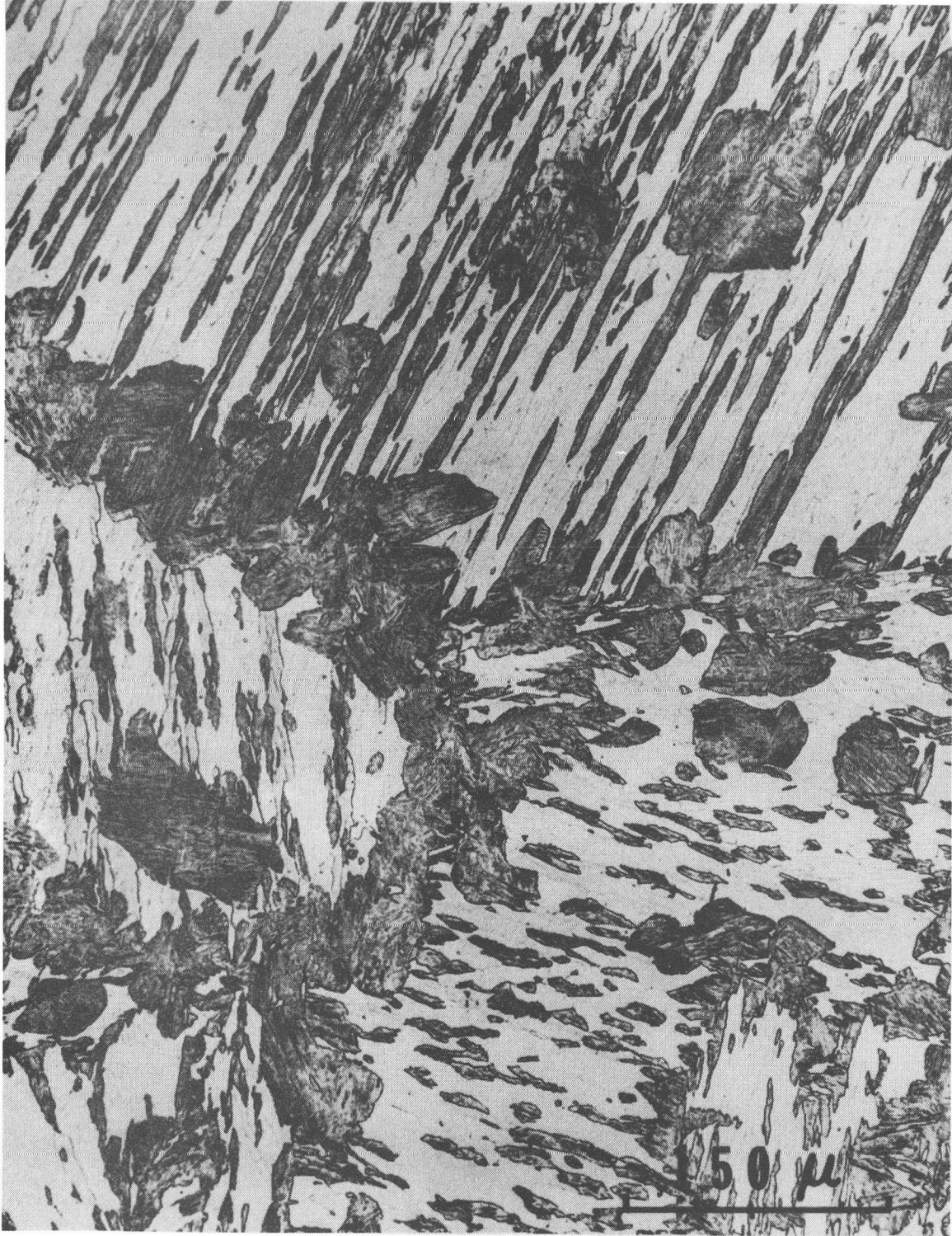
Alloy number	C	Cr	Si	Fe
1	0.06	0.5	-	Bal.
2	0.07	-	0.5	Bal.
3	0.07	-	2.0	Bal.

## REFERENCES

1. "Formable HSLA and Dual-Phase Steels," A.T. Davenport, ed., AIME, New York, N.Y., 1979.
2. "Structure and Property of Dual-Phase Steels," AIME Symposium, New Orleans, Feb., 1979.
3. J.Y. Koo and G. Thomas: Met. Trans., 3A, 525 (1977).
4. J.Y. Koo and G. Thomas: "Formable HSLA and Dual-Phase Steels," A.T. Davenport, ed., AIME, New York, N.Y., p.42 (1979).
5. Annual Book of ASTM Standards, Designation E23-72, p. 277 (1973).
6. M.R. Plichta and H.I. Aaronson: Met. Trans., 5, 2611 (1974).
7. J.Y. Koo: Ph.D. Thesis, University of California, Berkeley, LBL Report #6657
8. R.R. Preston: J. of Metals, 29, 9 (1977).
9. M.J. Young: M.S. Thesis, University of California, Berkeley, LBL Report #6620.

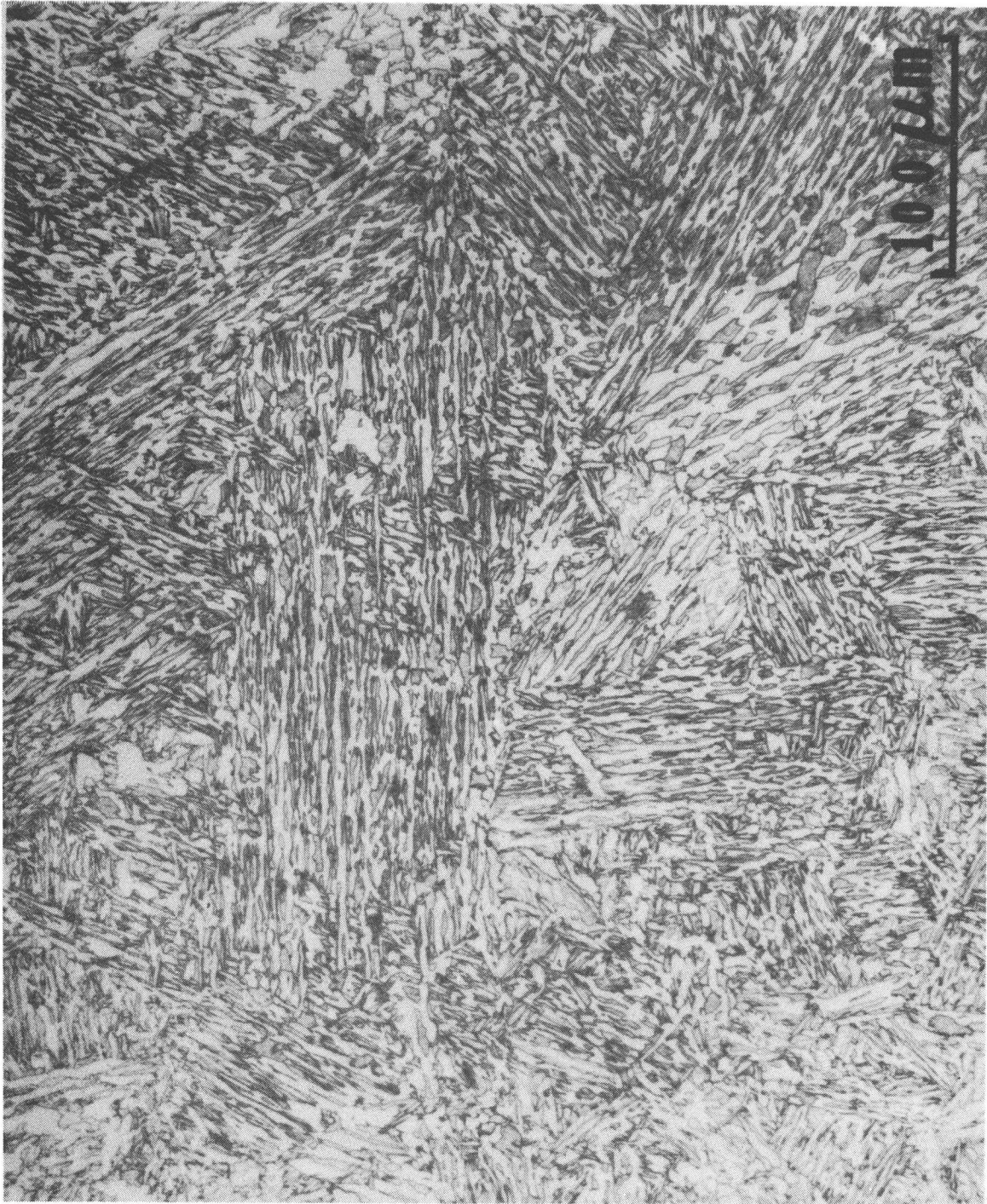
#### FIGURE CAPTIONS

- Fig. 1 Optical micrograph of DP structure developed in alloy 1 (Fe/0.5Cr/0.06C).
- Fig. 2 Optical micrograph of DP structure developed in alloy 3 (Fe/2Si/0.07C).
- Fig. 3 Three-fourth subsize CVN impact energy as a function of testing temperature for DP alloy 1 containing 35% and 90% martensite volume fraction.
- Fig. 4 Three-fourth subsize CVN impact energy vs. tempering temperature for the DP alloys 2 and 3 containing 30% and 60% martensite volume fraction.
- Fig. 5 Comparison of 3/4 subsize Charpy impact properties of the DP alloys 1 and 3, each having 35% martensite.
- Fig. 6 Scanning electron fractographs of broken subsized CVN impact specimen of (a) DP alloy 1 having 90% martensite, and (b) DP alloy 3 having 30% martensite. Tested at 0°C.



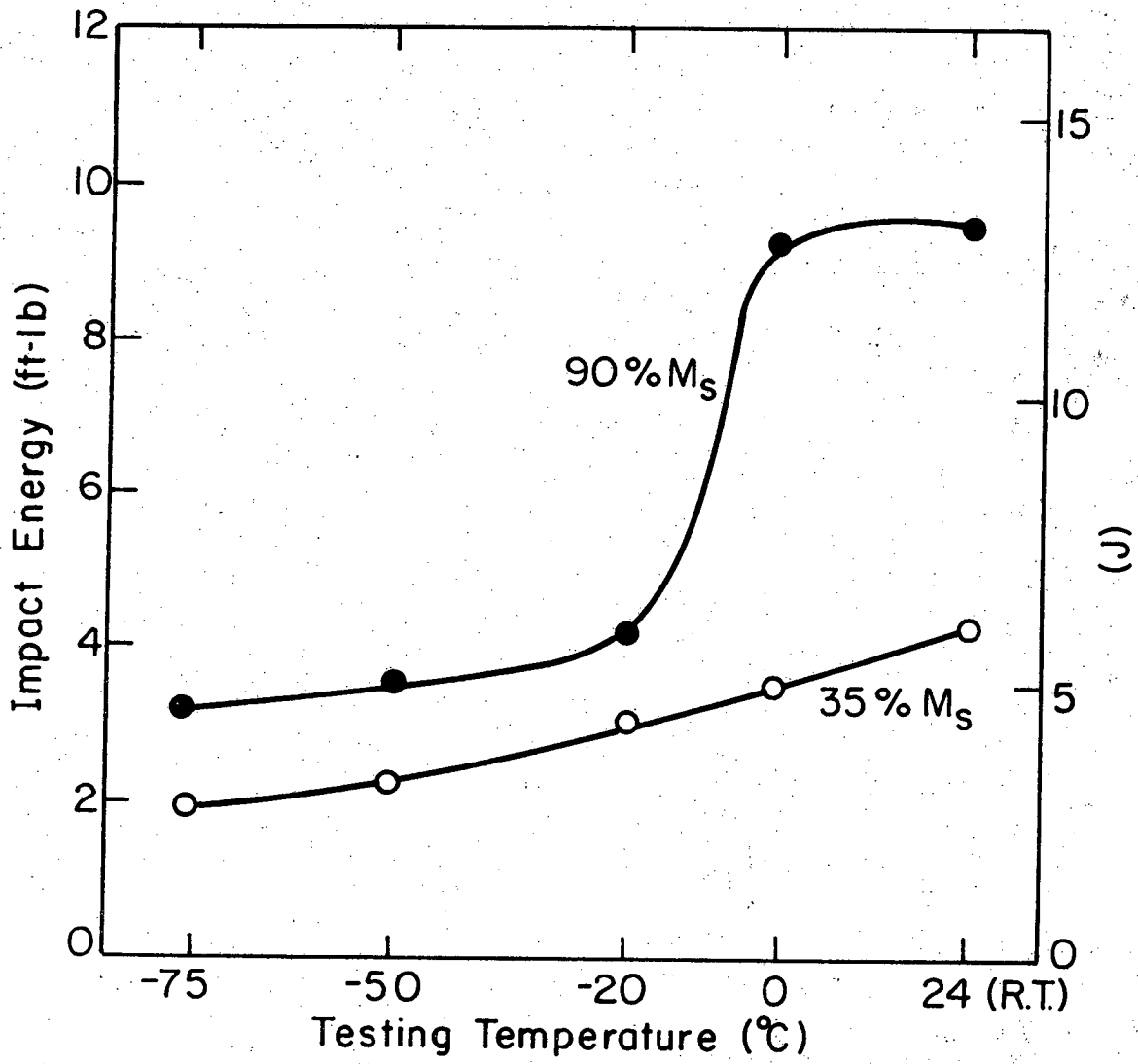
XBB 778 7550

Fig. 1



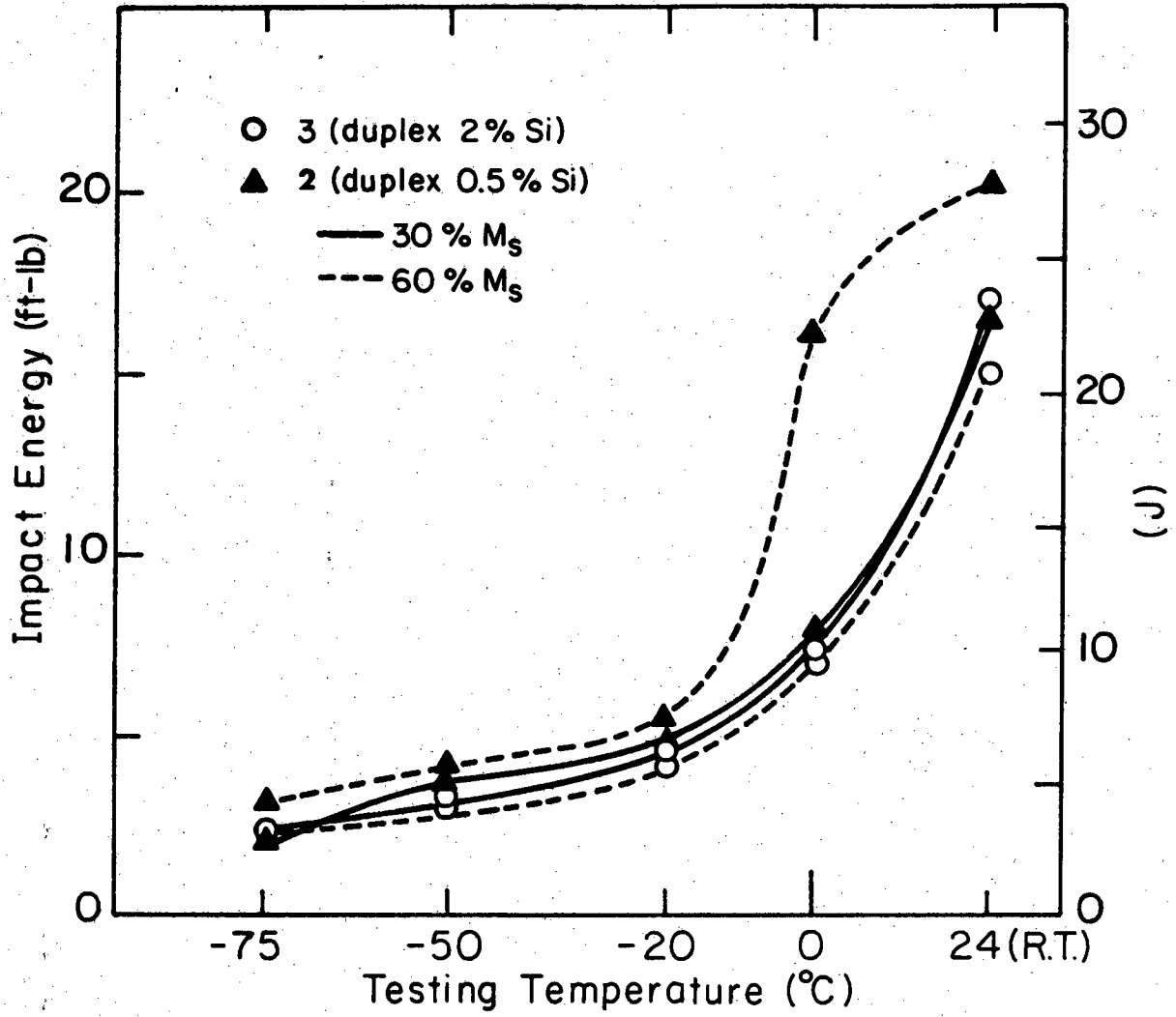
XBB 798-10688

Fig. 2



XBL 798-6737

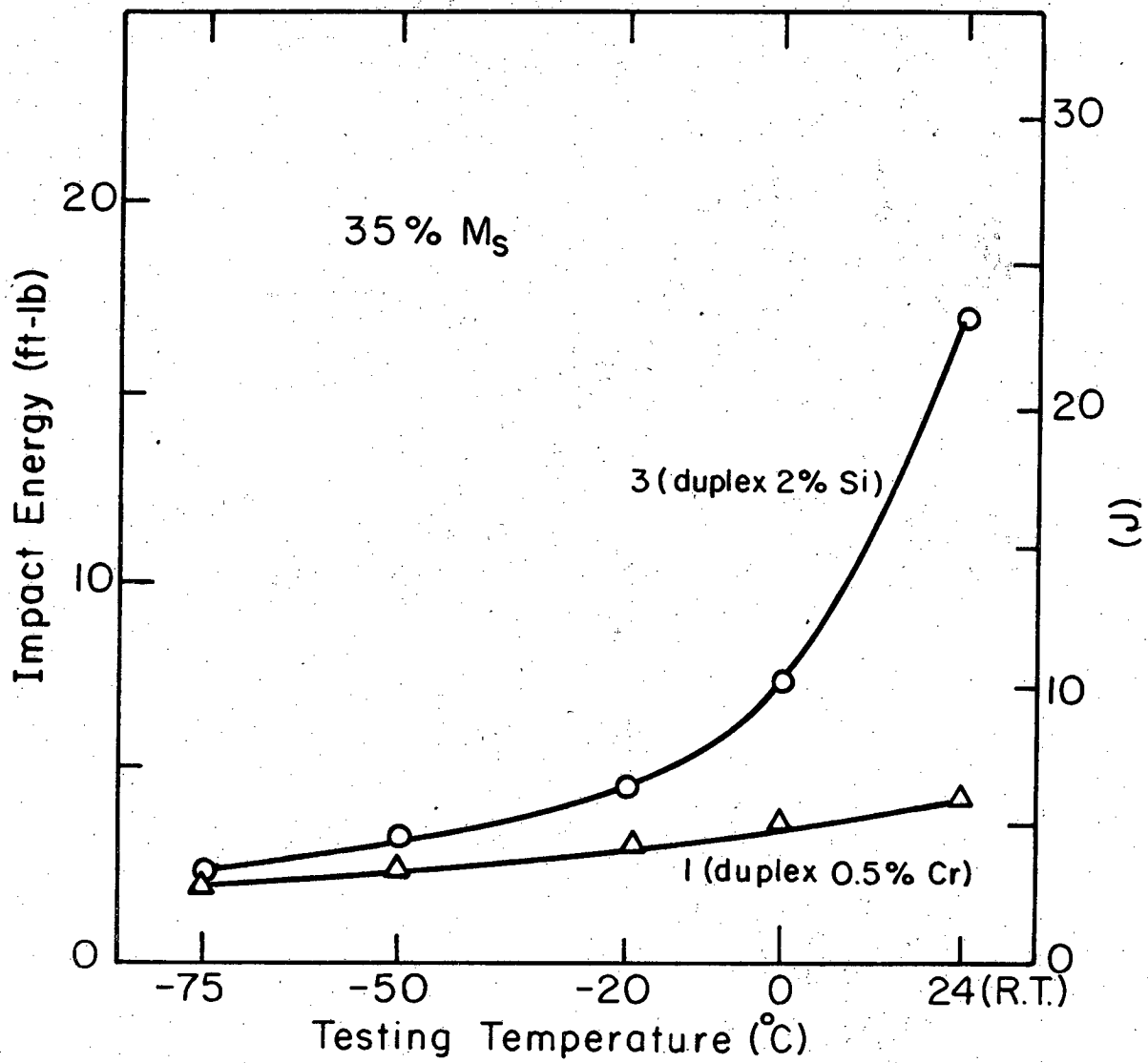
Fig. 3



XBL798-6738

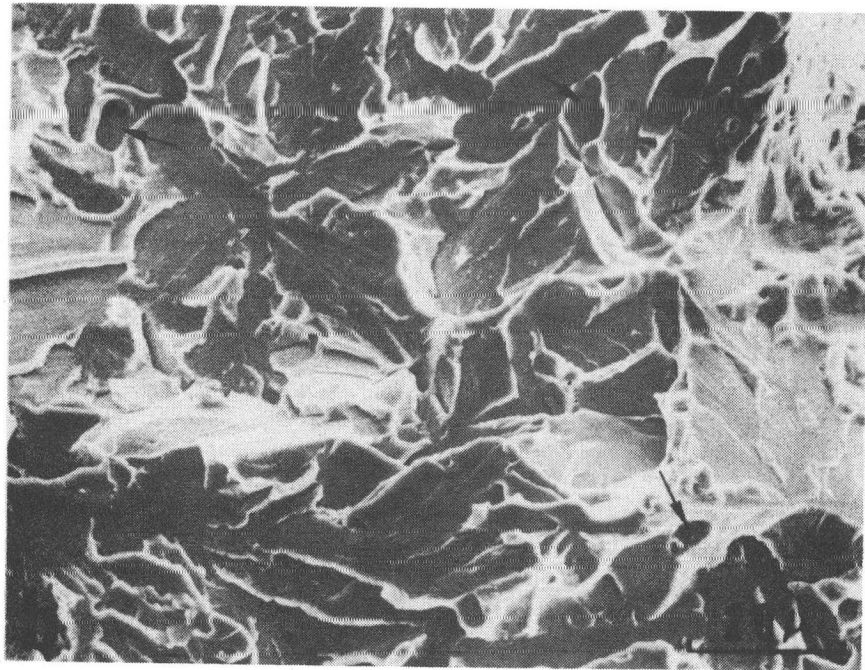
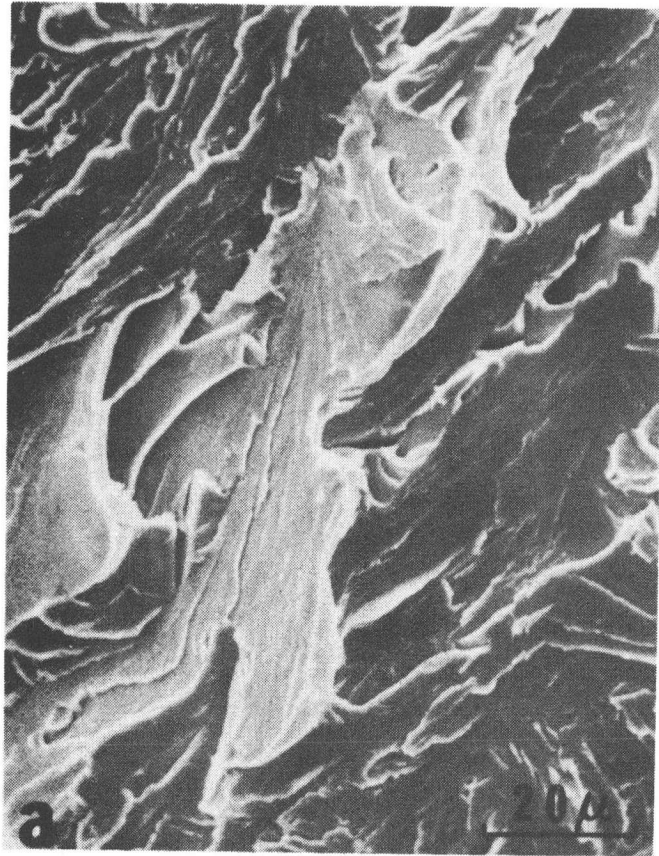
Fig. 4





XBL798-6739

Fig. 5



XBB 778-7554A

Fig. 6

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

TECHNICAL INFORMATION DEPARTMENT  
LAWRENCE BERKELEY LABORATORY  
UNIVERSITY OF CALIFORNIA  
BERKELEY, CALIFORNIA 94720