

Lawrence Berkeley National Laboratory

Recent Work

Title

ON THE MORPHOLOGY AND SUBSTRUCTURE OF MARTENSITE

Permalink

<https://escholarship.org/uc/item/2nh9b65f>

Authors

Das, S.

Thomas, G.

Publication Date

1969-05-01

Submitted to Trans. AIME

UCRL-19019
Preprint

cy. 2

ON THE MORPHOLOGY AND SUBSTRUCTURE OF MARTENSITE

RECEIVED
LAWRENCE
RADIATION LABORATORY

JUL 16 1969

LIBRARY AND
DOCUMENTS SECTION

S. Das and G. Thomas

May 1969

AEC Contract No. W-7405-eng-48

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. 5545

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

cy. 2

UCRL-19019

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.

ON THE MORPHOLOGY AND
SUBSTRUCTURE OF MARTENSITE

S. Das and G. Thomas

Inorganic Materials Research Division, Lawrence Radiation Laboratory,
and Department of Materials Science and Engineering,
College of Engineering, University of California,
Berkeley, California

In iron-nickel and iron-carbon alloys two different morphologies of martensite have been well recognized. In Fe-C steels up to $\sim 0.3\%C$ and in Fe-Ni alloys up to about 28 wt % nickel the martensite consists of groups of laths. The laths within each group are separated by low angle boundaries and one group of laths may be separated from another by a high angle boundary. The martensite of this type has been called massive martensite,¹ lath martensite,^{2,3} needle-like martensite⁴ and is known to be dislocated. In high carbon* or high nickel alloys acicular or plate-like martensite is seen which is internally twinned. So far, no evidence of internal twinning in lath martensite has been reported in the literature. Recently, Ansell et al.⁵ indicated that there were internal twins in a needle-like martensite formed after very high quench rates in 0.50% C steel. In this report direct evidence of $\{112\}$ internal twinning in such a martensite is presented. The steels investigated are basically 9Ni-0.24C, one with no cobalt, and the other with 7% cobalt.

Figure 1 shows an example of transformation twins in the laths in the 9Ni-0.24C alloy. The presence of twins was verified in the usual way from diffraction pattern identification and by dark field imaging

*However, small amounts of internally twinned plates are observed even in 0.14% C alloys.

of twin spots. Also, the fact that the laths in a group are separated by low angle boundaries is shown from the observed single bcc orientation of a number of laths [Fig. 1(b)], and the dark field micrograph of a matrix spot which reversed contrast for adjacent laths. Fine transformation twins in some of the relatively narrow laths is seen in Fig. 2. The twins appear to be lenticular and their width varies from 100 to 700Å. Such small twins in laths look very much like fine carbides in lower bainite laths and can be often misinterpreted unless properly identified. Similar twins are also seen in the cobalt containing alloy [Fig. 3]. The fact that additions of cobalt do not reduce twinning has been pointed out earlier.⁶

These results show that the inhomogeneous shear in massive or lath martensite need not be always slip. Thus, it is not necessarily a condition that twinning is always associated with a martensite which is plate-like (see Wayman⁷). It follows that the morphology of martensite, i.e., plate-like or lath-like does not depend on the substructure, i.e., whether twins are present or not.⁸ Thus, the classification of ferrous martensites into lath and twinned, as adopted by many workers,^{2,3} is not very appropriate and a further distinction between twinned and dislocated laths is necessary.

Thus, one should use metallographic descriptions with caution. All we really can say is that there are two types of martensite: dislocated martensite (e.g., in low carbon steels) and twinned martensite.

A recent investigation⁶ of a series of Fe-Ni-Co-C steels has shown that the martensites in alloys with the same Ms temperatures may have widely different amounts of twinning, and so the Ms temperature alone

is not a sufficient indication of internal twinning. From a comparison of Fe-C and Fe-N martensites Bell and Owen⁹ suggested that the transition from a dislocated to a twinned martensite may occur when a critical driving force of the martensitic transformation (ΔG) of about 315 cal mole⁻¹ is expected. Pascover and Radcliffe¹⁰ extended this concept to Fe-Ni and Fe-Cr systems and found that in Fe-Ni system the critical driving force is about 300 to 370 cal mole⁻¹ at 29 at % Ni, where actually the substructural transition is observed. In the Fe-5 Wt % Cr alloy although their computed driving force was between 300 and 350 cal mole⁻¹, they did not observe any twinning in the martensite. Thus, in addition to the effect of composition on the driving force, it is also necessary to consider its effect on the critical resolved shear stress for twinning and slip. If the CRSS for twinning is less than that for slip at the temperature where martensite forms, it will twin as discussed by Johari and Thomas.¹¹ If the driving force is enough and the CRSS for twinning is lower than that for slip, twinned martensite is expected irrespective of its morphology (i.e., lath or plate). The absence of twinning in Fe-5% Cr alloy,¹⁰ even though a high driving force exists, may thus be explained on the basis that the CRSS for twinning is higher than that for slip at the transformation temperature.

ACKNOWLEDGMENT

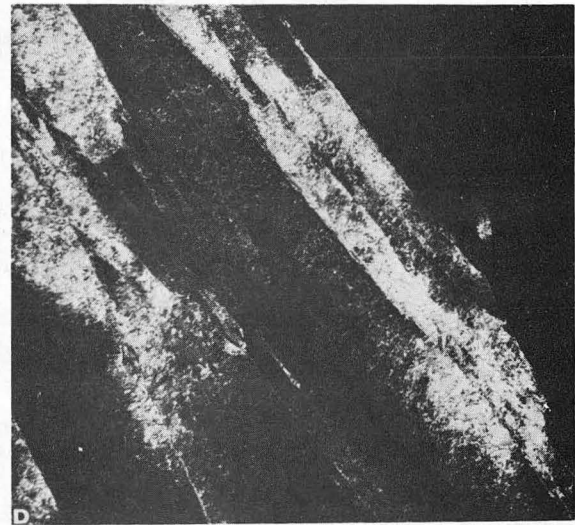
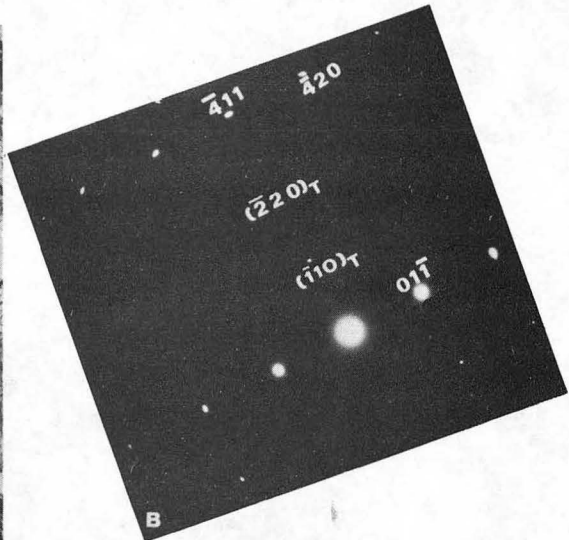
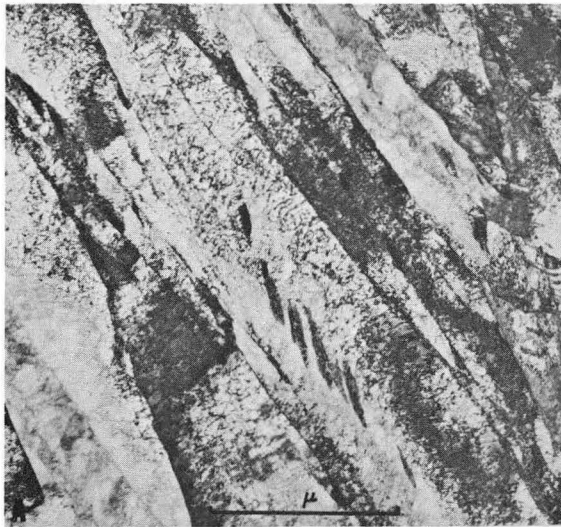
This work was done under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

1. W. S. Owen, E. A. Wilson and T. Bell, in High Strength Materials, ed., V. F. Zackay, John Wiley and Sons, New York, 167 (1965).
2. G. R. Speich and H. Warlimont, J. Iron and Steel Inst. 206, 385 (1968).
3. R. F. Vyhna1 and S. V. Radcliffe, Acta Met, 15, 1475 (1967).
4. P. M. Kelly and J. Nutting, Proc. Roy. Soc. (A) 259, 45 (1960).
5. G. S. Ansell, V-l Lizunov and R. W. Messler, Jr., Trans Japan Inst. of Metals, 9, 933 (1968 Supplement).
6. S. Das and G. Thomas, submitted to Trans ASM.
7. C. M. Wayman in "Physical Properties of Martensite and Bainite," Special Report 93, The Iron and Steel Inst. (London), 147, (1965).
8. R. L. Patterson and C. M. Wayman, Acta Met, 14, 347 (1966).
9. T. Bell and W. S. Owen, Trans. Am. Inst. Min. Metall. Engrs, 239, 1940 (1967).
10. J. S. Pascover and S. V. Radcliffe, Trans. Am. Inst. Min. Metall. Engrs., 242, 673 (1968).
11. O. Johari and G. Thomas, Acta Met, 13, 11 (1965).

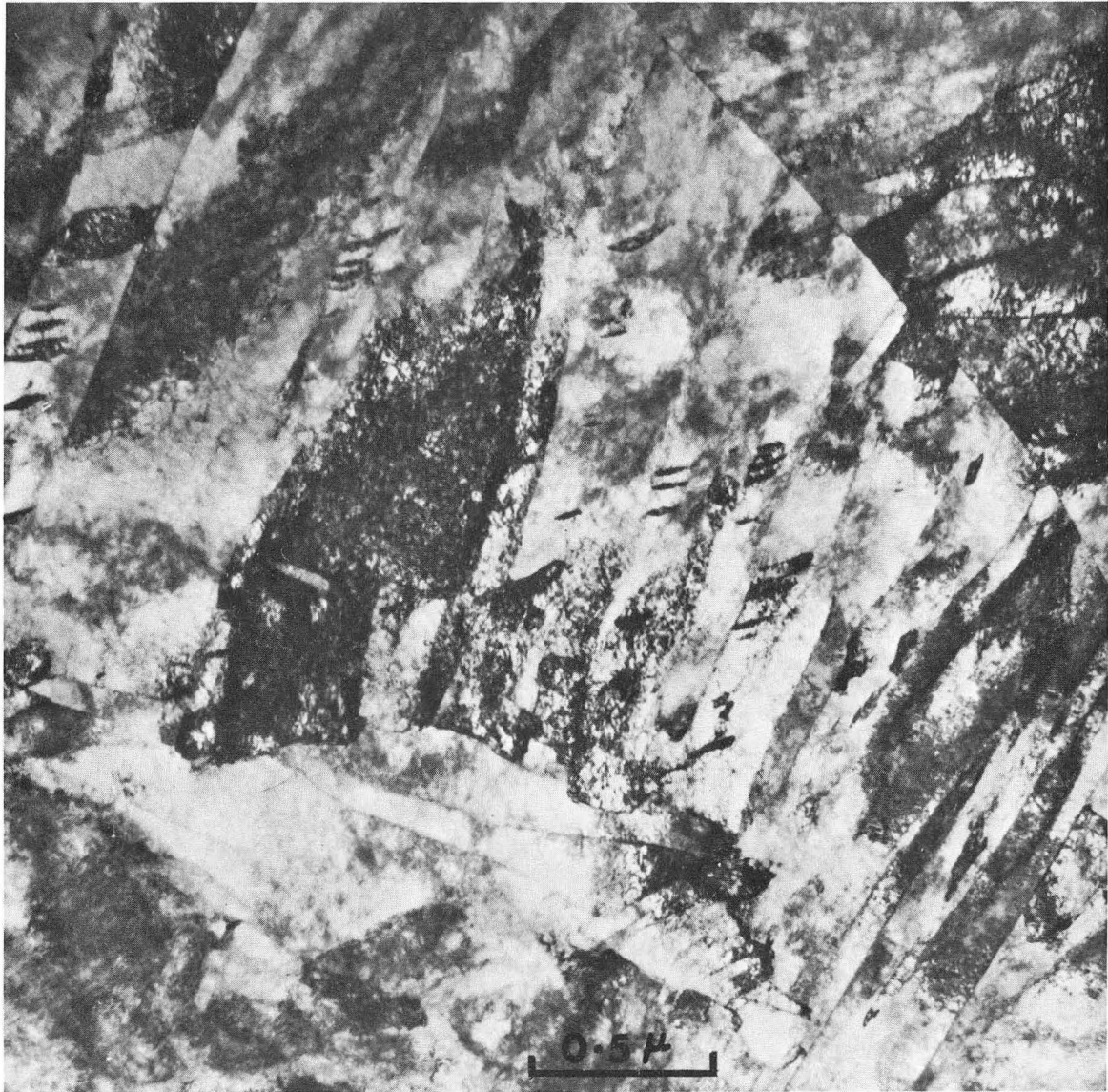
FIGURE CAPTIONS

- Fig. 1 (a) Bright field micrograph of martensite in 9Ni-0.24C steel showing internal twins inside the laths.
- (b) Selected area diffraction of the encircled area in (a), with matrix in $\sim[122]$. Twinning on $(12\bar{1})$ plane and then on $(11\bar{2})$ plane brings a $(\bar{1}10)$ twin reflection at $\frac{1}{3}(\bar{4}11)_{\text{matrix}}$ position and a $(\bar{1}\bar{1}\bar{4})_{\text{twin}}$ reflection at $(03\bar{3})$ matrix position. The other extra spots are due to double diffraction.
- (c) Dark field micrograph of $(\bar{1}10)$ twin reflection showing reversal of contrast for twins.
- (d) Dark field micrograph of $(01\bar{1})$ matrix reflection. There is no twin spot coincident with $(01\bar{1})$ matrix.
- Fig. 2 Another group of relatively narrower laths than Fig. 1, showing fine internal twins.
- Fig. 3 Internal twins in lath martensite in 9Ni-7Co-0.24C steel.



XBB 695-3499

Fig. 1



XBB 695-3500

Fig. 2



XBB 694-3501

Fig. 3

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or*
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.*

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720