Behaviour of Precipitates in Bond Region of Overlay Welding (Report III)†

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Abstract

The authors presented the results about overlaid cladsteel which is generally used for the nuclear reactor and the chemical industry. Especially, the application of ion micro-probe analysis to the residues extracted from overlaid layers showed the detection of various impurities.

From this, the precipitates appeared at the boundaries between austenite and ferrite was thought as carbonitride or complex carbide.

1. Introduction

In the previous reports[1), 2)], the following specimens were investigated to determine the shape, the composition, and the location of the precipitates at the boundaries between austenite and ferrite.

In this report, the authors presented the results about overlaid cladsteel which is generally used for the nuclear reactor and the chemical industry. The specimens used are one layer and two layers welded.

Although there are many sorts of overlaying methods, especially, band electrode mean has many advantages to obtain higher coverage, to necessitate poorer dilution effect, and, further, to get stabilizing behaviour with high efficiency. These circumstances could be understood from Table 1.

In the first stage, the materials prescribed in AWS have been used. However, stainless steel band and flux to be used for are prescribed as shown in Tables 2, 3 and 4. (JIS Z 3322-1975)

From the requirement of higher efficiency in the overlay procedure, various designs such as the application of wider electrode like 180mm, use together with magnetic mean, and the use of multiple electrodes are planning now.

As previous stated, band electrode and flux must be chosen depending on the chemical composition of base metal, depth of penetration, control of the component added. Usually, the following procedures are being used, mean which overlays steel such as 308, 347 and 316 as second layer after first overlay was done with 309 steel by considering the dilution effect from the base metal, and an another mean which the use with one layer treatment is possible when the control of iron dilution and carbon content.

It has been reported that, in the band arc welding, fine crack due to the precipitation of chromium carbide often occurred. Furthermore, embrittlement cracking of weld metal appears after post-heattreatment. To prevent the troubles, the additive effect of niobium in the case of 347 steel has been emphasized to fix carbon for the formation of chromium carbide. Further, the addition of molybdenum is intended to obtain higher corrosion resistance.

Like these statements, it is an important subject to study the behaviour of carbide in the overlay welding.

Alike previous reports, observation by optical and electron microscopes and analysis by electron and X-ray diffraction were carried out. Furthermore, the extracted residues were investigated with ion microprobe analyzer.

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Table 1 Comparison of the characteristic of various overlay weldings

Method	Coverage (kg/hr)	Dilution (%)	Minimum thickness (mm)	Electrode	Use
Coated arc	2.0	20	2.4	coated	manual
TIG	3.2	10	2.4	rod wire	manual
TIG hotwire	7.0	25	2.4	wire	non-ferrous
MIG	5.5	30	3.2	wire	non-ferrous overlay
MIG cold wire oscillate	11.5	10	4.0	wire	non-ferrous overlay
Submerged arc oscillate	6.8	20	3.2	wire	Hardend overlay
Series arc	12.0	15	4.0	wire	overlay
Series arc	15.0	15	4.8	wire	overlay
Band arc	36.0	10	3.0	hoop	overlay
Plasma arc	3.2	5	0.3	powder	special metals
Short arc	3.0	10	2.0	wire	semi-automatic
Non-gas (tube wire)	6.0	25	4.0	tube wire	semi-automatic

Table 2 Classification of sorts

Sort	Classification	Remarks
YB304	F D	F is applied to single layer or first layer overlay welding. D is applied to overlay welding more than second layer.
YB304L	D	
YB316	F D	
YB316L	D	
YB347	F D	

Table 3 Size and permitted error

Division	Size	Permitted error
Width	0.4	± 0.04
Breadth	25, 37.5, 50, 75	± 0.5

2. Experimental Specimens

Chemical compositions of base metal and band electrode are shown in Table 5. In Fig. 1. the overlaying mean is shown. In every case, A387 steel was used as base metal.

Table 4 Chemical composition of weld metal

Type	Chemical elements (%)							
	C	Si	Mn	P	S	Ni	Cr	Mo	Nb+Ta
YB304	0.08	1.00	2.50	0.04	0.03	8-11	18-21	-	-
YB347	0.08	1.00	2.50	0.04	0.03	9-13	17-21	-	8 × C% − 1.0
YB316	0.08	1.00	2.50	0.04	0.03	10-14	16-20	2-3	-
YB316L	0.04	1.00	2.50	0.04	0.03	11-16	16-20	2-3	-
YB304L	0.04	1.00	2.50	0.04	0.03	9-13	18-21	-	-

Table 5 Specimens used

No.	Base metal	First layer	Second layer	Welding process
1	A387D	NS347S	–	Submerged arc (strip electrode)
2	A387D	NS309L	NS347	
3	A387D	NS347S	NS347	
4	A387D	NS347S	NS316	
5	A387D	309R	347R (3rd)	Manual arc

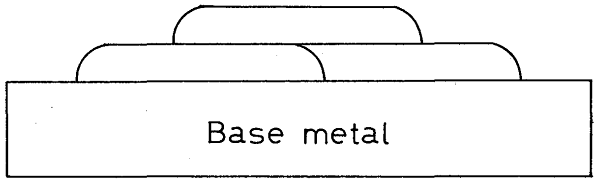


Fig. 1 Overlay procedure

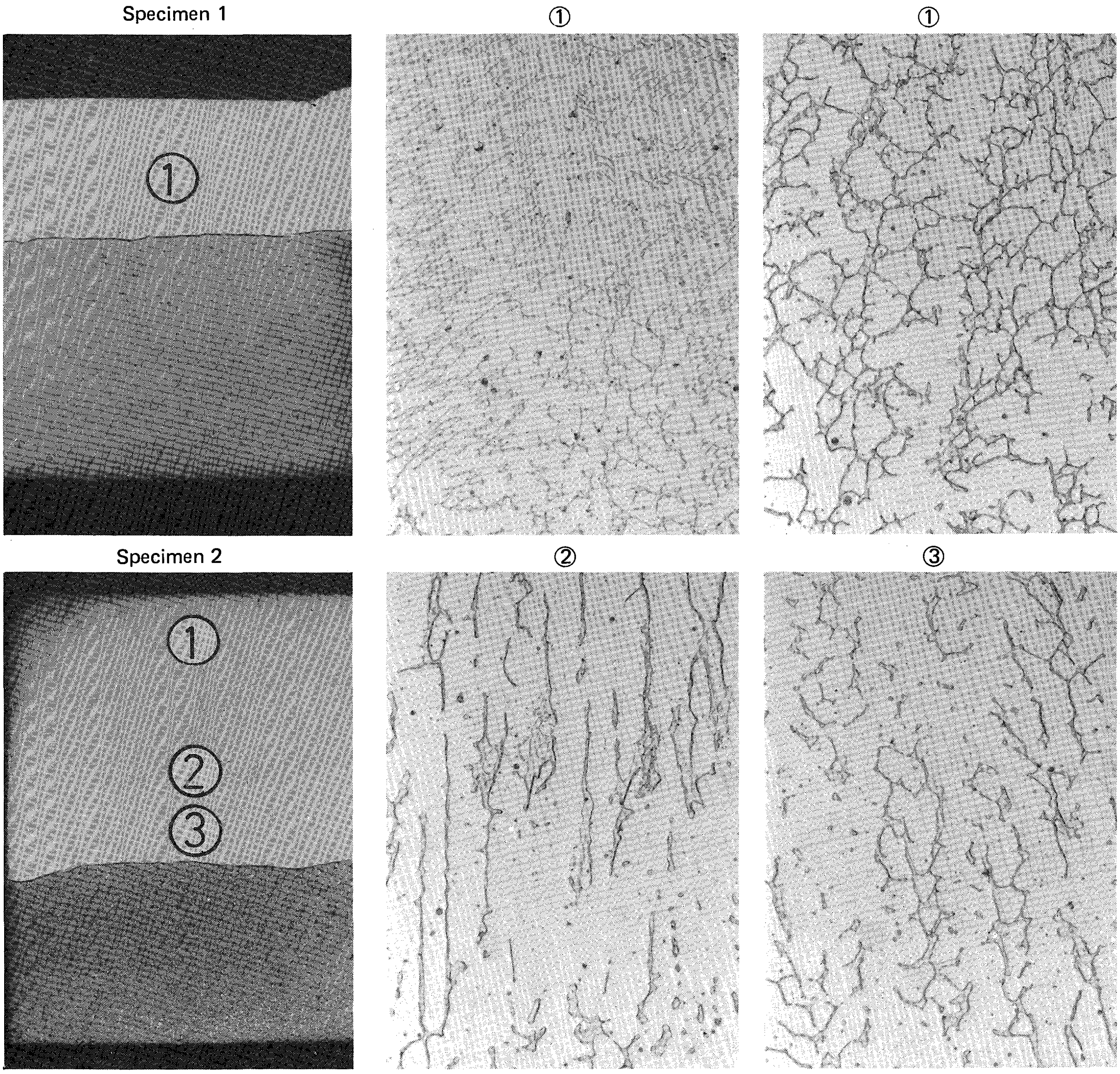


Photo 1 Metallographic results of specimens 1 and 2 (X400)

3. Experimental Procedures

Chiplike specimens were taken out from first and second layer for the acid extraction respectively. Extraction mean, vessel are same as reported in the previous paper[1].

For the electron microscopical observation and electron diffraction, specimen from base metal was reduced to be 50μ thickness and a portion was etched with needle method.

4. Experimental Results and Discussion

The extracted residues were identified to be NbC. With the electron microscopical observation, it was observed that niobium carbide precipitated at boundaries between austenite and ferrite.

In Photos. 1, 2 and 3, metallographic textures of overlaid divisions of specimens 1, 2 and 3 are shown. From the results, it is anticipitated that the amount of ferrite differs with the location.

The results by electron microscopical observation and electron diffraction are shown in Photos. 4, 5, 6 and 7. It was confirmed that the precipitates observed at the

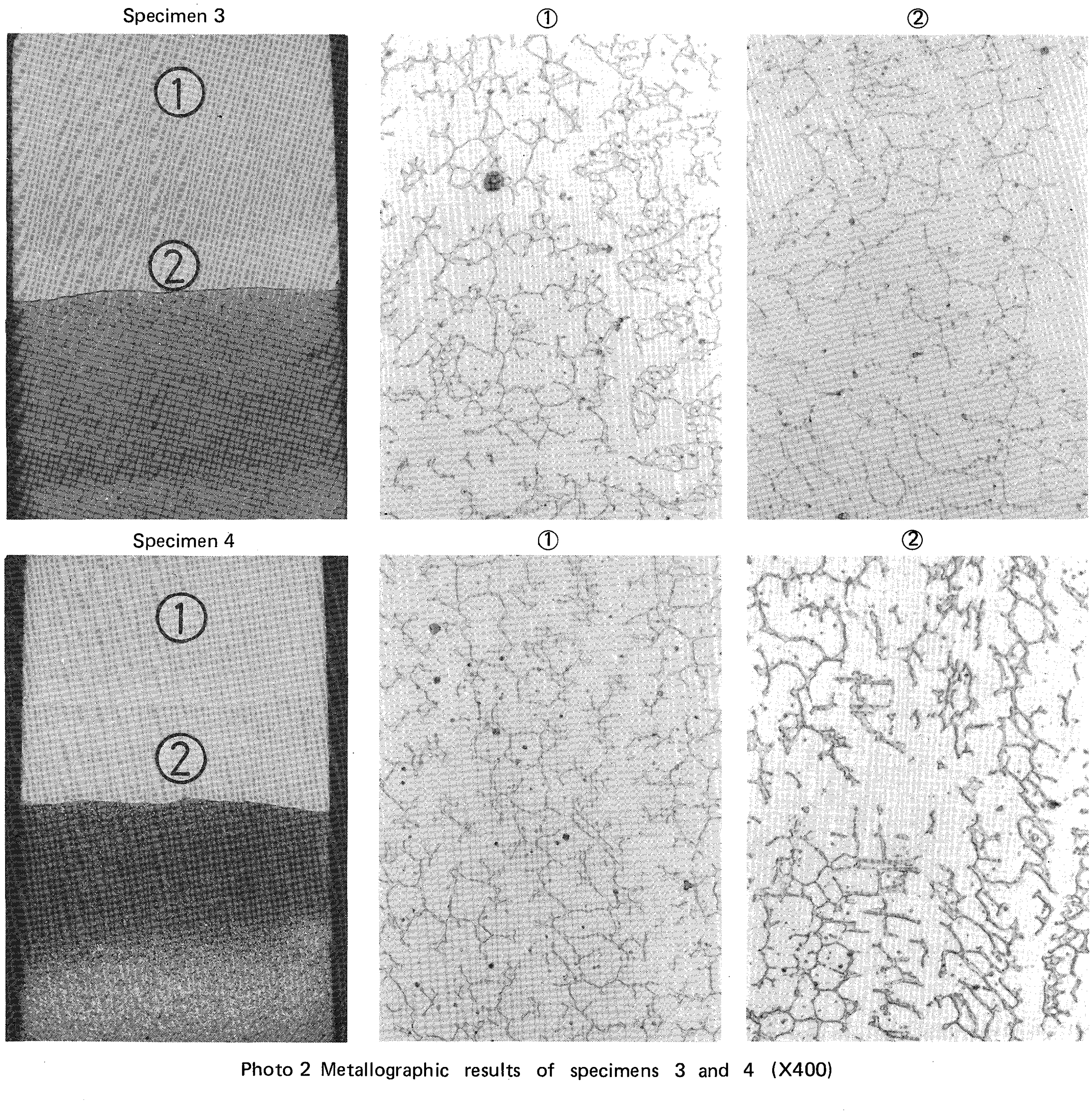


Photo 2 Metallographic results of specimens 3 and 4 (X400)

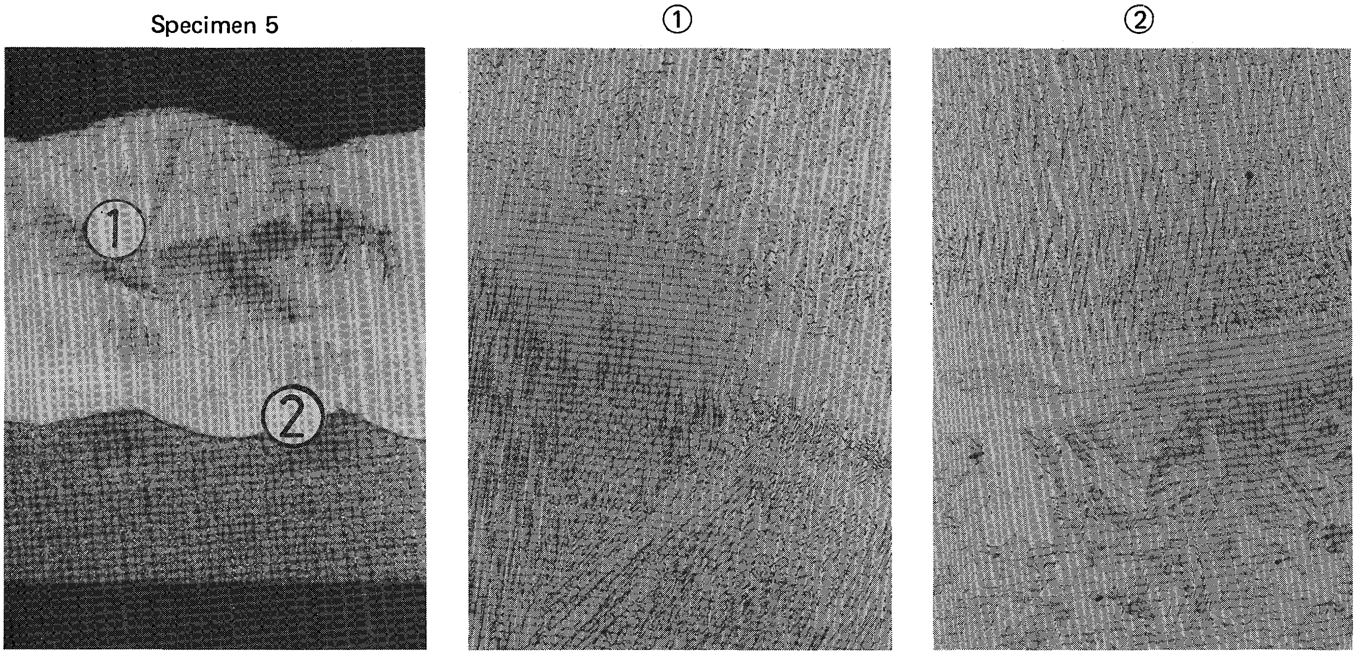


Photo 3 Metallographic result of specimen 5 (X100)

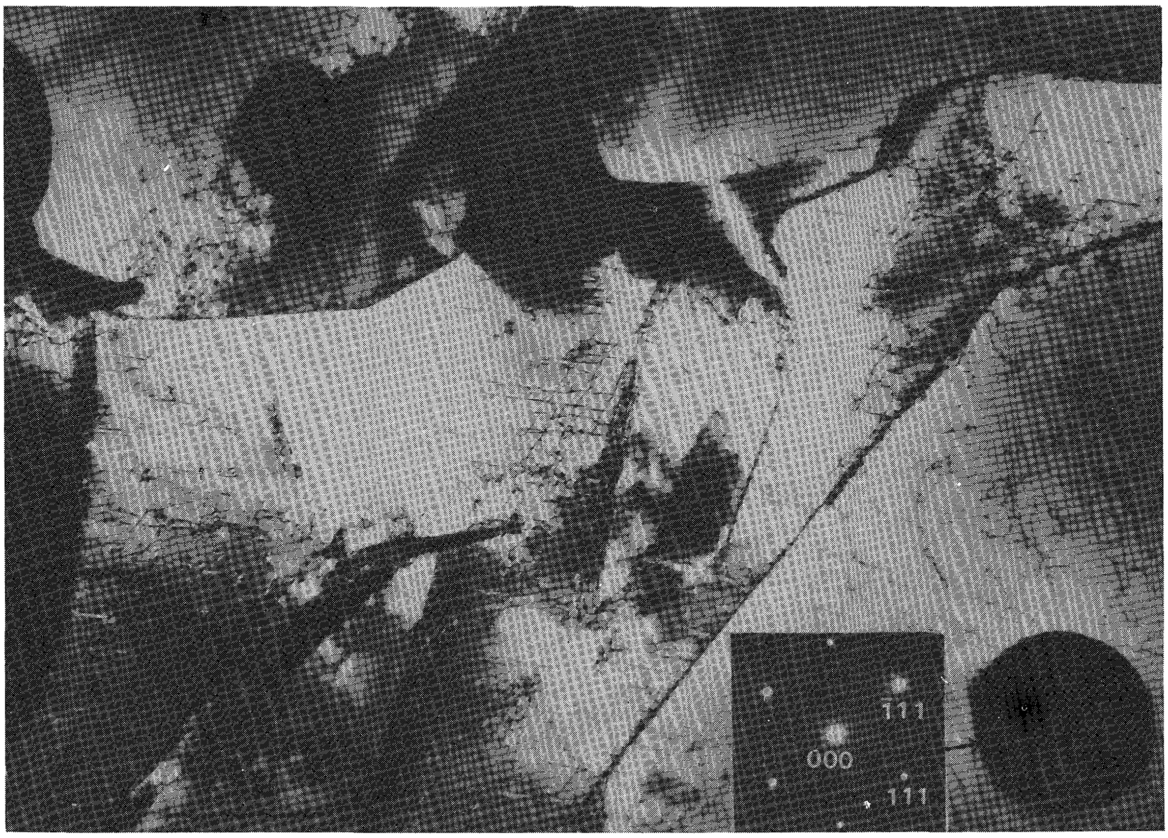
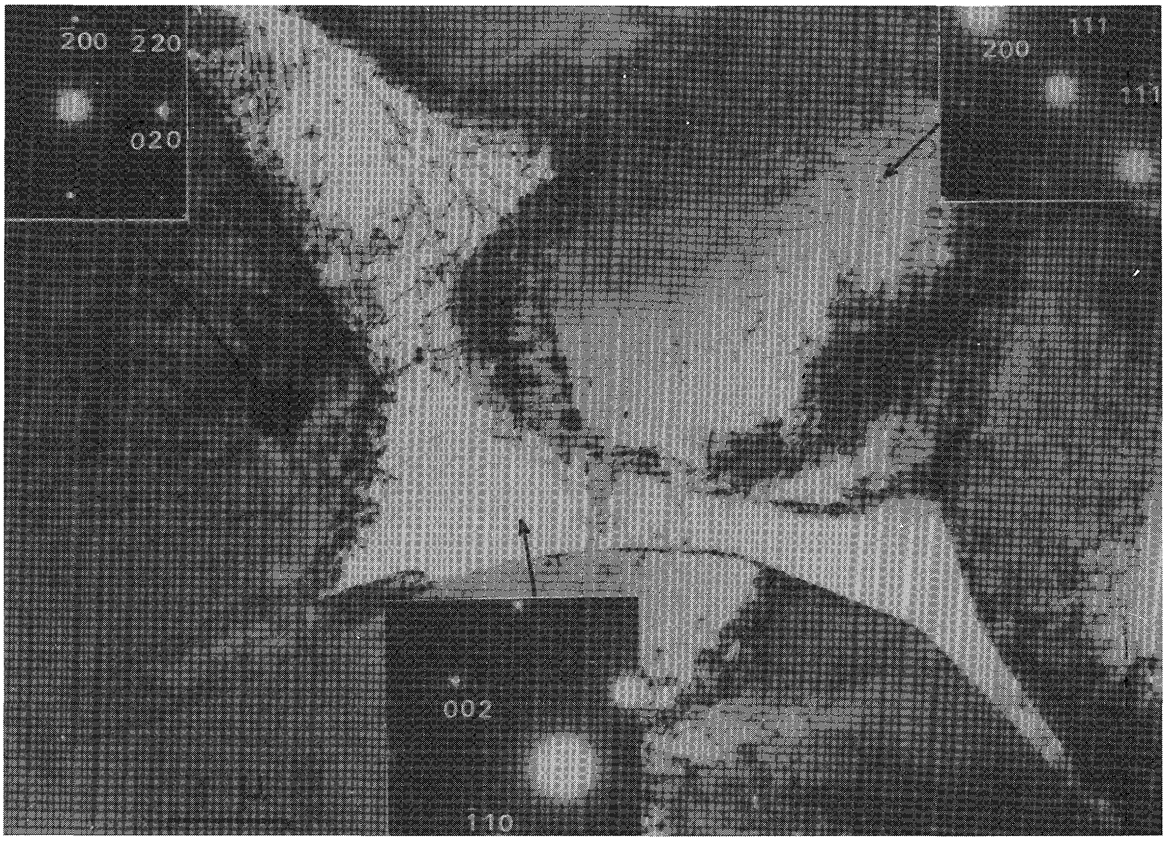
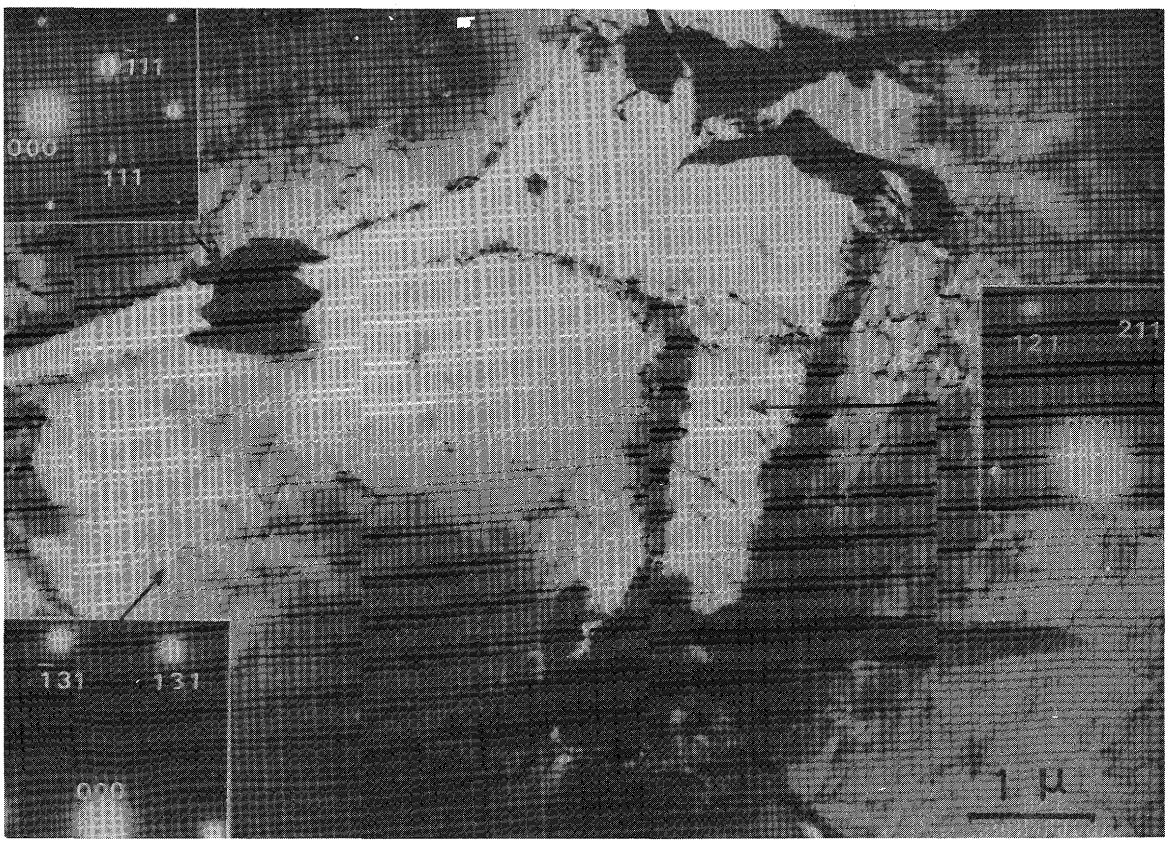


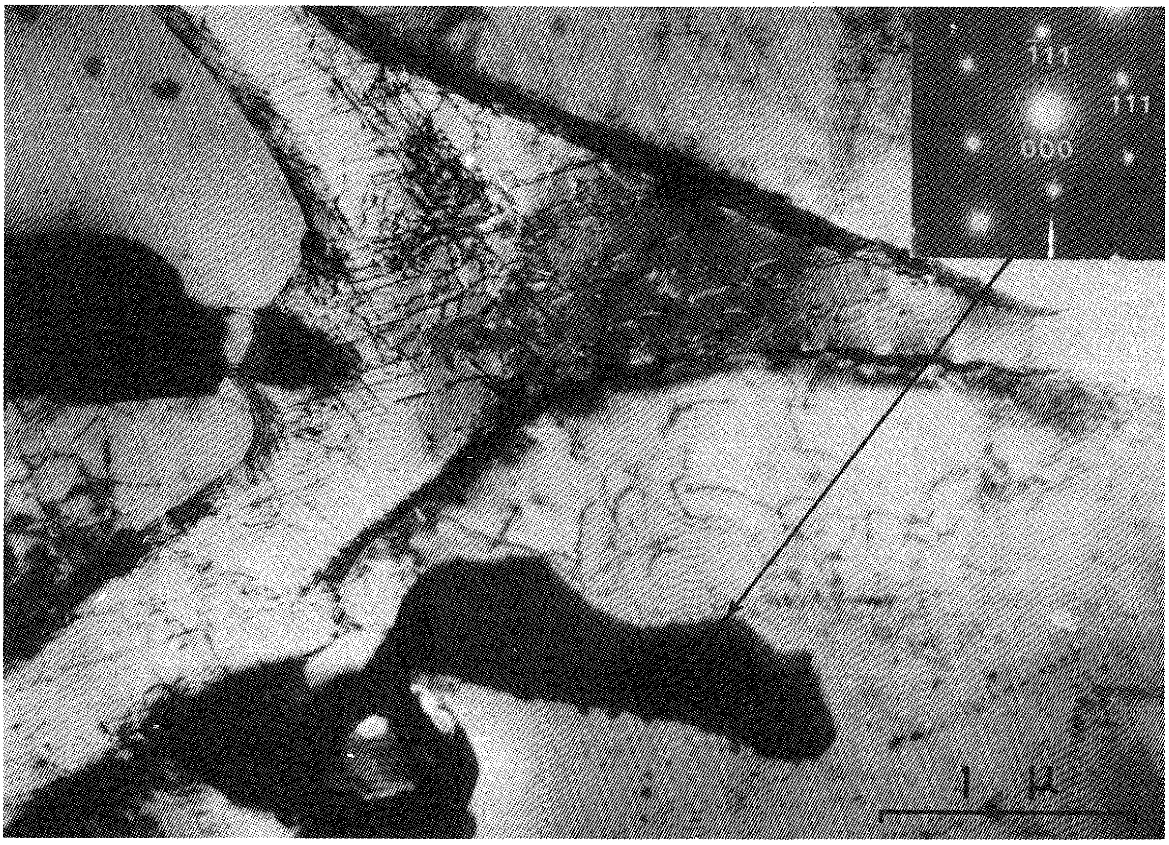
Photo 4 Transmission electron micrograph of specimen 1.



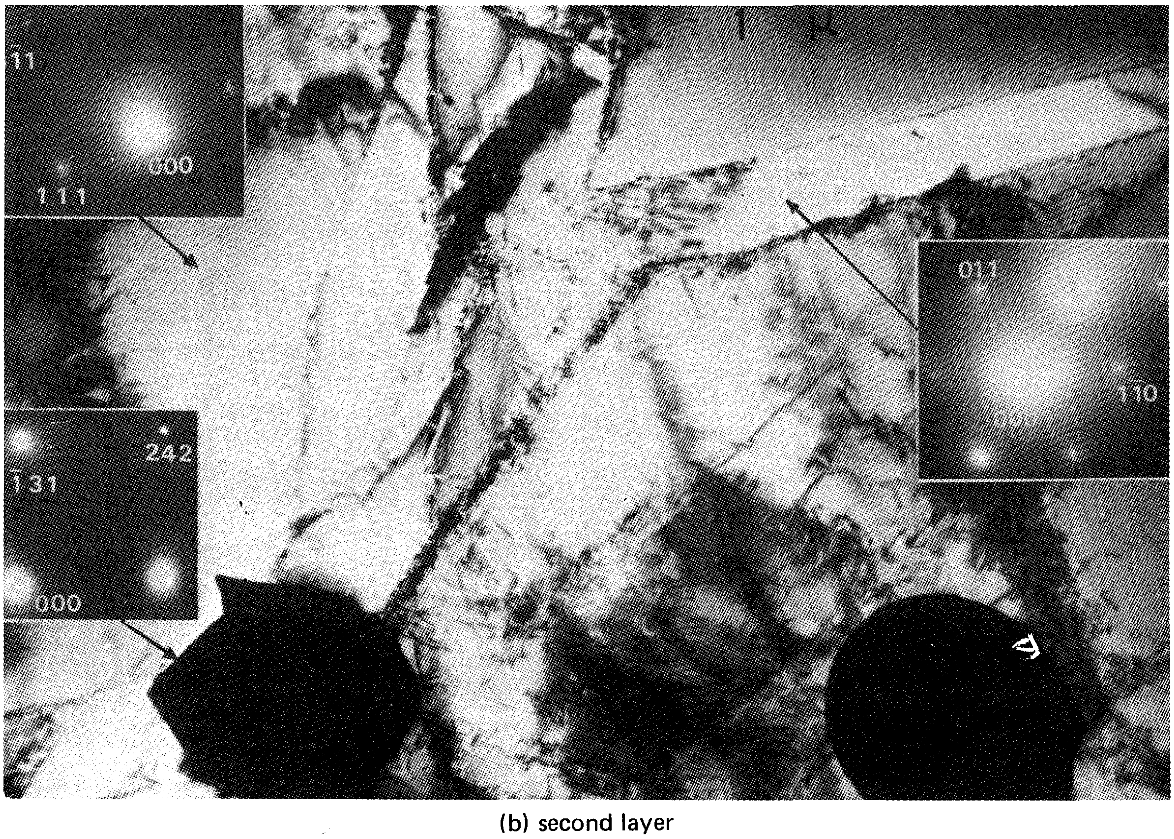
(a) first layer
Photo 5 Transmission electron micrograph of specimen 2.



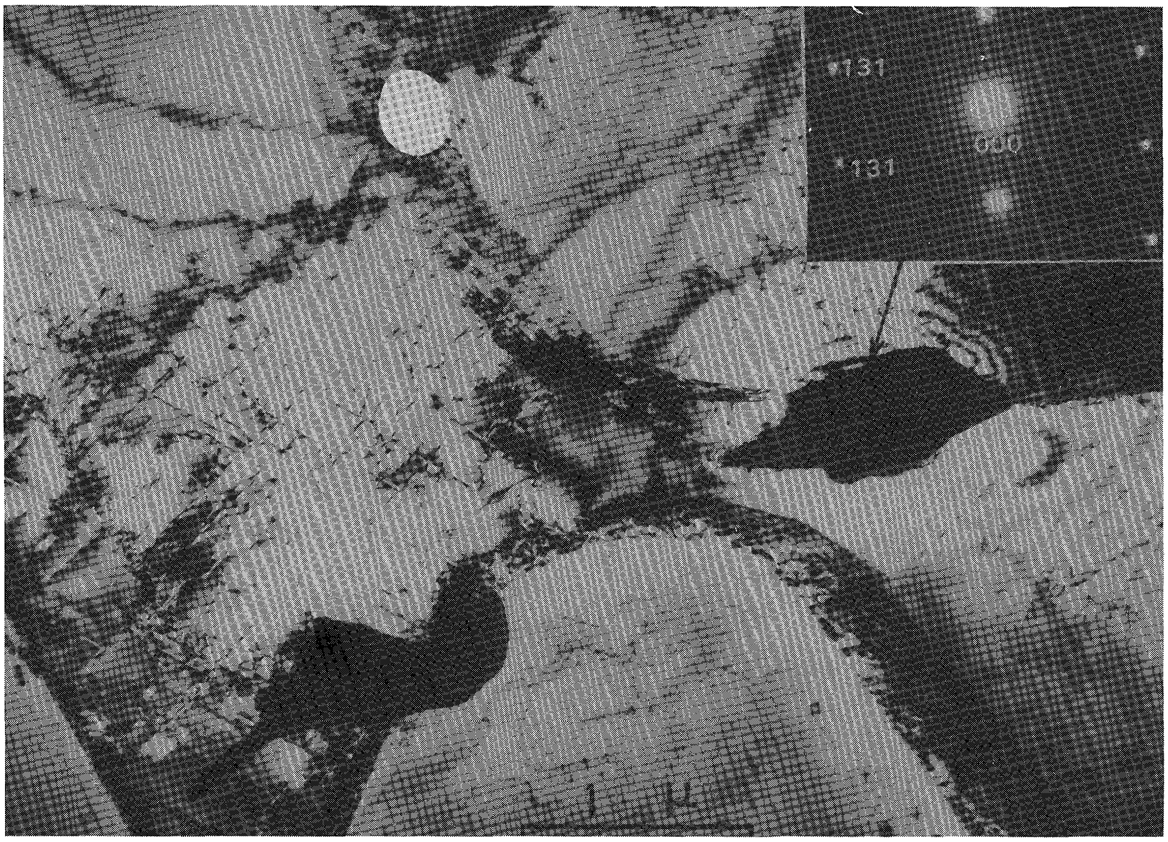
(b) second layer
Photo 5 Transmission electron micrograph of specimen 2.



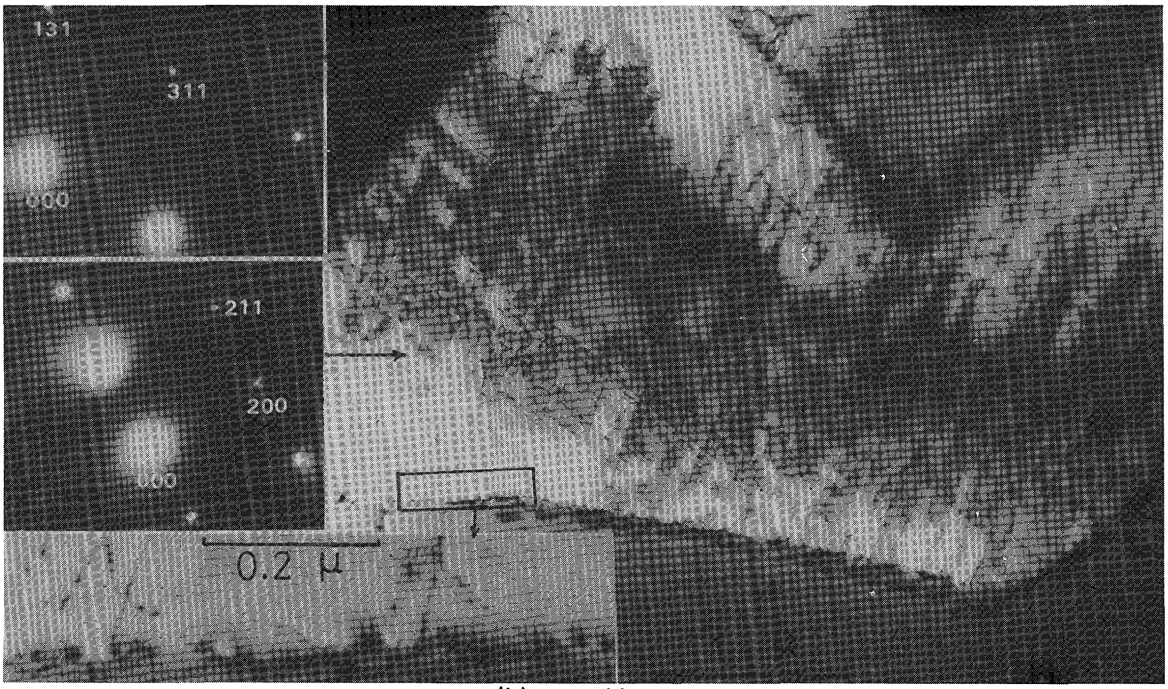
(a) first layer
Photo 6 Transmission electron micrograph of specimen 3.



(b) second layer
Photo 6 Transmission electron micrograph of specimen 3.



(a) first layer
Photo 7 Transmission electron micrograph of specimen 4.



(b) second layer
Photo 7 Transmission electron micrograph of specimen 4.

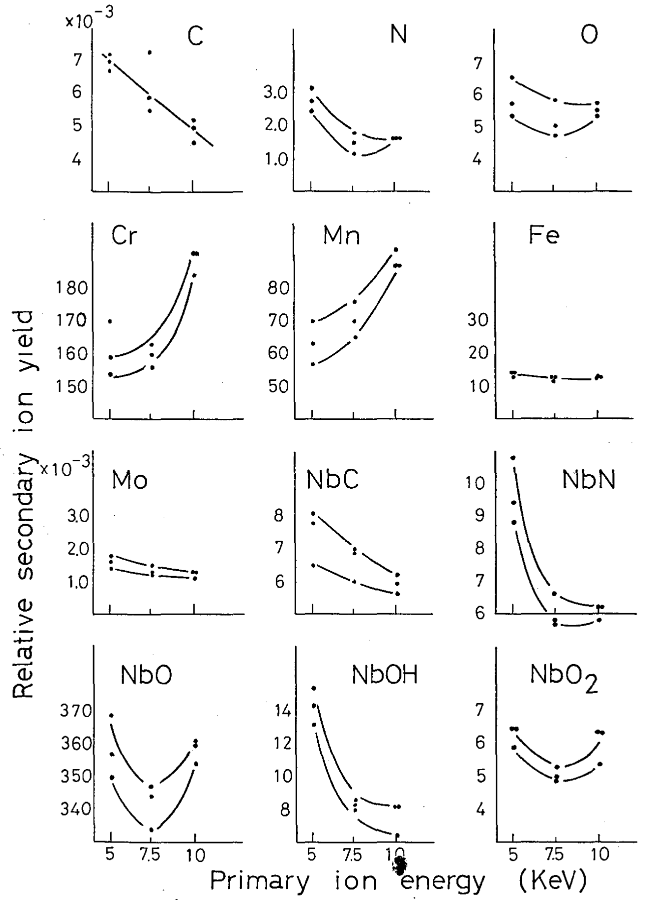


Fig. 2 Various ions sputtered from the extracted residues

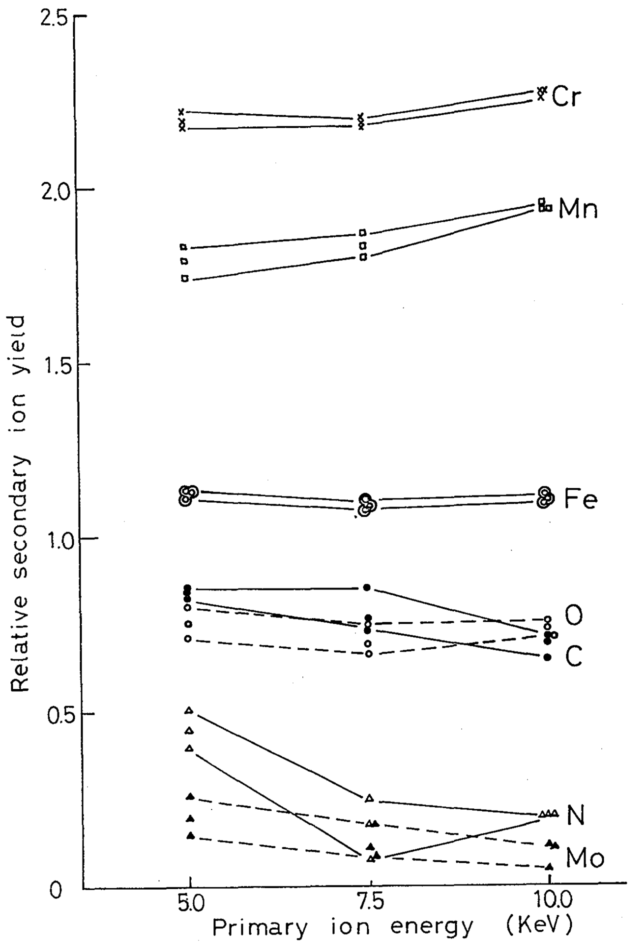


Fig. 3 Relationship between primary ion energy and ion yield

boundaries between austenite and ferrite were niobium carbide.

Successively, the residues extracted were examined with ion microprobe analysis to obtain the information of the fine structure. The measurements were performed with the accelerating voltages such as 5, 7.5 and 10kV, and each measurement was done three times with the check of sample current. The results obtained are shown in Figs. 2 and 3. Ionic sputtering as follows was remarkably observed: C, N, O, Cr, Mn, Fe, Mo, NbC, NbN, NbO. Accordingly, carbide as NbC identified by X-ray and electron diffraction analyses should be considered as Nb·(C N) or complex carbide (Nb, Mo, Cr, Fe, ·····) · (C N) and is necessary to do precise study.

References

1) N. Iwamoto, K. Murata and M. Oka: Trans. JWRI., 4 (1975), p. 49

2) N. Iwamoto, K. Murata, M. Oka and Y. Taniguchi: ibid, 5 (1976), p. 53