In-situ Surface Alloying of Mild Steel During Casting Process

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Introduction

- Improve corrosion resistance of mild steel and achieve **corrosion resistance** comparable to stainless steel using conventional casting techniques
- Improve the life of cast WCB steel components
- Remove need for post-processing surface improvement treatments
- Scaling of lab casting methods to industrial level to make surface alloyed prototypes casting

Objectives

- The control of thickness and composition of the surface alloyed layer during in-situ casting
- Ease the transition from lab scale to industrial scale
- Improve the hardness and corrosion resistance of cast surface alloyed components
- Provide a balance between lower costs and improve life as compared to currently available mild steel alloys
- Understand the effect of heat treatment on the microstructure and phases

Experimental Techniques Used:
Surface analysis: Optical microscopy, EDS, Potentio-dynamic, Polarization Testing, Salt Spray Testing, Vickers Microhardness Tests, Nanoindentation, X-Ray Diffraction, and Solution Annealing.

Experimental Approach

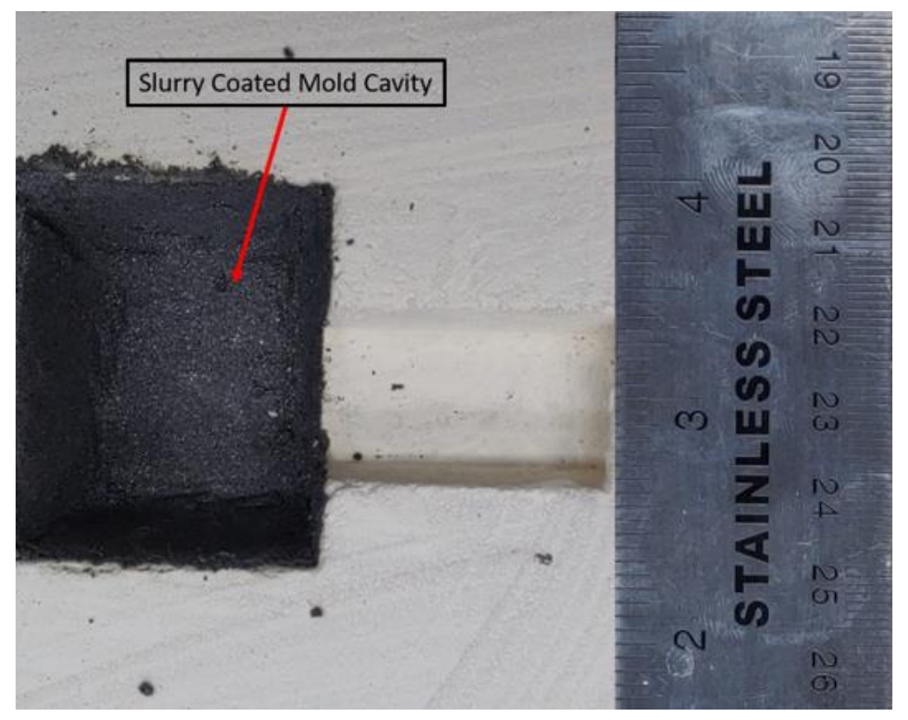


Fig 1. Mold cavity coated with slurry of alloying powder and binder

Fig 2. Surface enriched sample cast at UWM Foundry Lab

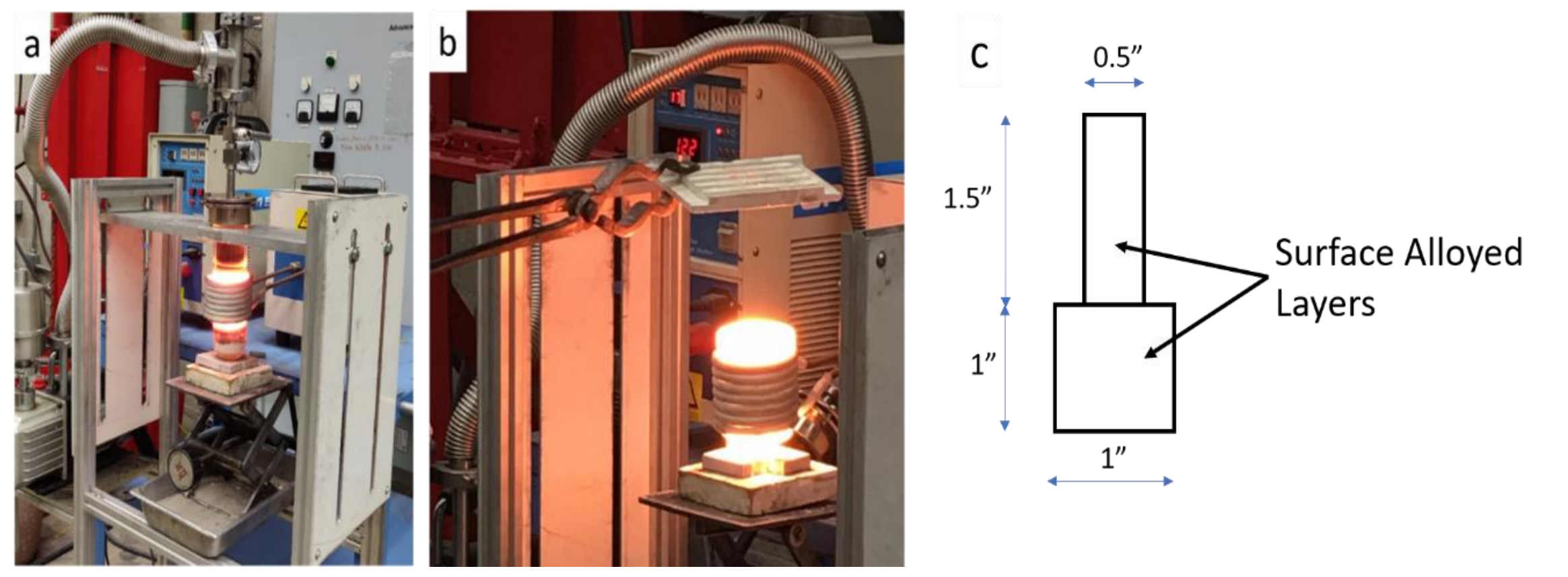


Fig 3. Lab scale experimental setup for (a) quartz tube experiments and (b) open pour experiments. (c) Schematic of open pour molds

Sample Name	Thickness of Layer (μ)	Comparable Composition
R1	950-1000	316L Stainless Steel
R2	1950-2050	316L Stainless Steel
R3	2900-3100	316L Stainless Steel
R4	**3950-4100**	316L Stainless Steel
R5	980-1070	Super Duplex 2205
R6	990-1100	Super Duplex 2205
R7	1895-2050	Super Duplex 2205
R8	1950-2080	Super Duplex 2205

Table 1. List of castings made at UWM Foundry Lab showing increasing thickness

Project Results

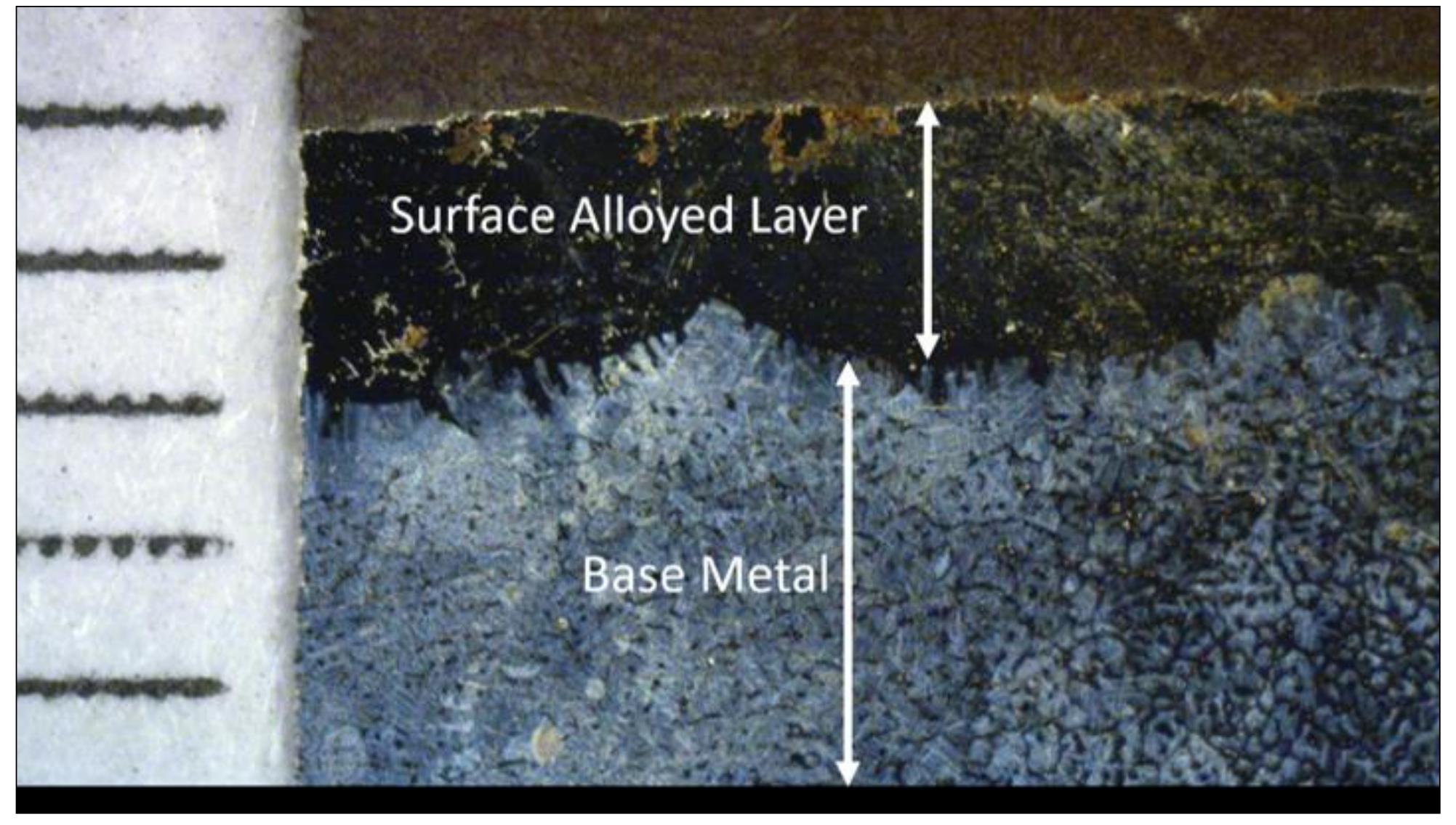
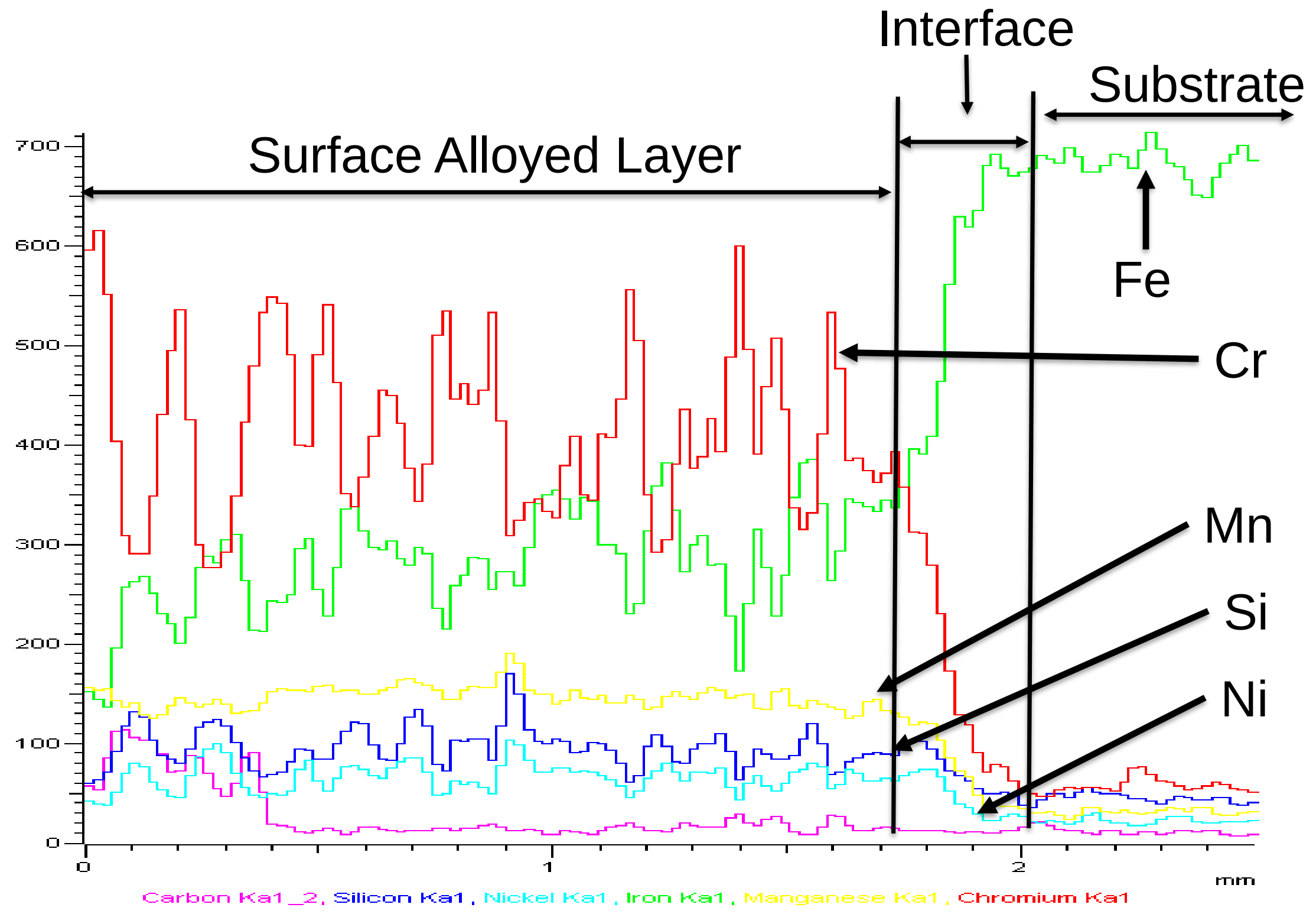


Fig 4. Stereoscopic image of sample R8 with 2000 μm (2 mm) surface alloyed layer and base metal. Each division on scale is 1 mm.



Graph 1. EDS Line scan of UWM sample R8 starting from surface alloyed layer to substrate

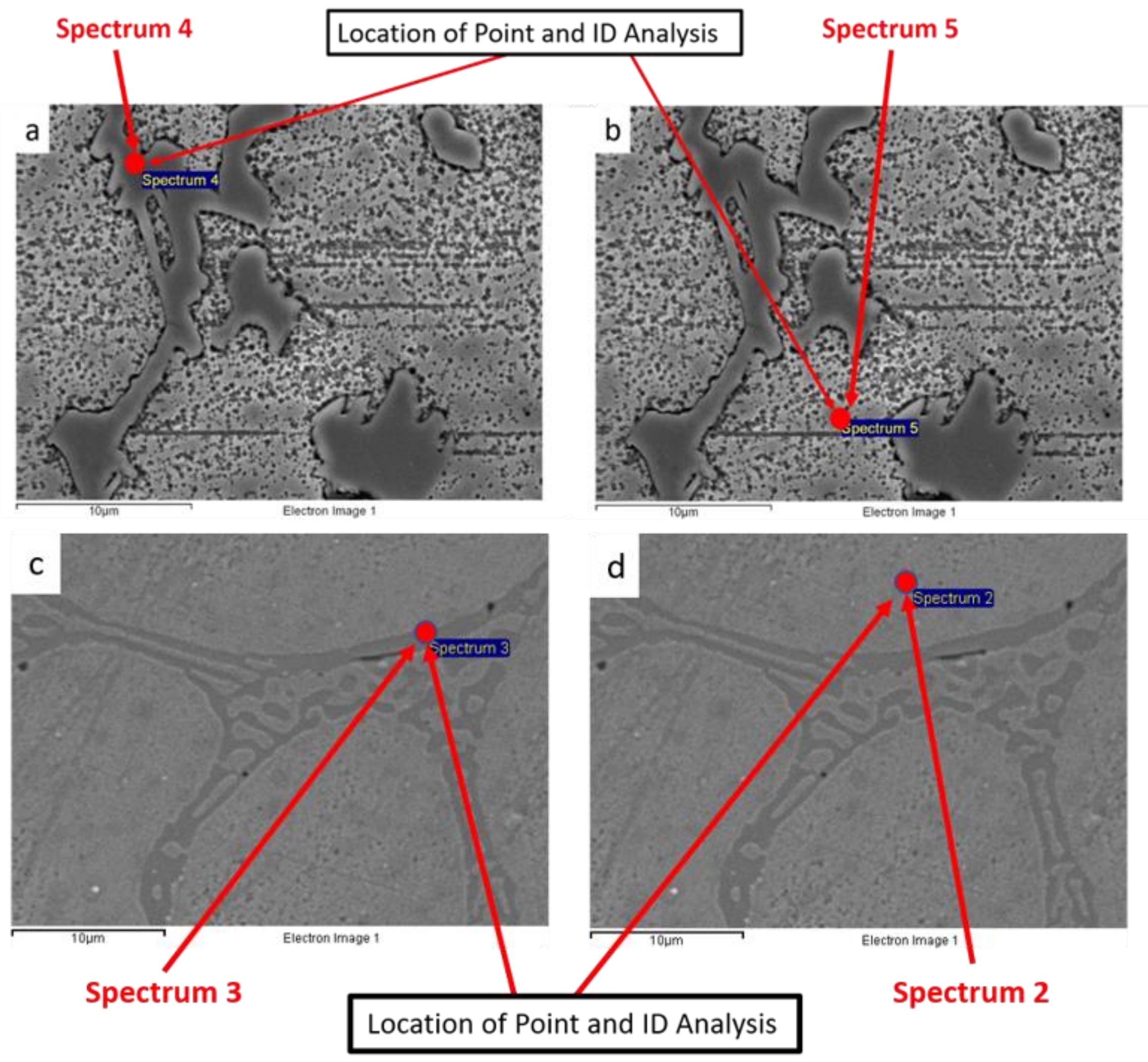


Fig 5. Point and ID mapping of sample R8 before (a & b) and after (c & d) heat treatment. Spectrum 4 and 3 are in the interdendritic region and spectrum 5 and 2 are in the phases.

Element	Weight %			
	Spectrum 4 (As-Cast)	Spectrum 5 (As-Cast)	Spectrum 3 (Heat Treated)	Spectrum 2 (Heat Treated)
Si	-	2.77	-	0.64
Cr	62.85	23.22	56.78	23.15
Mn	6.17	8.35	2.27	3.29
Ni	2.19	15.63	2.86	11.73
Fe	Balance	Balance	Balance	Balance

Table 2. Comparison of alloying element wt % in as-cast and heat treated state in the samples.

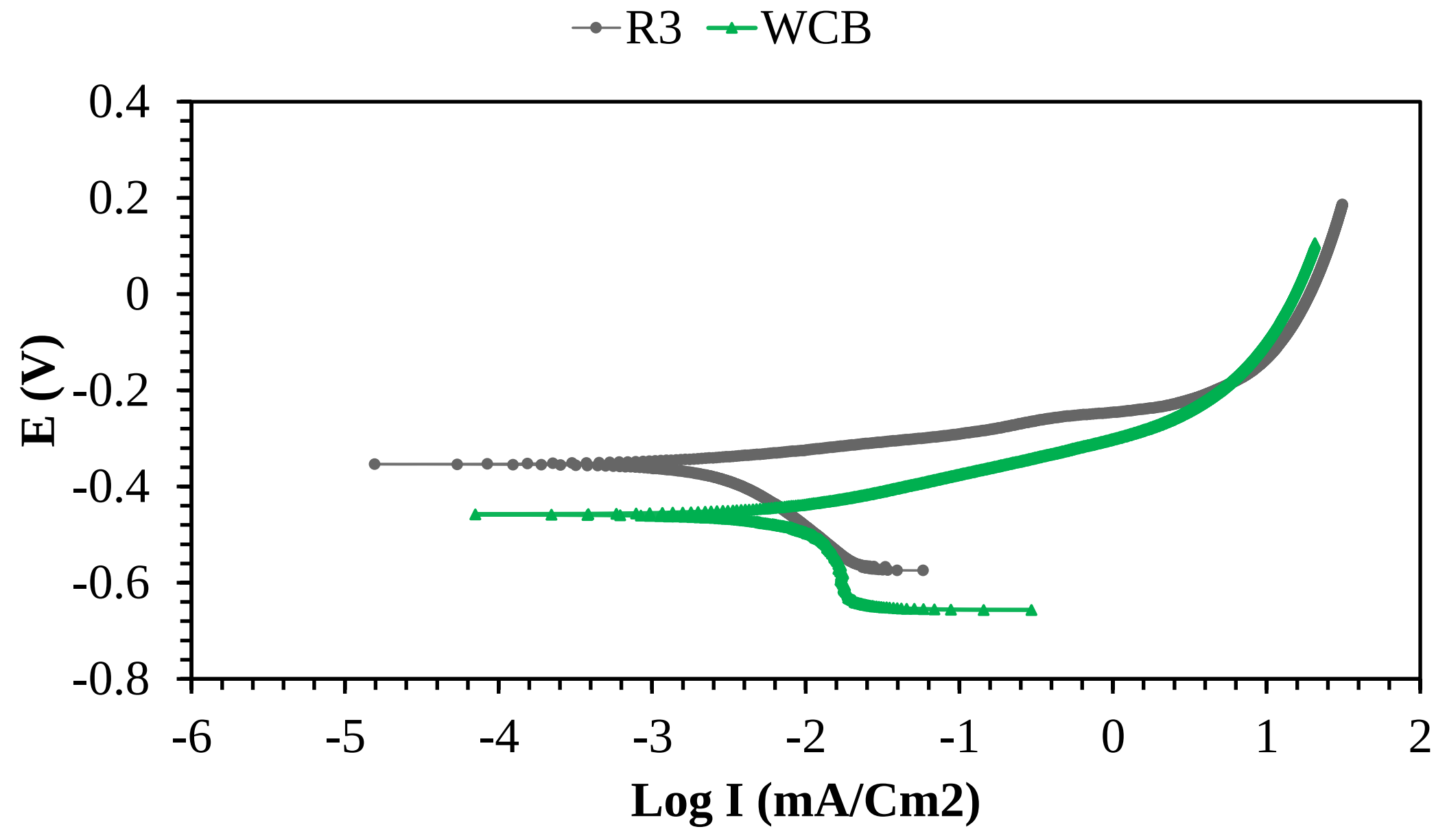


Figure 6. Tafel plots showing improved corrosion resistance of sample R3 as compared to WCB steel

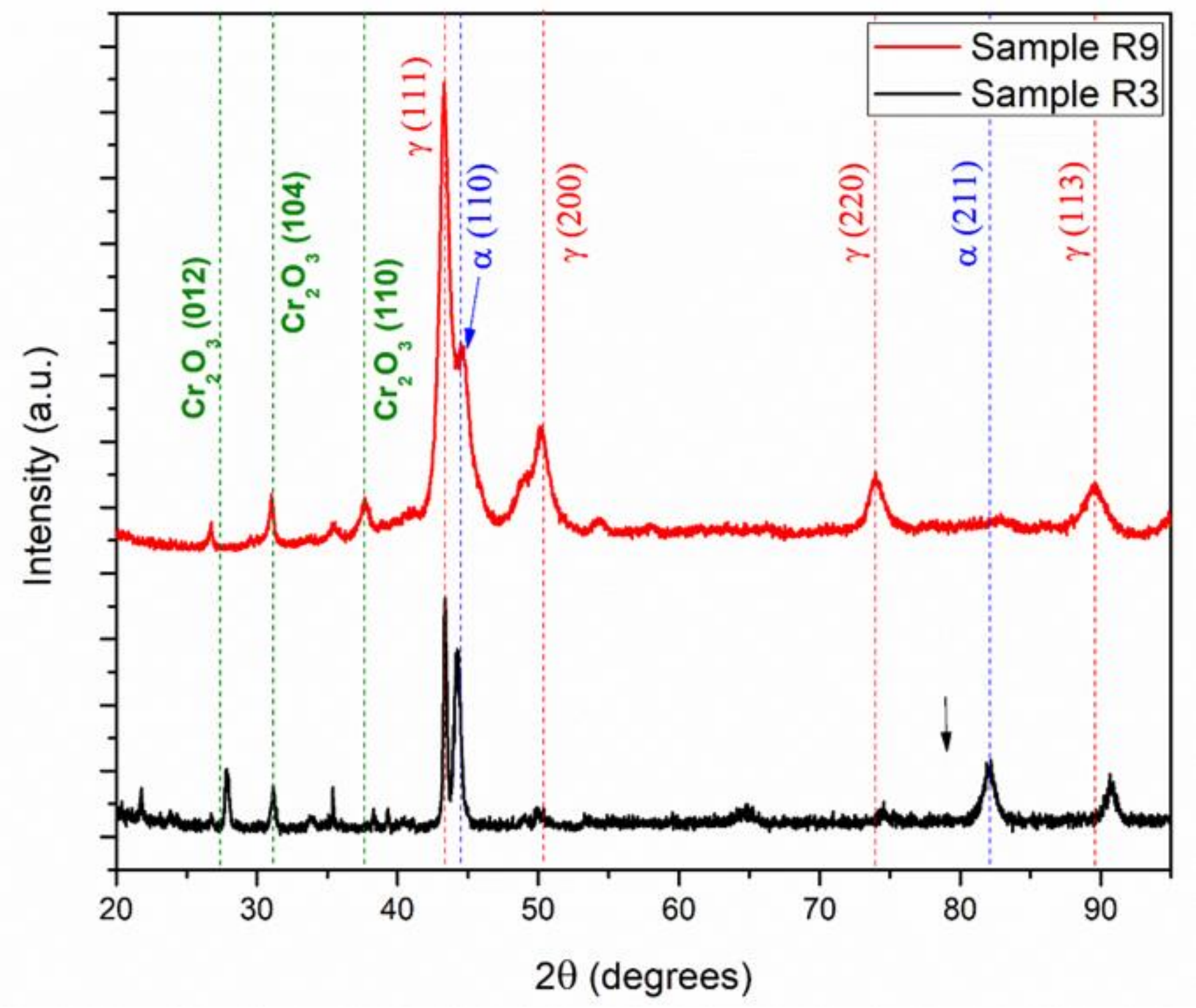


Figure 7. XRD plot of UWM sample R3 and heat treated sample R9

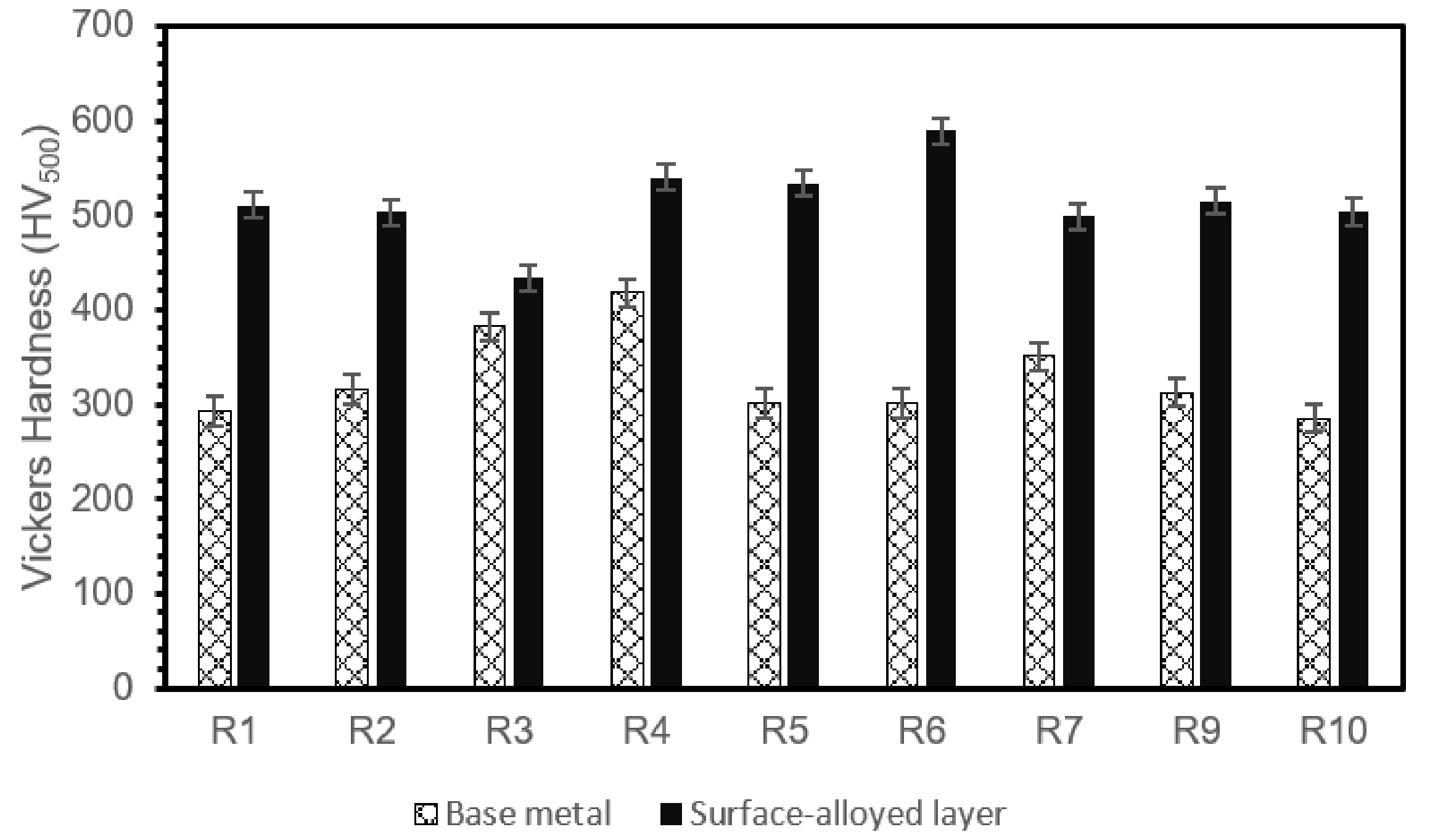


Figure 7. Comparison of hardness of the samples with and without the surface alloyed layer

Conclusions:

1. The depth of surface alloyed was controlled in the range of 1000 – 4000 μm range during lab castings.
2. Enrichment with Ni, Cr, Si, and Mn was confirmed by EDS.
3. Water based binder is easier to apply and viable for the process thus, easing transition to industry.
4. Increased hardness of surface alloyed layer indicating possibility of increased wear resistance.
5. Heat treatment helps to reduce the σ phases in the interdendritic region.
6. Improvement of the corrosion resistance as compared to WCB steel.

References

1. Jiru, Woldetinsay G., Mamilla R. Sankar, and Uday S. Dixit. "Surface Alloying of Aluminum with Copper Using CO2 Laser." Lasers Based Manufacturing. Springer India, 2015. 107-116.
2. Hosmani, Santosh S., P. Kuppusami, and Rajendra Kumar Goyal. An introduction to surface alloying of metals. Springer, 2014.