

SLAG JEWELLERY: A NON-TRADITIONAL SLAG VALORISATION PROCESS

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1. Introduction

As I approached the final stages of my PhD study in 2014¹, I searched for a way to obtain closure, emotionally, on my PhD process. I asked a jeweller to prepare jewellery from slag utilised in the study: one set of earrings and a set of cuff links for my supervisors (Merete Tangstad and Chris Pistorius) and another set of earrings for me. The design was based on a quote by Maya Angelou (1928 – 2014): ‘We delight in the beauty of the butterfly, but rarely admit the changes it has gone through to achieve that beauty.’

2. Design and Manufacturing

The jeweller prepared initial design concepts and I chose the designs as indicated in Figure 1. The intention was to prepare the slag according to the cabochon gemstone cut and set the stones in silver. Due to technical difficulties in the grinding stage, only one set of cabochons was prepared and the designs of the manufactured jewellery were adjusted (see Figure 1).

During the initial stages of my PhD studies, I wanted to measure the thermal conductivity of slag produced in manganese ferroalloy production². Initial test work² (sample preparation and measurement) was conducted in Norway on industrial slag. In South Africa, I tried to duplicate the method used in Norway (diamond tipped core drilling and slicing with a diamond blade)². I failed at my attempt to prepare samples from synthetic manganese-bearing slags that met the requirements of the laser flash method. The difficulty did not lie in core drilling the slag samples to 10mm diameter but in slicing them to 2mm thickness or less, at the same time preparing slices with no cracks or pores.

Preparation of the slag jewellery offered an opportunity to study the sample preparation method once more. When preparing the cabochons, the gemstone cutter did not find drilling and slicing difficult, but grinding the slag to a spherical shape with a smooth surface. Should I prepare slag samples for thermal conductivity measurements in future, I will ask gemstone cutters for assistance.

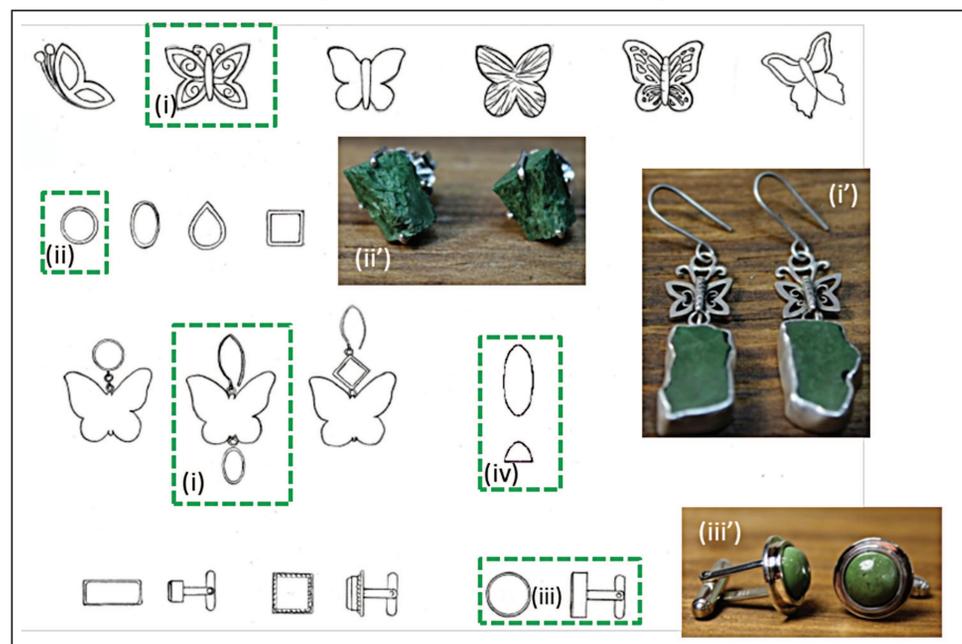


Figure 1: Design concepts prepared by a jeweller and designs selected for (i) drop earrings, (ii) stud earrings and (iii) cuff links with slag cut according to the (iv) cabochon gemstone cut. Manufactured jewellery consisted of: (i') Sliced slag as drop earrings; (ii') broken off slag as stud earrings and only the (iii') cuff links containing cabochons.

3. Slag Characterisation

Two commercial processing routes apply in the production of silicomanganese: The integrated route, where 75% of the manganese fed into the furnace originates from slag produced during high carbon ferromanganese production, and the ore-based route in which 100% originates from ore (Figure 2).

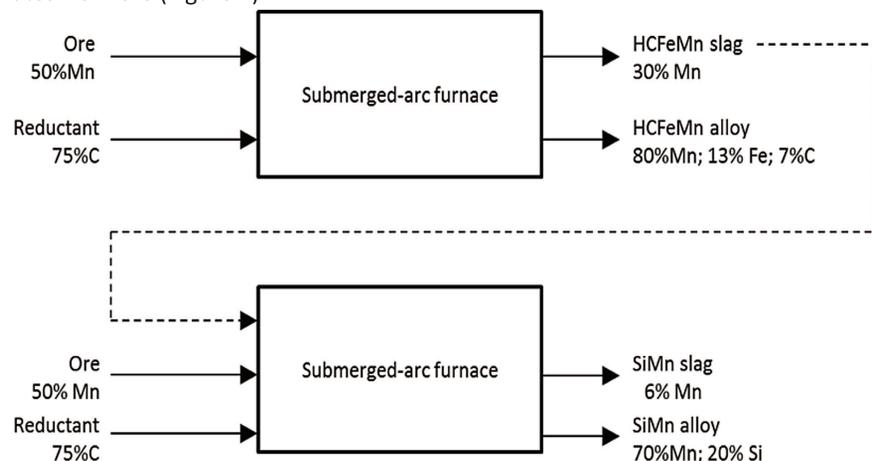


Figure 2: Simplified flowsheet for silicomanganese production according to the integrated route (where manganese originates from ore as well as slag from high-carbon ferromanganese production) and the ore-based route. Main chemical components applicable – derived from data in Olsen *et al*³ – are indicated. Not indicated are sources of Si (quartz) and fluxes utilised in the process.

In the PhD study I used slag originating from the integrated route in laboratory-scale experiments to study slag/refractory interaction¹. Prior to the experiments the chemical and phase chemical compositions of the slag was determined¹. The slag, set as jewellery, offered an opportunity to characterise slag from the ore-based route (*Slag O*) and compare the results to that of slag from the integrated route (*Slag I*). Sample preparation methods, analytical methods and the thermodynamic calculation method described in the PhD study, were applied¹.

The bulk chemical composition of *Slag O* in Table 1 was similar to that of *Slag I* in terms of MnO and MgO, but slightly lower in SiO₂ and CaO, and significantly lower in Al₂O₃ (44.3%, 23.8%, and 15.5% for *Slag I* respectively¹).

Table 1: Bulk chemical composition of *Slag O* determined by wet chemistry methods

Normalised	MnO	FeO	SiO ₂	CaO	MgO	Al ₂ O ₃	Total
Average	12.5	0.1	48.4	28.9	5.8	4.3	100
Std Dev.	0.0	0.0	0.3	0.4	0.0	0.1	

The differences in chemical composition resulted in a calculated liquidus temperature of 1313°C for *Slag O* as opposed to 1235°C for *Slag I*; calculated solidus temperatures were similar (961°C and 954°C respectively). In both instances the calculated primary phase upon cooling was anorthite (CAS₂) – Figure 3 (a) and thesis¹.

The X-ray diffractogram for *Slag O* (Figure 3(b)) reported a significant increase in crystalline phases compared to *Slag I*¹, attributed to *Slag O* being cooled at a slower rate than *Slag I*. For *Slag O*, moissanite (SiC) was easily identifiable in the diffractogram. Only after conducting SEM EDS analyses (results reported in Figure 4, Table 2, and Table 3), were alabandite (MnS), the intermetallic phase (Mn₅Si₃) and the solid solution of augite and diopside (secondary slag phase in Figure 4; both pyroxenes) identified in the diffractogram. All of these phases were identified previously for *Slag I*¹. As for *Slag I*¹, no anorthite was found in *Slag O*.

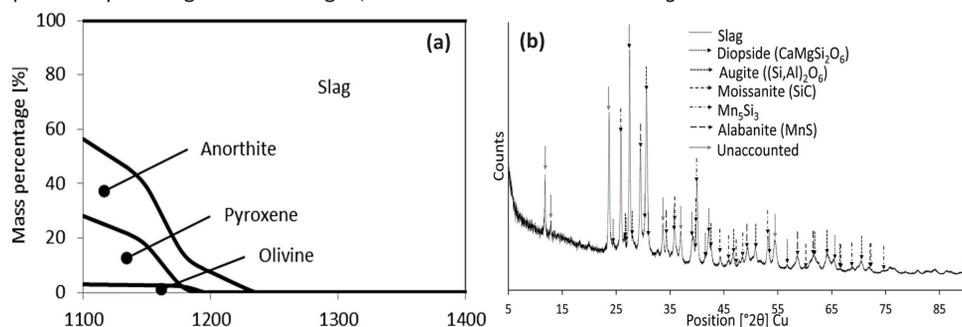


Figure 3: (a) Calculated (FACTSage 6.4, Equilib module, FToxid and FACTPS databases) equilibrium phase distribution as functions of temperature for *Slag O* in Table 1 and (b) X-ray diffractogram of powdered *Slag O* sample with significant peaks for crystalline phases identified, indicated.

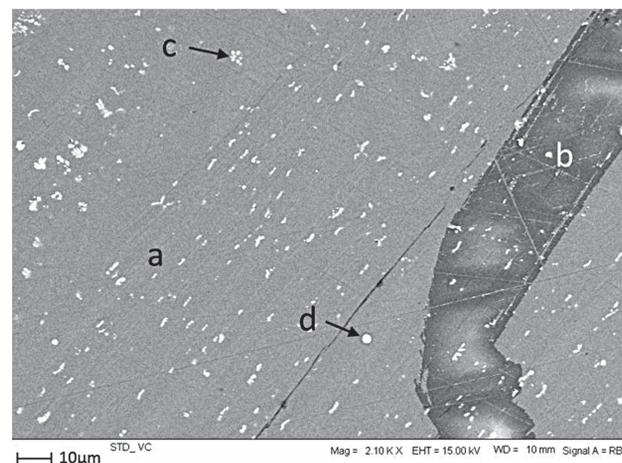


Figure 4: SEM BSE image of *Slag O* polished section at 15kV with (a) primary slag phase, (b) secondary slag phase, (c) manganese sulphide and (d) manganese metal containing silicon and traces of iron.

Table 2: Chemical compositions of slag phases in *Slag O* [per cent by mass]

	a	b
MgO	4.9	4.1
Al ₂ O ₃	16.1	20.1
SiO ₂	48.3	47.3
CaO	19.6	19.6
MnO	11.0	8.9
FeO	0.0	0.0

Table 3: Molar ratios of slag phases in *Slag O* with M – the monoxides listed in Table 2, A – Al₂O₃ and S – SiO₂.

			a			b		
M	A	S	2	1	2.5	1.5	1	2

4. Conclusion

Manufacturing jewellery from slag is a novel way of adding value (both financially and emotionally) to a waste product. Methods utilised in the manufacturing of jewellery from semi-precious gemstones could be investigated when preparing slag samples for thermal conductivity measurements. Chemistry and phase chemistry of slag produced in the ore-based route was similar to that of the integrated route.

5. References

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