

Damascus Steel Khanjar

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Introduction

Assumptions for reconstruction of the oriental Damascus steel blade, on the basis of existing (18/19th century) specimen from National Museum in Cracow:

- to use traditional blacksmith techniques and modern scientific methods
- to manufacture a high-carbon-content wootz ingot, showing dendritic structure
- to modify microstructure by heat treatment
- to hand-forged the blade similar to the museum-quality Damascus steel blade in respect of a shape, properties, micro- and macrostructure
- to analyze properties and microstructure of the final product

Manufacturing the blade

-obtaining the wootz ingot: Induction furnace melting process was employed. Graphite-clay crucible was used. As charge Armco iron with graphite and minor addition of carbide-forming materials was used. Low cooling rate was provided.

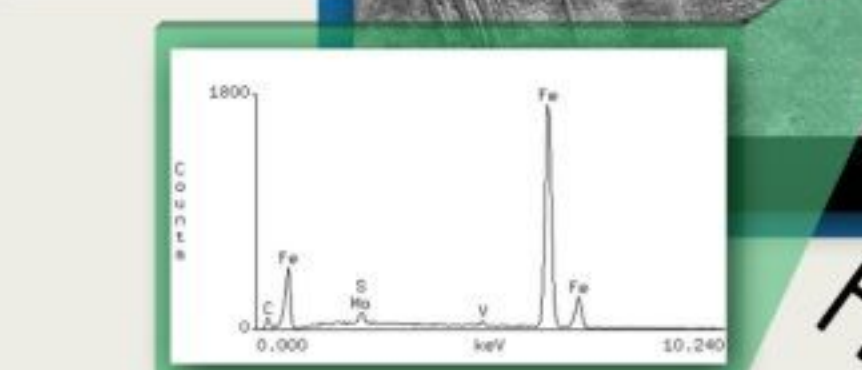
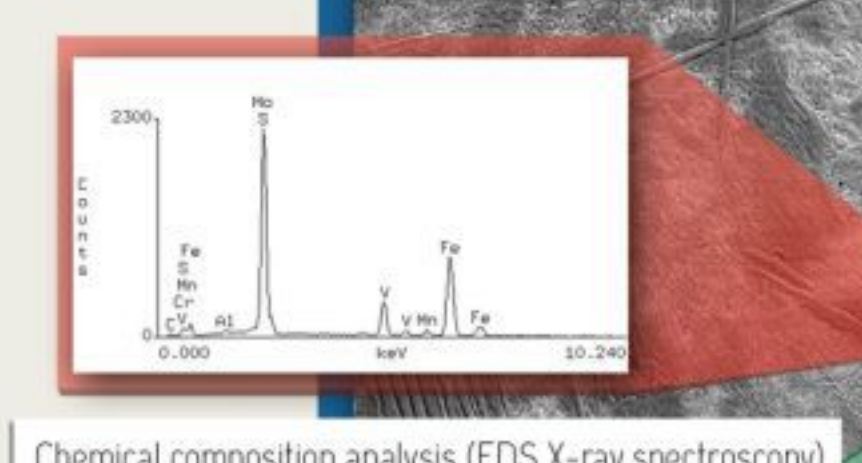
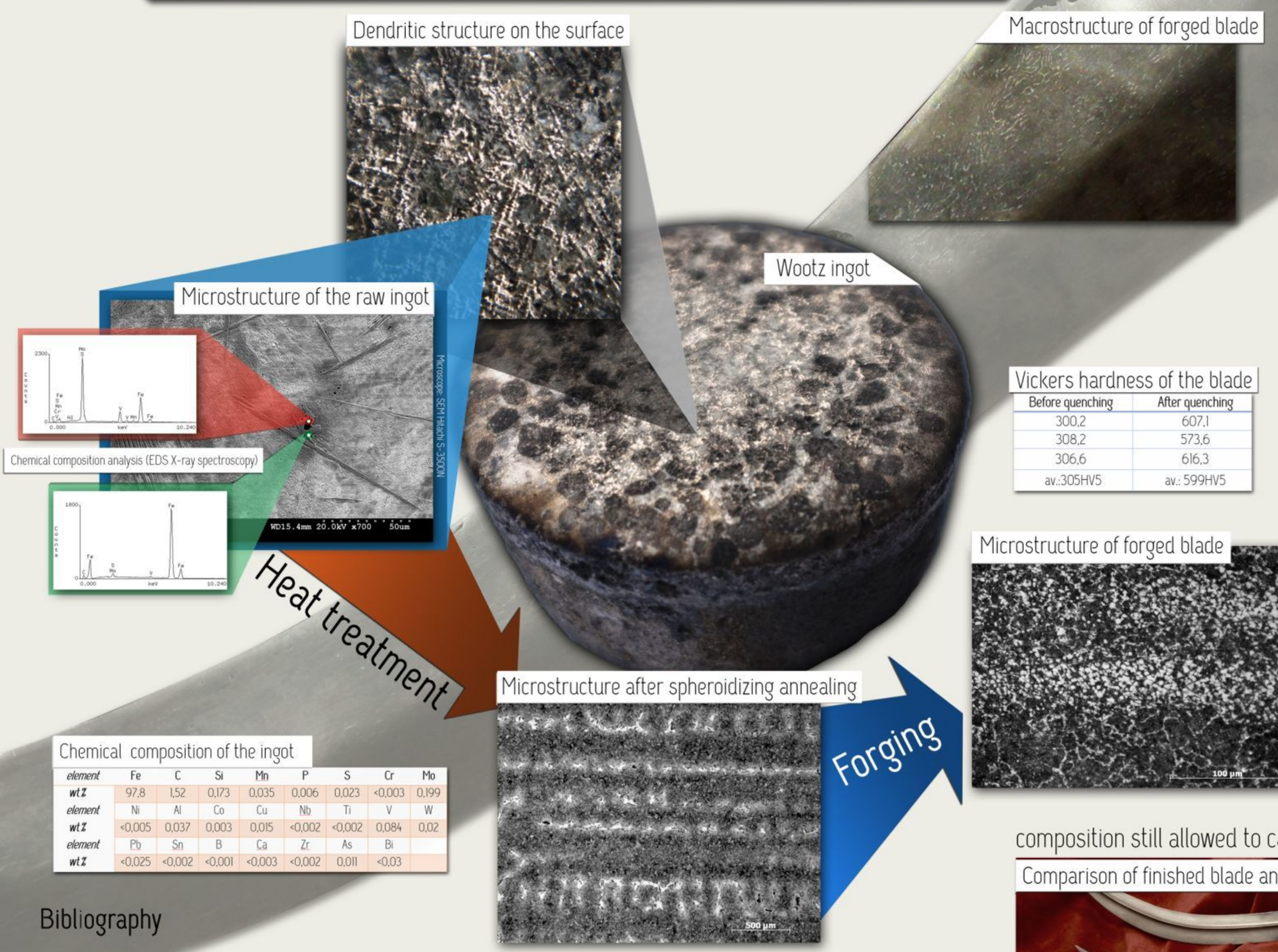
-heat treatment: Cycle spheroidizing annealing



-forging the blade: The blade was hand-forged in 850-650 °C range. 85 cycles of forging and heating were necessary.

-hardening: Water quenching at 50 °C above A_{c1} curve with high tempering

-finishing: Mechanical polishing and etching in sulfuric acid



Chemical composition of the ingot

element	Fe	C	Si	Mn	P	S	Cr	Mo
wt%	97,8	1,52	0,173	0,035	0,006	0,023	<0,003	0,199
element	Ni	Al	Co	Cu	Nb	Ti	V	W
wt%	<0,005	0,037	0,003	0,015	<0,002	<0,002	0,084	0,02
element	Pb	Sn	B	Ca	Zr	As	Bi	
wt%	<0,025	<0,002	<0,001	<0,003	<0,002	0,011	<0,03	

Vickers hardness of the blade

Before quenching	After quenching
300,2	607,1
308,2	573,6
306,6	616,3
av.:305HV5	av.: 599HV5

Bibliography

References:

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3. Verhoeven J. D. (2002) Genuine Damascus Steel: a type of banded microstructure in hypereutectoid steels. *Materials Technology*, no.73 no. 8 p. 356-365
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Conclusions

1. Microstructure of the manufactured blade matches microstructure of museum-quality wootz blades. [1]
2. Desired shape of the blade has been obtained.
3. Hot processing of the obtained ingot is possible after proper heat treatment and causes development of visible Damascus pattern on the etched surface.
4. Melting conditions executed in induction furnace did not provide controlled carburization of an ingot. Although, received chemical composition still allowed to carry out further forging.