An example of the application of combined use of Neutron Imaging and Time of Flight Neutron Diffraction: characterization of Japanese ancient swords

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A total of five fragments of Japanese swords, pertaining to a period ranging from 15th until 17th century [1], have been analyzed through neutron imaging and neutron diffraction techniques. The samples represent the lower part of ancient swords, purposely broken approximatively at 50-60 mm from the beginning of the blade, at the end of second world war in Japan. Most of them are signed and the authorship and attribution have been accurately identified. The samples have been made available by the Stibbert Museum staff as test samples for non destructive characterization through innovative methods.

A white beam and energy resolved neutron imaging study have been performed using the ICON beamline at the spallation neutron source SINQ in Switzerland [2] on all the five samples. The sword fragments have been analyzed with white beam in order to create a 3D map of the different components: metal, mineralization products, slag inclusions and empty volumes. Martensitic rich areas inside the metal have been also identified. By exploiting the ICON energy selector, we used two distinct wavelengths, immediately before and after the 110 ferrite Bragg edge, to map the distribution of ferrite and cementite inside the metallic volumes of the samples [3]. We have hence performed two tomographic reconstructions using the two different wavelengths previously described. The two tomographic reconstructions have been combined together in order to maximize the ferrite phase contrast compared with all the other phases, and showing the distribution of the ferrite phase inside the samples.

Neutron diffraction has been performed on the selected samples by using the INES diffractometer at the ISIS pulsed neutron source in UK [4]. The measurements have been done on the average gauge volume, both in the tang and in the blade, in order to determine the quantitative distribution of the metallic and non-metallic phases. Moreover, the cementite to ferrite ratio has been used to quantify the carbon content. The comparative analysis of the phase distribution among the samples (together with the results of tomography) allowed us to identify the peculiar characteristics related to the forging traditions and periods of the Japanese history. I.e. the carbon content, the fayalite amount, the presence of wuestite and troilite have been comparatively checked. On few selected samples a diffraction scan has been performed dividing the blade into three different sections: the edge, the core and the ridge, thus determining the inner phase distribution and confirming the highly differentiate specialization of the single parts of this kind of swords already seen through neutron imaging. The shape of the ferrite peak has also been studied in order to semiquantitatively determine the texture level, the strain level and the domain size of the grains, to gain knowledge about the several forging methods used by the different Japanese schools and traditions.

The combination of the two techniques (neutron tomography and neutron diffraction) allowed us to quantitatively characterize the morphology and composition of the samples in a totally non destructive way, giving invaluable information about forging methods and thermal treatments applied to Japanese swords.

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