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The manufacturing of Japanese swords: a non destructive quantitative analysis of steel composition and microstructure through neutron diffraction and neutron imaging techniques

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In this work we present the characterization of the peculiar compositional and micro-structural properties of the different kinds of steel used to forge ancient Japanese swords according to the five historical different forging traditions (Gokaden) and to the period [1-2]. In order to achieve such a goal, a large number of samples needs to be studied and, due to the unique nature of the artifacts, only a non-destructive approach is now possible. Japanese swords were analyzed in the past through traditional methods [3-6] aiming to characterize the steel composition and microstructure, always applying a destructive methods (metallography and electron microscopy) and the results were of great interest but this kind of approach is impossible to be applied at a large extent. Neutron diffraction and neutron imaging represent the ideal method to reach the proposed goal in a non destructive way since they permit to obtain quantitative information about composition, microstructure, morphology and spatial distribution of the material in the samples.

A total of seven intact Japanese swords and nine broken ones, pertaining to different periods ranging from 14th until 19th century, have been analyzed through neutron diffraction and neutron imaging techniques [7-10]. The samples have been made available by the Stibbert Museum and Wallace Collection staff and by private collectors.

Neutron experiments have been performed in two different facilities: ISIS (UK) and SINQ (CH). Diffraction measurements have been applied on all the selected samples by using the INES [11], ENGIN-X [12] and POLDI [13] diffractometers while neutron imaging measurements have been performed on the ICON [14] beam-line. Neutron imaging measurements covered the full body of most of the samples while neutron diffraction experiments were focused on specific parts of the swords as the tip, the core of the blade (differentiating among the cutting edge, the centre and the back) and the tang to determine the quantitative distribution of the metal and non metal phases. The comparative analysis of the phase distribution and the tomographic reconstruction of the samples permitted to identify peculiar characteristics related to the forging traditions and periods of the Japanese history and to determine the inner metal phase distribution thus confirming the differentiate specialization of the single parts of this kind of swords.

Due to the high quality level of the results in terms of spatial resolution and quantification of phases and microstructures, this multi-methodological non-destructive approach presents an incomparable potential in the field of historical metallurgy.

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