High Sensitivity Synchrotron XRD of Copper Alloy Artifacts from the Mary Rose

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The Mary Rose was one of the most powerful warships in King Henry VIII's navy. She sank on 19th July 1545, probably through overloading and poor seamanship, during a battle with the French at the entrance to Portsmouth harbour. A significant fraction of the hull was buried in the Eocene silt of the sea bed and consequently preserved leaving a remarkable record of Tudor marine engineering and shipboard life. Much of the wreck was raised in 1982 and is now on display in the Mary Rose Museum [1]. There are thousands of artifacts made from a wide range of materials in the reserve collection. These can, with very tight constraints on possible sample damage, be analysed using modern techniques in order to study, *inter alia*, their composition, possible manufacturing methods, use, and conservation. In any museum, a constant battle goes on behind the scenes, to fight artifact degradation due to corrosion, biological attack, fading of pigments and so on, and the Mary Rose museum, situated in Portsmouth Historic Dockyard with its salt-laden air, is no exception.

In this talk we will describe a generally applicable method [2] for obtaining synchrotron X-ray diffraction data (SR-XRD) with a dynamic range of 10^5 or better (largest peak height/minimum detectable peak height above noise) using an arbitrarily large number of transformed 2D surface powder diffraction images from a Pilatus camera blended over a range of camera angles into a single image from which the 1D pattern can be easily extracted. The measurements were carried out on the XMaS beam line run jointly by Warwick and Liverpool Universities at the ESRF, with complementary measurements using XRF and XEOL-XAS at XMaS, and laboratory XRD and electron microscopy at Warwick. The software which handles the image processing (part of the esaProject package) was written for the experiment and is available on XMaS [3].

The data reveal a huge range of different types of information such as

- Surface modification driven by the synchrotron X-ray beam during analysis.
- Different corrosion mechanisms at work in different parts of the wrecked ship.
- Confirmation of particular corrosion mechanisms.
- The effectiveness of the simple "first aid" conservation applied when the artifacts were recovered *circa* 40 years ago.
- Possible contamination of the sea bed by heavy metals from historic mining operations in Hampshire and the heavy bombing of Portsmouth in WW2.

Some of these topics will be discussed in the talk and others are dealt with in detail in [2].

[1]   https://maryrose.org/
[2]   Mark G. Dowsett, Pieter-Jan Sabbe, Jorge Alves Anjos, Eleanor J. Schofield, David Walker, Pam Thomas, Steven York, Simon Brown, Didier Wermeille and Mieke Adriaens, *J. Synch. Rad.* 27 (2020), DOI: 10.1107/S1600577520001812
[3]   Mark Dowsett, esaProject 2020 Manual, ©EVA Surface Analysis, UK