

# XAS investigations of faience from ancient Egypt and from lab-syntheses

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Egyptian faience was produced over a period of approximately 5000 years, with the first examples dating to *ca* 4000 BC. Faience is a glazed, quartz-based material that was commonly used to make objects such as beads, pendants, rings, tiles, bowls, jars, gaming pieces and specialist funerary equipment (e.g., [1, 2]). The most common colours are light and dark blue, probably developed to imitate valuable stones, such as turquoise and lapis lazuli, but the colours red, yellow, white, purple and black also occur, albeit less frequently. Although faience is relatively common on archaeological sites dating from *ca* 1550 BC onwards, the chemical makeup and manufacturing techniques used to produce faience remain somewhat enigmatic.

Previously, we used XAS to investigate selected faience objects from the site of Amarna<sup>(1)</sup> and laboratory-synthesized faiences [3], as well as faiences beads of unknown provenance sourced from the Australian Institute of Archaeology (AIA) [4]. Some of the beads from the AIA showed distinct fine-structure that was not observed in the Amarna objects or the laboratory-made faiences. The distinct features were linked to the presence of higher coordination spheres (EXAFS) consistent with the structure of chrysocolla (Cu-silicate). Since the synthesized faiences were produced at only one firing temperature (900°C), it was suggested that the firing temperature had an effect on the presence or absence of the fine-structure observed.

For the study reported on here, laboratory-made faience were investigated using XAS at the Cu-K edge. The measurements were performed at DORIS Beamline C in fluorescence mode using a PIPS fluorescence detector. Faiences were synthesized using 80 wt-% SiO<sub>2</sub>, Ca/Na flux (either CaCO<sub>3</sub> or CaOH<sub>2</sub> and either NaHCO<sub>3</sub> or NaCl; total ~17 wt-%) and CuO or CuCO<sub>3</sub> (3 wt-%) as colourant. Faience were fired in a laboratory kiln at 860°C, 800°C, 900°C, and 950°C for 5 hours. For the fluorescence XAS measurements the faience pieces were used *as is*. The data were processed and

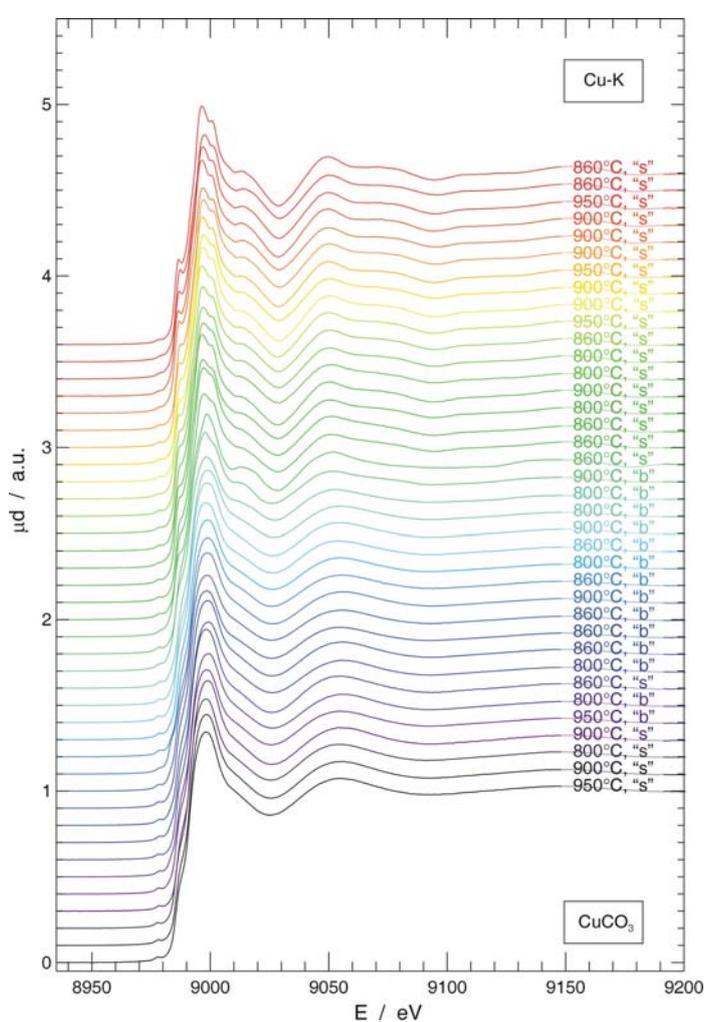


Figure 1: XAS data of lab-synthesized faiences using CuCO<sub>3</sub> as colourant and different flux compositions and temperatures. „s“=NaCl used in the flux; „b“= NaHCO<sub>3</sub> used.

<sup>1</sup> Amarna is located in middle Egypt and was the seat of reigning God-King Akhenaten and Queen Nefertiti. It was occupied only for a very short period of time (1350-1325 BC), and thus faience objects from Amarna are well suited to study the faience industry in ancient Egypt.

self-absorption corrected using the freeware *XANDA Dactyloscope* [5]. In Figure 1, a series of spectra are shown after sorting using principal components analysis.

None of the spectra exhibit the distinct XAS feature found in faience beads from the AIA, indicating that the structure in question did not depend on the firing temperature (within this set of the flux-temperature variations). However, there is a trend in the series: Faiences prepared using  $\text{NaHCO}_3$  in the flux exhibit spectra (marked “b”) very similar previous lab-made faiences and Amarna objects; faiences made using  $\text{NaCl}$  (marked “s”) mostly show a splitting of the whiteline and a broad shoulder at  $\sim 9010\text{eV}$ . A corresponding data-set of faience made using  $\text{CuO}$  as a colourant does not show this trend so clearly. Given the similarity of the spectra “b” in Figure 1 with spectra from the Amarna objects (see [3]), it may be concluded that  $\text{NaCl}$  may not have been a key addition to the flux in Amarna. Furthermore, the relative consistency of spectra in the series in Figure 1 suggests that, in combination with  $\text{NaCl}$ ,  $\text{CuCO}_3$  (e.g., malachite) would have resulted in faience with a more consistent structure than glaze made using  $\text{CuO}$  and  $\text{NaCl}$ . It may be expected that a more consistent structural makeup would relate to more consistent material properties beneficial for further use of the object. Hence, it appears likely that  $\text{NaCl}$  was not added as key source of sodium, in particular in combination with  $\text{CuCO}_3$ .

It is interesting to note that for all laboratory-synthesized faiences there was no evidence of the key signature observed previously in some faience beads from the AIA [4]. This observation indicates that the structural composition giving rise to the feature remains somewhat special in the phase-space of typical and viable flux-temperature compositions. As mentioned above, this special structure is quite consistent with that of chrysocolla (as indicated by EXAFS modelling and comparison to data from chrysocolla). It is also noteworthy that eventually two objects sourced from the Aegyptisches Museum collection showed spectra with the specific structures. One of the objects can be dated to *ca* 664-610 BC (i.e., *ca* 900 years post Amarna), according to the inscriptions on the object. The other object remains undated but the intricacy of the work indicates that it may have been produced at Amarna. Thus, the chrysocolla-like structure as observed in some AIA beads was also found in faience from possibly different times and origins. The fact, that only few of the objects sampled so far show this specific structure underscore its special nature and indicate that there may have been some specific production technology or choice of source materials leading to this structure.

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