SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 2, No. 3, (2016), pp. 17-23
Open Access. Online & Print

DOI: 10.5281/zenodo.60332

STUDY OF COLOR CONVERSION BY TIME IN ANCIENT EGYPTIAN FAIENCE ARTIFACTS

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Received: 01/02/2016
Accepted: 17/06/2016
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ABSTRACT

The Ancient Egyptians manufactured faience beads, amulets, rings, bracelets, scarabs, small figurines, bowls, tiles, as well as pieces for inlayment of their ornaments, since the predynastic age (3050 B.C.), and continued through the Roman period (30 B.C). That industry was developed through old, middle kingdoms, and reached its highest level in the knew kingdom. In the previous 20th century, serious deterioration phenomenon was observed on ancient Egyptian faience artefacts. There is a continous transformation of the blue color of faience into pale green, and from red color to nearly white. The aim of the present study is diagnosis and interpretation of this phenomenon, so saving these artefacts from complete distortion. Scanning electron microscope attached with EDX unit, inductively coupled plasma atomic emission spectemetry ICP-AES, Raman microscope attached to FTIR, infrared spectrometry, and x-ray diffraction analyses were carried out on faience fragments. Experimental laboratory work was done on new manufactured faience models after exposure to artificial weathering cycles. The obtained data showed that the causes of transformation in colors are due to the presence of chlorine ions and decomposition of the precipitated phases which led to change in the chemical composition of the coloring compounds in blue and red faience respectively.

KEYWORDS: Ancient Egyptians, faience, chemical composition, spectroscopy, transformation in colors, artifacts

1. INTRODUCTION

Ancient Egyptians used faience not only in decoration of their artifacts, but also in the manufacture of separate objects such as Ushabti, bowls, figurines, tiles, etc through different ages since the Badarian period. They produced several colors of faience: blue, green, reddish brown, yellow, and black ones. They could form several shapes of tabular, cylindrical and circular beads, as well as, inlay pieces.

Figure 1. Faience Hippos, 11th dynasty (2060-1991 B.C) show transformation of the blue color and green (Egyptian Museum in Cairo).

Faience means ornaments have their bodies either of quartz, or silica powder, or steatite stone covered with a surface glazed layer, (Andrews, 1990). There were two methods for the manufacture of faience: in two processes, 1st preparation of the internal core, 2nd application of the glazed layer on the surface. Or in one process in which the preparation of the core and the glazed layer was carried out together in an one stage, (Nicholson, *1993,* Simth, 1996; Tite, et al., 1983, 1987, 1989; Vandiver, 1998).

There are two types of the glazed layer, 1st: alkaline glaze, and 2nd lead one. The alkaline glaze was formed from silica, calcium oxide, sodium oxide, and secondary quantities of copper, aluminium, titanium and magnesium oxides. This type of glaze was used in Egypt since the pre dynastic period (3050 B.C.) till Roman period (30 B.C.). Whereas the lead glaze was created from lead oxide, silica, aluminium oxide, and trace amounts of sodium, potassium, and magnesium oxides (Forbes, 1957). The lead oxide was used as a flux material instead of sodium compounds. It began since the 22th dynasty (945-712 B.C.) and continued parallel to the alkaline glaze.

A serious transformation phenomenon in color was observed in ancient Egyptian faience artifacts. There is a continuous change in color from blue to green and from reddish brown to nearly white as shown in Figs 1-4.

The aim of the present work is diagnosis and interpretation of this deterioration phenomenon. So, it could inhibit occurrence in the future.

Figure 2. Faience tiles, Zoser tomb, Saqqara, 3rd dynasty (2613-2181 B.C) shows blue and green.

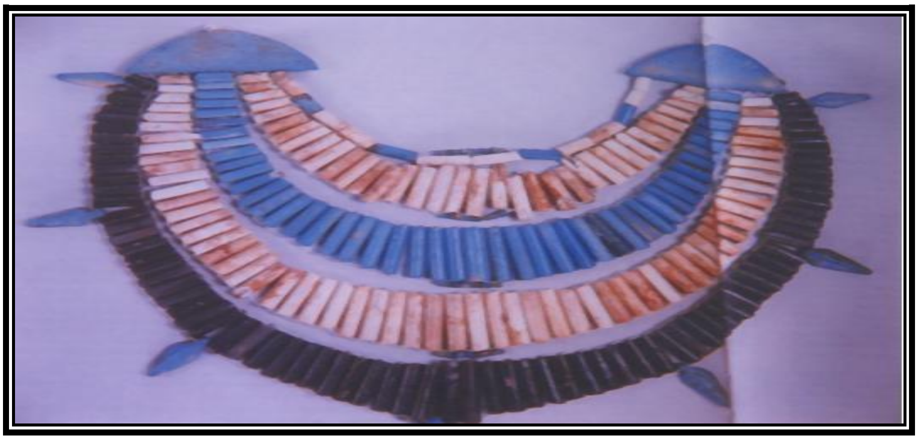

Figure 3. Faience Necklace 11th dynasty (2060-1991 B.C) shows the change of red color into nearly white (after Andrews, 1990).

Figure 4. Faience amulets of TutAnkh Amun show the change of red color into nearly white (Egyptian Museum in Cairo).

2. EXPERTIMENTAL PROCEDURES

Selected ancient Egyptian blue and reddish brown faience fragments were studied by scanning electron microscope attached with EDX unit, inductively coupled plasma atomic emission spectrometry (ICP-AES), Raman microscope attached to Fourier transform infrared spectrometer (FTIR) and I.R spectrometry methods to determine the constituting and coloring elements and compounds. Deteriorated faience specimen was also analysed by X-ray diffraction to interpret the transformation of red faience into nearly white.

New blue and reddish brown faience models were manufactured similar to the chemical composition of the archaeological faience.

These models were exposed to artificial weathering cycles to deduce the mechanism and causes of transformation in color. They were exposed to artificial successive separate cycles of high temperature, humidity, and salt effect. The new faience models were exposed to 120 cycles of high temperature and humidity. Each cycle consists of heating for 4 hours at 65^{o}c, then damping in water for 4 hours, then left at room temperature for 16 hours. On the other hand, second group of faience models were exposed to 15 cycles of salt effect. Each cycle consists of immersion in 10% salt solution of sodium sulphate and sodium chloride for 10 hours, then to dryness at room temperature for 14 hours.

3. RESULTS AND DISCUSSION

Faience fragments from Ainshams and Mataria excavations were analysed by SEM and EDXRF. Data declared that the coloring elements of the blue and red faience are copper and iron respectively. (See Figs 5,6).

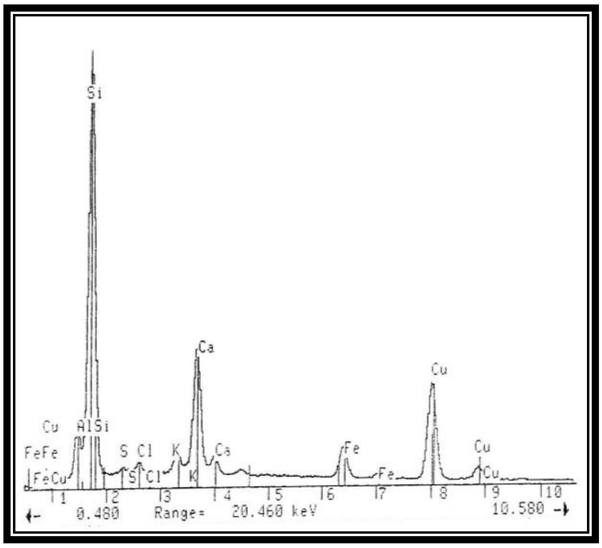

Figure 5. EDX analysis results of blue faience beads, 26th dynasty, Ainshams & Mataria excavations.

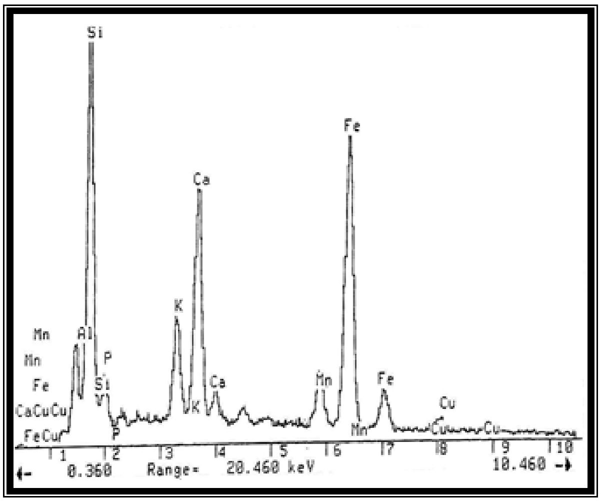

Figure 6. EDX analysis results of red faience beads, 26th dynasty, Ainshams & Mataria excavations.

ICP (AES) analysis of blue and red faience specimens from 26th dynasty, late period, and Graeco-Roman periods was made as well. Results showed that the main coloring blue element is copper and for the red is iron as shown in (Table 1).

Three blue faience samples from 19th, 20th and 21th dynasties from Anishams and Mataria excavations were analysed by Raman spectroscopy (Raman attachment FTIR spectrometer Jasco, Model 2020 was used). The data declared that they contain Egyptian blue $CaCuSi_4O_{10}$ as shown in Fig. 7.

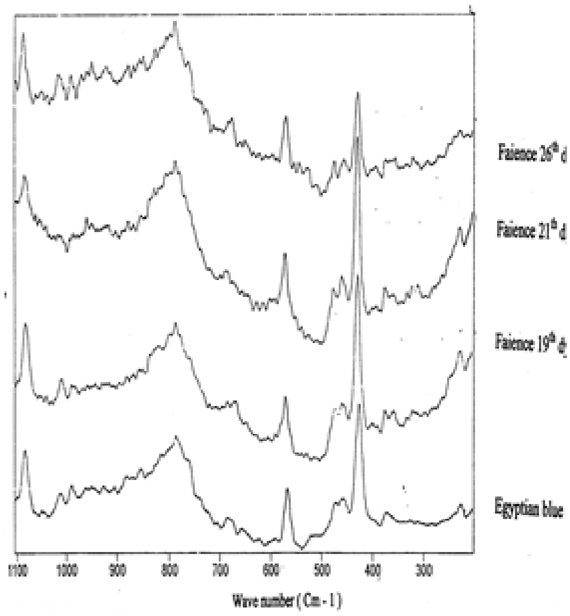

Figure 7. Raman microscopic FTIR analysis data of three blue faience beads (26th, 21th, 19th dynasties), Ainshams & Mataria excavations, and Egyptian blue pattern.

Blue and red faience specimens from 26th dynasty from Ainshams, Mataria, and Oases excavations were analysed by IR. The data showed that Egyptian blue and azurite are the coloring compound for the blue faience, whereas red ochre hematite is the coloring one for the red faience (see Figs 8, 9, 10).

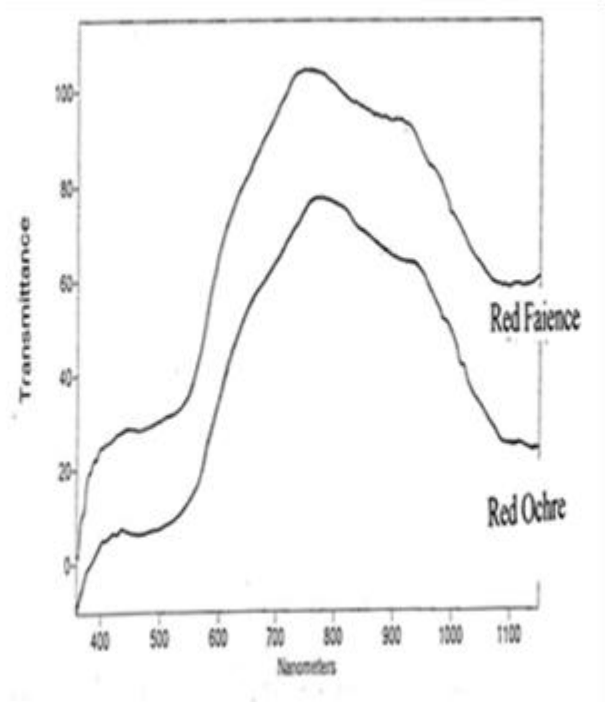

Figure 8. FTIR pigment pattern of red faience 26th dynasty and red ochre pattern.

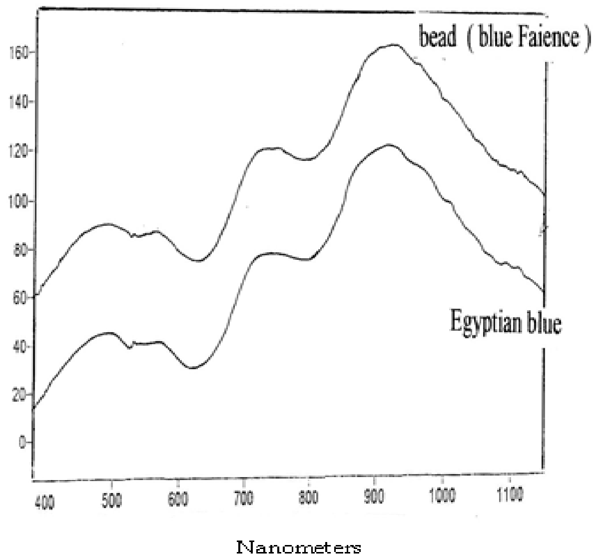

Figure 9. FTIR pigment pattern of blue faience bead, 26th dynasty and Egyptian blue pattern.

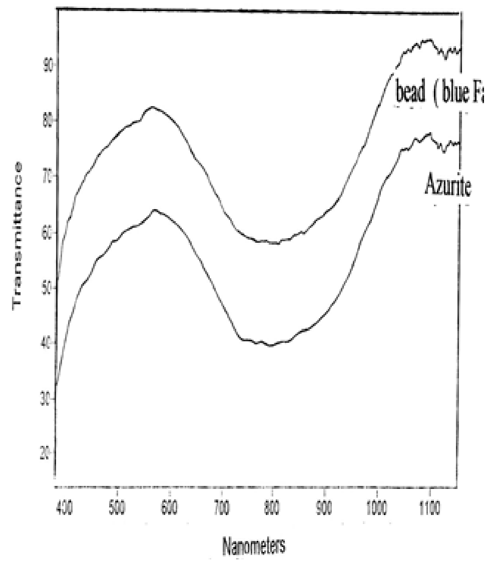

Figure 10. FTIR pigment pattern of blue faience bead, 26th dynasty and azurite pattern.

Table 1. ICP (AES) analysis data of blue and red faience

Type	Color	Fe_2O3 %	TiO %	PbO %	Na_2O %	K_2O %	CuO %	CaO %	Al_2O_3 %	Co ppm	Cr ppm	Mn ppm
Bead	blue	0.97	0.13	0.23	0.87	0.20	9.02	5.33	0.49	20.14	42.36	169.44
Oshabty	blue	2.82	0.21	0.02	2.82	1.03	1.28	0.71	1.10	30.89	51.02	155..69
Bead	blue	0.56	0.13	0.10	0.34	0.34	0.74	1.13	1.04	/	8.33	99.44
Bead	blue	1.04	0.06	0.17	1.08	0.18	5.04	3.57	0.55	6.21	270.13	38.93
Bead	blue	0.35	0.02	0.15	0.52	0.14	0.40	0.28	0.22	38.28	35.94	205.47
Bead	blue	1.25	0.21	0.20	1.54	0.25	10.89	3.93	0.51	3.51	155.50	37.27
Bead	red	4.24	0.93.	0.01	1.04	2.05	0.20	8.98	4.59	24.26	202.94	1072.79

A pale red faience bead fragment from Ainshams & Mataria excavations was analysed by XRD. XRD data declare the existence of calcium tetra silicate phase Ca_2SiO_4 card No. 33-0302, as shown in Fig. 11.

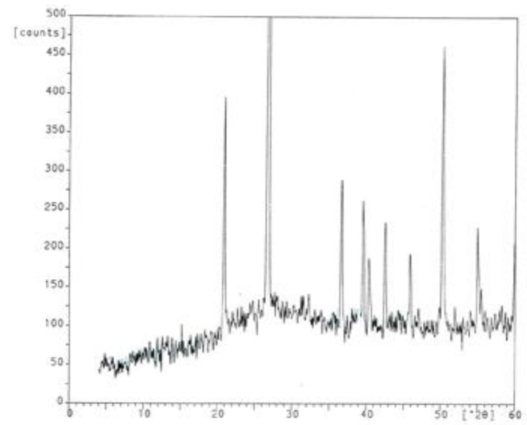

Figure 11. X-ray diffraction pattern of deteriorated red faience bead.

3.1 Artificial Aging

After exposure to artificial aging cycles the faience models showed change in color from blue to green

after salt cycles, and from red to near white after exposure to high temperature and humidity cycles.

In the current study, it is proved that the source of the blue color in ancient Egyptian faience artefacts is due either to the presence of Egyptian blue cuprorivatie calcium copper tetra silicate $CaCuSi_4O_{10}$ or to azurite hydrated copper canbonate $2CuCO_3.CU(OH)_2$. The transformation of the blue color into green one in faience may be interpreted as follows: there was a decomposition of the previous blue coloring compounds in faience due to dispersion and migration of copper ions through the glass structure net work. Then reaction was occurred with the active chlorine ions forming nantokite cuprous chloride CuCl (green), which in the humid atmosphere, atacamite hydrated copper chloride $Cu_2(OH_3)Cl$ (green), could be produced. These previous processes could be initiated during exposure to ultraviolet radiation of sunlight or/and in the presence of humidity. Our experimental study through artificial aging of salt cycles confirmed this interpretation. The source of chlorine may be due to natron salt which were widely used anciently in the manufacture of alkaline glazed faience and existed in the Egyptian soil, which is characterized by its salinity.

On the other hand, the change of the reddish brown color of faience artefacts into nearly white is due to breakdown in the chemical composition of the precipitated phase hematite Fe_2O_3 ferric oxide the coloring compound of red faience. There was a leaching of iron from the coloring compound hematite. This migration of iron into the matrix of faience may react and/or introduce in the structure of calcium silicate forming ferro calcium silicate Ca_2SiO_4, which was confirmed by x-ray diffraction analysis of the deteriorated red faience bead.

4. CONCLUSIONS

The transformation phenomenon of the blue color into the green one in ancient Egyptian faience artefacts is due to the formation of nantokite and atacamite. This is referred to the presence of chlorine ions in natron salts through manufacture and its abundance in the Egyptian soil. On the other hand, the change of the faience color from red to nearly white is due to the decomposition of the precipitated hematite phase by ultraviolet radiation and or humidity. This gave rise to leaching of iron and formation of ferro-calcium silicate**.**

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