SEM/EDS Analysis of Bicentennial Penny Patina

The process and nature of corrosion is of utmost importance across a wide array of fields. Knowing the properties of the corroded material is a crucial step in gaining an understanding as to why and how the corrosion occurred. Corrosion can take on various forms and behaviors even within a small area of a given material, so being able to examine a specific point on the sample is greatly useful in the analysis of the corrosion.

One method for analyzing corrosion is by means of a SEM (Scanning Electron Microscopy) equipped with EDS (Energy Dispersive X-ray Spectroscopy). Working in tandem, SEM and EDS analyses can reveal a tremendous amount of useful information on corrosion processes and mechanisms, as well as material anti-corrosion properties. With the SEM system, micrographs can be taken for morphological inspection to understand how the corrosion surface is forming and changing. Pits, cracks, fractures and other microscopically observable characteristics of the corroded materials are useful to visualize what may have happened. In addition to SEM observations, the EDS system can further assist in identifying and quantifying the chemical compositions of the micro areas of interest by measuring the characteristic X-rays produced by atoms that are present in the lattice of the material when excited by electron bombardment. To obtain quick and accurate results, the EDS system in use operates using a peak to background ZAF algorithm analysis technique. This method utilizes the Bremsstrahlung X-rays created to calculate fundamental peak to background ratios which are then used to analyze the detected peak characteristic X-rays from the sample. This analysis procedure provides accurate results without the need for calibration using reference standards.

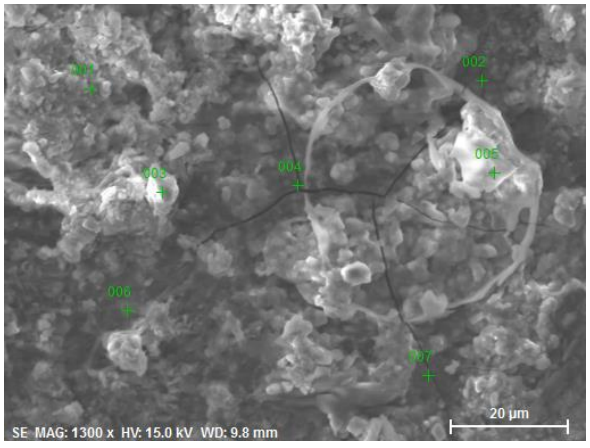

Figure 1. Micrograph image of corroded area, taken with SEM; EDS point analysis locations indicated in green numbers.

Table 1 Elemental Composition Results of the Corroded Penny in Indicated Locations

	Normalized Mass Percent					
Location	C	O	Na	Cl	Cu	Zn
001	13.74	22.91	11.15	4.56	43.25	4.40
002	5.02	8.07	-	10.96	75.95	-
003	12.66	29.76	-	10.59	41.61	5.38
004	20.57	27.72	-	5.63	41.44	4.64
005	15.54	21.62	-	11.48	51.37	-
006	11.75	30.58	8.45	3.02	40.89	5.32
007	28.33	17.97	-	7.71	45.99	-

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As an example to illustrate the above points, a corroded penny of 1976 was briefly studied in our JEOL JSM-6610LV SEM with Bruker QUANTAX 200 EDS system. A SEM micrographic image was taken on a green colored area and EDS compositional spectra were taken at several points as indicated by the numbers in Figure 1. The elements found in the corroded points are listed in Table 1. Figure 2 shows a typical EDS spectrum of the corroded area.

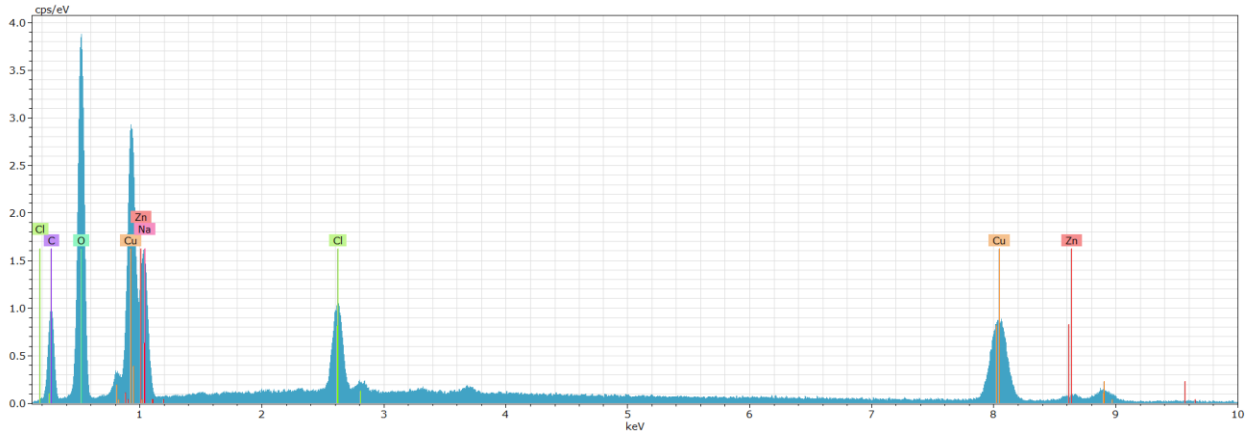

Figure 2. Spectra results of the point analysis at location 001.

From the SEM image, it is obvious that the corroded area has characteristics of severe metal corrosion: uneven, porous and powdery microstructure, and cracks on the surface caused by corrosion stresses. The EDS compositional analysis has indicated that three main elements in the majority of locations are copper, oxygen, and carbon. It is suspected that these elements are existing in the forms of copper (I) carbonate or copper (II) carbonate as the results of penny corrosion. Some small amounts of zinc, the alloying material used in pennies produced between 1962 and 1982, such as the 1976 penny we examined, were also detected in some of the locations. In addition, all analyzed locations show some amounts of chlorine. This could be evidence of copper or zinc chlorides present due to corrosion. Furthermore, the presence of sodium suggests some amount of sodium chloride, likely due to sweat deposited on the surface when handling of the penny.