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Elemental Analysis of Two Rupee Indian Coins by EDXRF Technique

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Abstract. Energy Dispersive X-Ray Fluorescence (EDXRF) technique has been used to study two Rupee Indian coins minted during the period 1993 to 2010 for their elemental concentrations. From the analysis of the coins, it is found that the coins are made of binary alloy and it was observed that from 2005 onwards, the composition of the coins has been changed from Cupro-Nickel to Ferritic Stainless Steel (FSS).

Keywords: EDXRF system, Elemental analysis, Numismatic study, Indian coins

1. Introduction

Energy Dispersive X-ray Fluorescence (EDXRF) technique is a very well known analytical tool for the determination of elemental concentrations of various types of samples of archeological, biological, geological or environmental in nature. It is a non-destructive technique and is capable of detecting elements up to the limit of ppm. Compared to the other non-destructive methods, namely Particle Induced X-ray Emission (PIXE), Electron Probe Micro-analysis (EPMA), etc., EDXRF is a simple, less expensive technique and also needs less space. An EDXRF system needs an x-ray source (radioactive source/x-ray tube), an x-ray detection device and a data acquisition system. Whatever might be the source of x-rays, the basic principle remains the same: primary x-rays hit the target, emerging fluorescence x-rays are detected by an energy dispersive detector, characteristic x-ray peaks of different elements are identified, integrated using a suitable peak fitting program and finally the peak integrals are converted to elemental concentrations. Study of old coins in India is not a recent phenomenon. The Indian Institute of Research in Numismatic Studies, situated at Nasik, Maharashtra has been doing this job for quite sometimes. But their main technique related to the compositional analysis of a coin is the specific gravity method by which only coins based on the binary alloys could be analyzed. Although EDXRF, PIXE, NAA have been in use in other advanced countries for a long time no effort has been made in the past to apply these sophisticated techniques in Indian numismatic studies. Recently PIXE, EDXRF etc. [1-9] are available for elemental analysis of Indian coins. Here, we have used EDXRF system to analyze few recent two Rupee Indian coins to show how this technique can be routinely used for numismatic studies in India. We have analyzed 14 coins minted during the period of 1993 to 2010 and also 5 different coins minted in the same year (2000). The obverse and reverse side of the two coins of 2000 and 2008 is shown in Figure 1.

Figure 1: Obverse and reverse sides of Two Rupee Indian coins of 2000 and 2008.

2. Experiment

A schematic diagram of the present experimental setup is shown in Figure 2. A Kevex 60 watt Tungsten x-ray tube at 30 kV with a current of 0.2 mA was the source of primary x-rays. A Mo foil of thickness 0.0120 g/cm^2 was used as a secondary to get the almost monochromatic x-rays. The coins were first washed using distilled water and then cleaned with alcohol and finally irradiated under K x-rays of Mo. The coins were placed in such a way that the entrance and exit angles of x-rays with respect to the target were 45° each. The ORTEC Si(Li) detector having a resolution of 180 eV at 5.9 keV with the necessary pulse processors and a PC based MCA card ware used for data collection. Distance between the secondary and the target was 5 cm and the distance between the target and the detector was 4.0 cm. Two such spectra are shown in Figures 3 and 4. The time required for a typical run varied from 30 to 45 minutes. Using pure foils of Ti, V, Fe, Ni, Cu, Zn a good energy calibration curve was obtained and is shown in Figure 5. With this curve, the qualitative picture of the coins could be readily predicted.

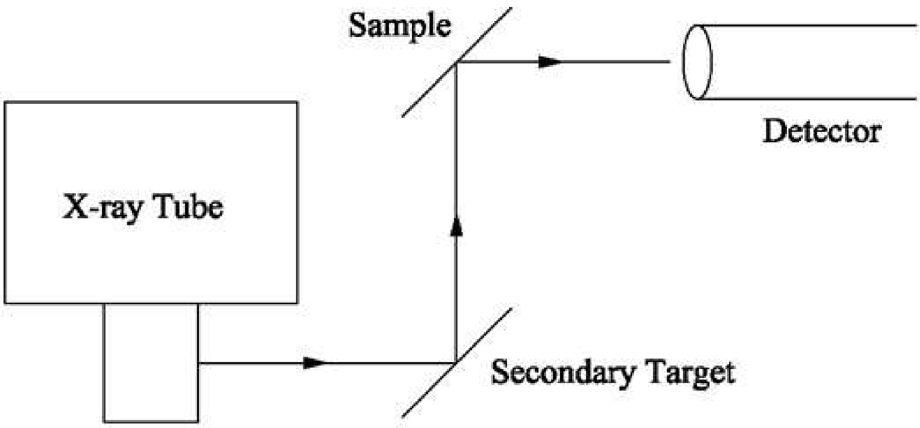

Figure 2: A schematic experimental setup used in the present measurement.

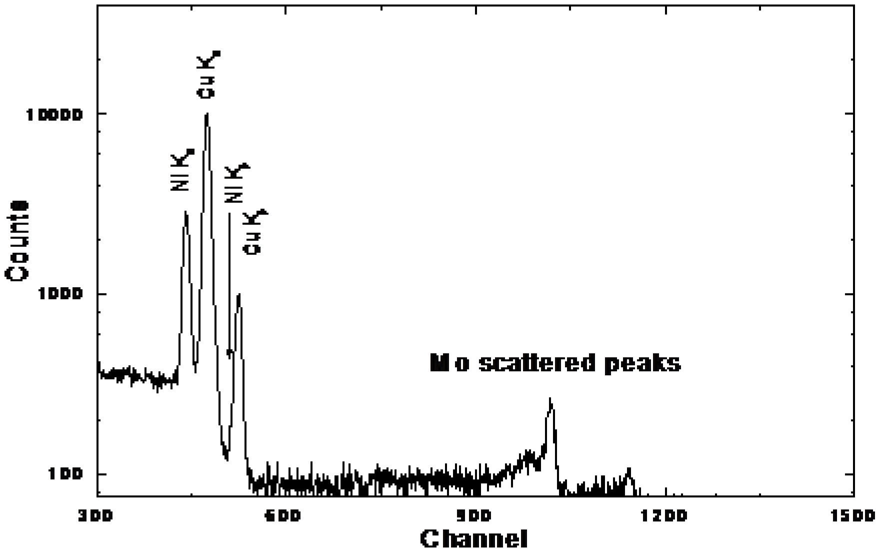

Figure 3. Spectrum from a Two Rupee Indian coin of 2000 excited with Mo K x-rays obtained from a Mo secondary target. The x-ray tube was run at 30kV with a current of 0.2 mA.

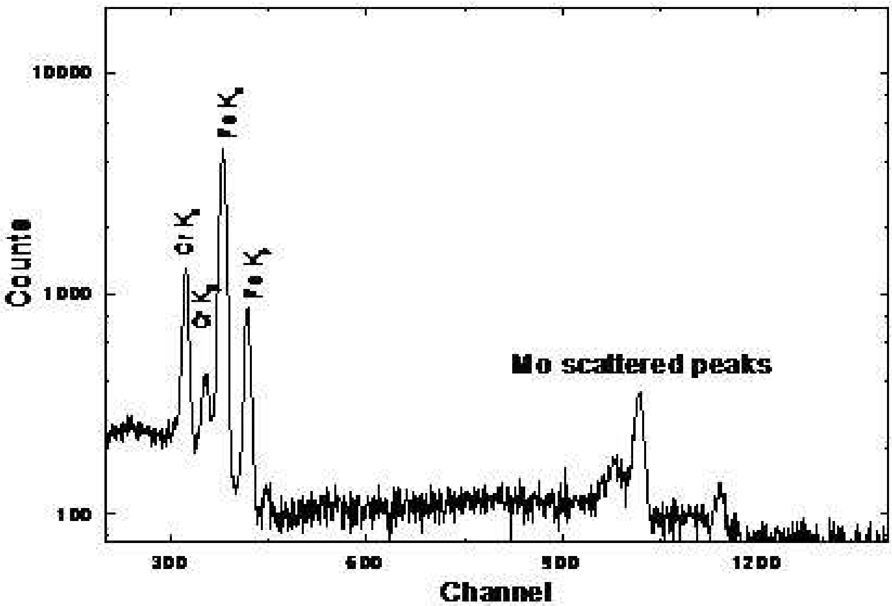

Figure 4. Spectrum from a Two Rupee Indian coin of 2008. Other conditions are the same as in Figure 3.

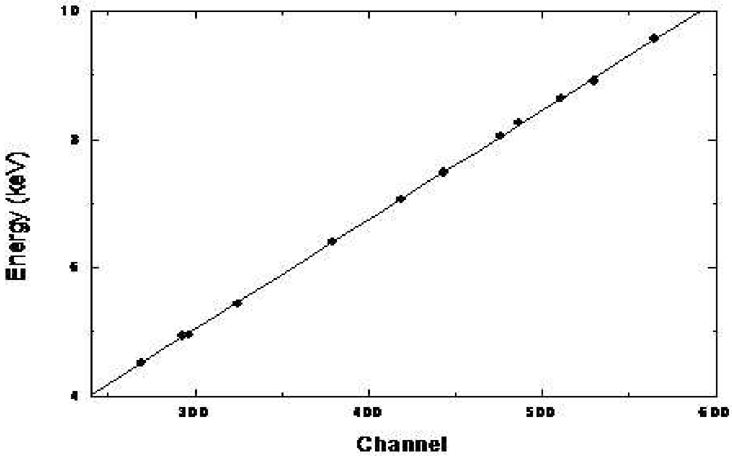

Figure 5. Energy calibration curve used in the present measurement.

4. Results and discussions

For the quantitative analysis, we used same principle that was stated in our earlier paper [10]. The results are shown in Table 1. Table 2 shows another set of results from 5 different coins minted in the same year (2000).

Year	Element (wt%)		Year	Element (wt%)		Year	Element (wt%)	
	Ni	Cu		Ni	Cu		Cr	Fe
1993	25.4	74.6	2000	25.3	74.7	2005	17.6	82.4
1994	25.1	74.9	2001	25.1	74.9	2007	16.8	83.2
1995	24.9	75.1	2002	25.4	74.6	2008	16.9	83.1
1998	25.2	74.8	2003	24.9	75.1	2009	17.8	82.2
1999	25.8	74.2				2010	16.6	83.4

Table 1: Elemental composition (in wt%) of Two Rupee Indian coins minted during the period 1993 – 2010.

Coin Number	Element (wt%)	
	Ni	Cu
1	25.4	74.6
2	25.8	74.2
3	24.9	75.1
4	25.3	74.7
5	25.7	74.3

Table 2: Elemental composition (in wt%) of five different two Rupee Indian coins minted in the year 2000.

It is evident from the Tables that the coins are basically fabricated from a binary alloy. From Table 1, it is observed that till 2003, Cupro-Nickel (Cu and Ni) coins with an average value of 25.2 ± 0.6% Ni and 74.8 ± 0.6 % Cu has been preferred for minting. From 2005 onwards, the composition of the coins has been changed from Cupro-Nickel to Ferritic Stainless Steel (FSS) with an average value of 17.1 ± 0.7% Cr and 82.9 ± 0.7% Fe. Basically ferritic-stainless steel is preferred to Cupro-Nickel alloy during this decade due to high and cheep availability of steel and high price and fewer productivity of Nickel in world market and also unavailability of Ni in excess.

It has been shown in earlier paper [10] that this method of determination of concentration gives rise to an overall error of 10% to 15% to individual concentration values. Keeping this figure in mind, it is observed that all the values mentioned in two Tables are well within the average values. It is normally assumed that the elemental composition of the coins of a particular year will remain the same. From Table 2, it is observed that the average concentration of Ni (in wt%) in those coins is 25.4. Although the error in individual measurement varies from 10 to 15% but from Table 2 it is clear that the present technique can predict the concentration values with a precision of 2%.

4. Conclusion

From the analysis of the coins, it is found that the coins are made of binary alloy and it was also observed that from 2005 onwards, the composition of the coins has been changed from Cupro-Nickel to Ferritic Stainless Steel (FSS). The advantage of the present technique is that one can calculate the elemental concentration of a coin by exposing it *only once* under the desired radiation without requiring any idea about the geometry and incident flux. This saves a lot of time compared to the method where different calibration curves are made by exposing different standards. The disadvantage of the present technique is that it calculates the relative abundance of the elements only, and not their absolute values and only the observed elements are taken into account.

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