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Numismatic Study of One Rupee Indian Coins by EDXRF Technique

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ABSTRACT

One Rupee Indian coins minted during the period 1975 to 2000 have been analyzed with Energy Dispersive X-Ray Fluorescence (EDXRF) system. From the analysis of the coins, it is found that the coins are made of binary alloy and it was observed that from 1992 onwards, the composition of the alloy has been changed from Ni-Cu to Cr-Fe.

Keywords: EDXRF system, elemental analysis, numismatic study, Indian coins

1. Introduction

The technique of Energy Dispersive X-Ray Fluorescence (EDXRF) is being successfully applied for quantitative elemental analysis in various fields of human endeavor e.g. Physics, Chemistry, Archaeology, Metallurgy, Pollution Studies etc. The special attraction of the technique lies in the fact that it is non-destructive, and this property makes it highly suitable for numismatic studies. Compared to the other non-destructive methods, namely Particle Induced X-ray Emission (PIXE), Electron Probe Micro-analysis (EPMA), Neutron Activation Analysis (NAA) etc., EDXRF is a simple, less expensive technique and also needs less space and so its demand for analyzing precious archaeological items, especially old coins, are very high. 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 sometime. 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. [1-8] are available for elemental analysis of Indian coins. Here, we have used EDXRF system to analyze few recent one Rupee Indian coins to show how this technique can be routinely used for numismatic studies in India. We have analyzed 25 coins minted during the period of 1975 to 2000 and also 10 different coins minted in the same year (1999). The obverse and reverse side of the two coins of 1976 and 2000 is shown in Figure 1.

(a) (b)

Figure 1. Obverse and reverse sides of One Rupee Indian coins of (a) 1976 (b) 2000.

2. Experiment

A schematic diagram of the experimental setup is shown in Figure 2. A Kevex 60 watt Tungsten x-ray tube at 35 kV with a current of 0.3 mA was the source of primary x-rays. A Mo foil 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. 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, Fe, Ni, Cu etc. a good energy calibration curve was obtained. With this curve, the qualitative picture of the coins could be readily predicted.

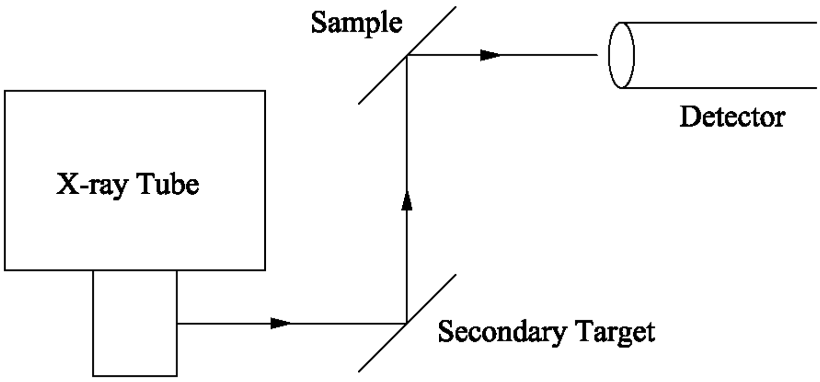

Figure 2. A schematic experimental setup used in the present measurement.

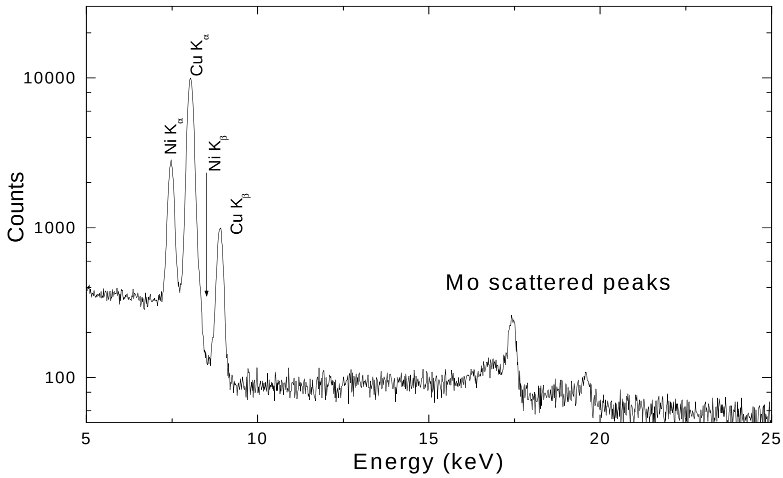

Figure 3. Spectrum from a One Rupee Indian coin of 1976 excited with Mo K x-rays obtained from a Mo secondary target. The x-ray tube was run at 35kV with a current of 0.3 mA.

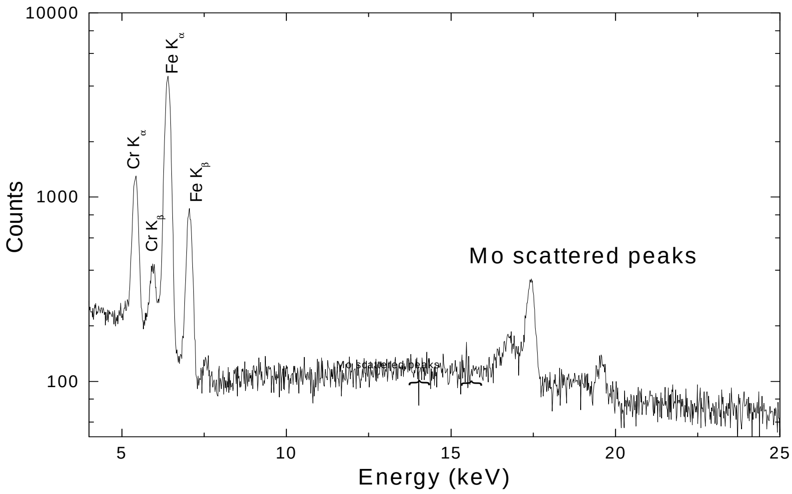

Figure 4. Spectrum from a One Rupee Indian coin of 2000. Other conditions are the same as in Figure 3.

4. Results and discussions

For the quantitative analysis, we used same principle that was stated in our earlier paper [9]. The results are shown in Table 1 and 2. Comparisons of present study with Reserve Bank of India (RBI) data [10-12] are also shown. Table 3 shows another set of results from 10 different coins minted in the same year (1999).

Year	Element (wt%) Present result		Element (wt%) Ref. [10-12] (RBI)		Year	Element (wt%) Present result		Element (wt%) Ref. [10-12] (RBI)	
	Ni	Cu	Ni	Cu		Ni	Cu	Ni	Cu
1975	26.2	73.8	25	75	1984	26.0	74.0	25	75
1976	26.1	73.9	25	75	1985	25.9	74.1	25	75
1977	24.8	75.2	25	75	1986	25.0	75.0	25	75
1978	24.3	75.7	25	75	1987	23.4	76.6	25	75
1979	26.0	74.0	25	75	1988	24.8	75.2	25	75
1980	24.0	76.0	25	75	1989	23.1	76.9	25	75
1981	24.5	75.5	25	75	1990	25.0	75.0	25	75
1983	25.7	74.3	25	75	1991	23.4	76.6	25	75

Table 1. Elemental composition (in wt%) of One Rupee coins minted during the period 1975 – 1991.

Year	Element (wt%) Present result		Element (wt%) Ref. [10-12] (RBI)		Year	Element (wt%) Present result		Element (wt%) Ref. [10-12] (RBI)	
	Cr	Fe	Cr	Fe		Cr	Fe	Cr	Fe

1992	17.8	82.2	17	83	1997	17.3	82.7	17	83
1993	16.9	83.1	17	83	1998	16.5	83.5	17	83
1994	17.5	82.5	17	83	1999	16.6	83.4	17	83
1995	17.7	82.3	17	83	2000	16.6	83.4	17	83
1996	17.8	82.2	17	83					

Table 2. Elemental composition (in wt%) of One Rupee coins minted during the period 1992 – 2000.

Coin Number	Element (wt%)		Coin Number	Element (wt%)	
	Cr	Fe		Cr	Fe
1	16.9	83.1	6	17.0	83.0
2	16.9	83.1	7	16.5	83.5
3	16.7	83.3	8	16.8	83.2
4	16.7	83.3	9	16.6	83.4
5	17.1	82.9	10	16.5	83.5

Table 3. Elemental composition (in wt%) of ten different One Rupee coins minted in the year 1999.

It is evident from the Tables that the coins are basically fabricated from a binary alloy. From Table 1 and 2, it is observed that till 1991, all the coins were of Ni-Cu alloy with an average value of 24.9 ± 1.7% Ni and 75.1 ± 1.7 % Cu. From 1992 onwards, the composition of the coins has been changed from Ni-Cu to Cr-Fe with an average value of 17.2 ± 0.7% Cr and 82.8 ± 0.7% Fe. These results agree well with RBI data [10-12]. This fact of changing over from Ni-Cu alloy to Cr-Fe alloy from the year 1992 has been confirmed from the web site of the Government Mint at Kolkata (www.igmint.org). Basically ferrite-stainless steel is preferred to cupper-nickel alloy during this decade due to high and cheep availability of steel.

It has been shown in earlier paper [9] 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 three Tables are well within the average values although the measured values show more scatter in the case of the Ni-Cu alloy (Table 1). It is normally assumed that the elemental composition of the coins of a particular year will remain the same. From Table 3, it is observed that the average concentration of Cr (in wt%) in those coins is 16.8. Although the error in individual measurement varies from 10 to 15% but from Table 3 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 1992 onwards, the composition of the alloy has been changed from Ni – Cu to Cr – Fe. 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.

REFERENCES

1. M. Hajivaliei, M.L.Garg, D.K.Handa, K.L.Govil, T.Kakavand, V.Vijayan, K.P. Singh and I.M.Govil, PIXE analysis of ancient Indian coins, *Nucl. Instr. and Methods B*, 150 (1999) 645-650.
2. V.Vijayan, P.K.Nayak and V. Chakravortty, PIXE astudies of Indian copper coins, *Indian J. Phys. A*, 76 (2002) 477-479.
3. A.C.Mandal, S.Santra, D.Mitra, M.Sarkar, D.Bhattacharya and S.Bose Majumder, Numismatic study of Malhar coins by the Energy Dispersive X-Ray Fluorescence (EDXRF) technique, *Indian Journal of History of Science*, 38.4 (2003) 351-366.
4. T. R. Rautray, V. Vijayan, K. Pranaba Nayak and S. Jena, Analysis of copper coins by EDXRF technique, *Int. J. PIXE*, 14 (3 & 4) (2004) 133-139.
5. P. K. Nayak, T. R. Rautray and V. Vijayan, EDXRF: A non-destructive technique for multi-elemental analysis of coins, *Ind. J. Pure & App. Phys.*, 42 (2004) 319-322.
6. S. Santra, D. Mitra, M. Sarkar, D. Bhattacharya, A. Denker, J. Opitz-Coutureau and J .Rauschenberg, Analysis of some coins by energy dispersive X-ray fluorescence (EDXRF) and high energy particle induced X-ray emission (PIXE) techniques, *Nucl. Instr. and Methods B*, 229 (2005) 465-470.
7. B. B. Tripathy, T. R. Rautray, R. Satya Das, R. Manas Das and V. Vijayan, Analysis of Indian silver coins by EDXRF technique, *Int. J. PIXE*, 19(3 & 4) (2009) 167-173.
8. R. Kumar, A. Rani and R. M. Singh, Elemental Analysis of One Rupee Indian Coins by Using EDXRF Technique, *J. Integr. Sci. Technol.*, 2 (1) (2014) 1-4.
9. A.C.Mandal, M.Sarkar and D.Bhattacharya, A simple EDXRF technique to analyse alloys, *Eur. Phys. J. AP, 17 (2002)* 81-84.
10. http://www.rbi.org.in/currency/museum/c-rep.html
11. http://www.rbi.org.in/scripts/BS_ViewCurrencyPressRelease.aspx?Id=24773
12. http://www.rbi.org.in/scripts/BS_ViewCurrencyPressRelease.aspx?Id=17411