International Review of Applied Engineering Research.
ISSN 2248-9967 Volume 4, Number 1 (2014), pp. 83-88

http://www.ripublication.com/iraer.htm

Compositional Study of Indian Five Rupee Coin by EDXRF Technique

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Abstract

Energy dispersive X-ray Fluorescence technique has been used to study five rupee indian coins of years 1992,1993,1994,1999,2009,2010,2011 and 2012 for their material/ elemental compositions. EDX-720 spectrometer provided with X-ray tube and Si(Li) detector having energy resolution 165 eV at 5.9KeV Mn K X-ray. Different metal compositions like Cupro-Nickel, Nickel-Brass and Ferritic Stainless-Steel (FSS) with traces of Mn, Cr, S, Si, Cl have been found in present investigation. Modern coins are found with amendment in composition that replaces Cupro-Nickel, Nickel-Brass. Variation in weights of coins have been observed from 9 to 6 gm.

Keywords: EDX-720 Spectrometer;Si(Li) detector;X-ray tube;Indian Coin;Material Compositions.

1. Introduction

Energy dispersive X-ray Fluorescence (EDXRF) technique is recognized as a powerful tool / method for multielemental sample analysis. EDXRF is the emission of characteristic secondary X-ray (also known as Fluorescent X-ray) from a material that has been excited by bombardment with high energy X-ray. The energy of each X-ray peak in spectrum is associated with the presence of particular element and the intensity of peak is related to the elemental concentration. This technique offers a fairly good detection limit, allows direct analysis of solid samples and non destructive in nature.

EDXRF has one of the main applications of characterization of coins. Coins are basically archeological objects to study and gain historical information. Various techniques are available to study metal compositions of coins like PIGE (Particle Induced Gamma-ray Emission), PIXE (Particle Induced X-ray Emission), NAA (Neutron Activation Analysis) and EDXRF (Energy Dispersive X-ray Fluorescence).Among these, EDXRF is very fast and sensitive to analyze metal compositions of coins. Various researchers like V Cojacaru et al, 2000; A C Mandal et al, 2003; P K Nayak et al, 2004; B Constantinescu et al, 2005, 2008; S Santra et al, 2005; M Fayze-Hassan et al, 2011; S A Abd El Aal et al, 2012; R Kumar et al, 2014 had successfully studied different types of old coins by using EDXRF technique. The present study reveals here the elemental analysis of Indian five rupee coin of different years 1992, 1993, 1994, 1999, 2009, 2010, 2011 and 2012 using EDXRF technique. The aim of this study is to check what type of changes had been adopted in metal compositions of coins in last three decades and what their significances are. Currency of any country played a very imperative role in its development. Currency in any form either paper or metallic is the important part of economy. From ancient time, coins are playing a major role to impart current circumstances of country. Basically, coins are the mirrors of culture, economy and development of any country in that scenario. In all over the world, coins of different metal compositions are available from ancient time to modern era. Various researchers and numismatists are directly involved in coin collection and their study work.

2. Experimental Details

A total number of eight Indian five rupee coins have been chosen for EDXRF analysis. Obverse and reverse sides of coins are depicted in Fig. 1. All coins were personal collection of authors. According to press release of Reserve Bank of India (RBI), the standard feature and specification are shown in table 1. All coins are dipped in Acetone for 24 hours to remove iron enrichment and other corrosion elements presents on the samples and cleaned with soft brush. Then coins are washed with distilled water and finally dried with air drier. The EDXRF system at Forensic Science Laboratory, Madhuban, (Karnal, Haryana) India has been used for elemental analysis of coins. The system EDX-720 provided with EDX Software version 1.00, release 017 was used and systematic diagram is shown in Fig. 2. The EDXRF system assembles here with liquid nitrogen (LN2) cooled X-ray tube as an excitation source. The X-ray tube was operated with voltage range 5-50 KV and current 1 to 1000 μA. The X-rays are incident on secondary exciter *Rh* (Rhodium) and generated X-rays of Rh were used to excite the elements present in the coins. The measurement time for each coin sample analysis is 500 seconds. The Si(Li) detector having energy resolution of 165 eV at 5.96 KeV K_α Mn line was used to detect fluorescence X-rays from the sample and finally detector was connected to the computer. The sample chamber was under observation with CCD camera which gave exact location of sample placement where X-rays are irradiated.

Fig. 1: Obverse and Reverse Sides of Coins.

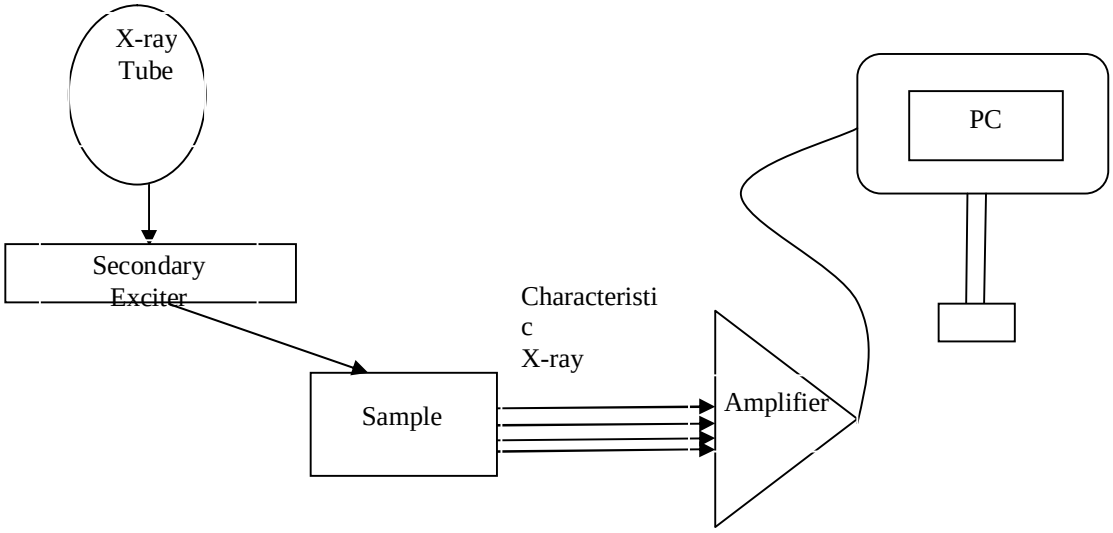

Fig. 2: Systematic diagram for measuring the EDXRF spectra.

The elemental composition of coins were determined by using the formula

$$m_{ij} = \frac{N_{ij}}{I_o G \varepsilon \sigma_{ij} \beta_i}$$

Where m_j is the concentration of j^{th} element present in the sample, N_{ij} is the net counts per unit time for the i^{th} group of X-rays of j^{th} element, I_oG is the intensity of the exciting radiation incident on the sample visible to the detector, ε is the detector efficiency for the j^{th} element, σ_{ij} is the theoretical X-ray fluorescence cross section at 20.21KeV excitation energy and β_i is the self absorption correlation factor that accounts for absorption of incident and emitted X-rays in the sample.

3. Result and Discussion

Eight coins were analyzed with known elemental compositions with EDXRF technique. Table 1 shows the data of RBI (Reserve bank of India) like weight and diameter and an elemental composition measured by this technique for coin samples taken. It is apparent view that compositions of coins have altered in last twenty years. Since year 1991 to 2000, Cupro-Nickel coins with Cu and Ni has been preferred for minting which is highly resistant against corrosion. Traces of Mn present here serve as

the strengthening element. In next decade of 2000 to 2010, coin minting alloy i.e. Cupro-Nickel had been replaced with Nickel-Brass that has less quantity of Nickel (Ni). And it must be because of higher price and fewer productivity of Nickel in world market and also unavailability of Ni in excess.

Table 1: Weight, Diameter and Elemental Compositions of Indian Five Rupee Coin.

Coin	Year of Issue	Weight and Diameter (RBI)	Weight and Diameter (Measured)	Elemental Composition (RBI)	Elemental Composition (Measured)
#1	1992	9gm, 23mm	8.86889gm, 23mm	Cupro-Nickel (Cu and Ni)	Cu,Ni,S,Mn,Fe,Se
#2	1993	9gm, 23mm	8.82835gm, 23mm	Cupro-Nickel (Cu and Ni)	Cu,Ni,Cl,Mn,S
#3	1994	9gm, 23mm	8.95547gm, 23mm	Cupro-Nickel (Cu and Ni)	Cu,Ni,Mn,Co,S,Se
#4	1999	9gm, 23mm	8.95793gm, 23mm	Cupro-Nickel (Cu and Ni)	Cu,Ni,Mn,S,Co
#5	2009	6gm, 23mm	6.02833gm, 23mm	Nickel Brass (Cu , Zn and Ni)	Cu,Zn,Ni,S,Mn
#6	2010	6gm, 23mm	5.92335gm, 23mm	Nickel Brass (Cu , Zn and Ni)	Cu.Zn,Ni,S,Mn
#7	2011	6gm, 23mm	5.83485gm, 23mm	Nickel Brass (Cu , Zn and Ni)	Cu.Zn,Ni,S,Mn
#8	2012	6gm, 23mm	5.889243gm 23mm	Ferritic Stainless Steel(FSS) (Fe and Cr)	Fe,Cr,Mn

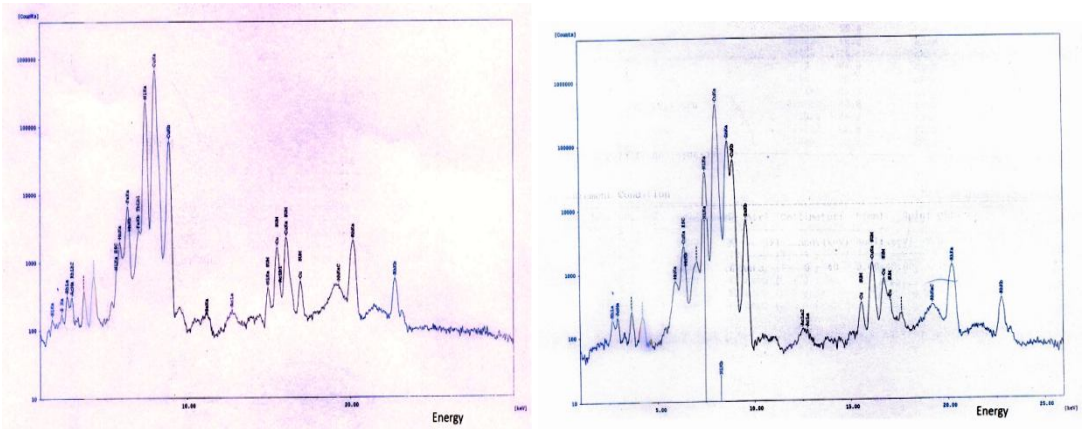

Fig. 3: EDXRF Spectra of Coin #1 and Coin #7.

During this period five rupee coins are fabricated with this alloy and we have found elements like Cu, Zn, Ni, S, Mn etc. Fundamentally content of Ni is reduced here and corresponding amount if Zn is increased for this metal composition. Traces of Mn were once more determined as before in these observations that once more act because the strengthening component. Latest forceful changes in metal composition are available in to result from 2008 that has been determined throughout measure of coin of year 2011. Each metal alloys Cupro-Nickel and Nickel-Brass were replaced by new Ferritic stainless-steel (FSS) because of high and low-cost accessibility of steel. Major content of FSS are Iron (Fe) and Chromium (Cr). Also weight has been reduced from 9 gm to 6 gm in new modern coins. Two examples of typical EDXRF spectra are shown in Fig. 3.

4. Conclusions

EDXRF technique has been used to study material compositions of five rupee coin. This technique also helped us to distinguish different coins in last three decades. Since year 1990-2000, Cupro-Nickel alloy, from 2000-2010, Nickel Brass alloy and from 2010 to till date, Ferritic Stainless Steel (FSS) has been preferred for coin manufacturing process. The possible reason for this material amendment could be the clearly attributed to high cost and low availability of nickel (Ni) as compare to low cost and easy accessibility of Iron (Fe) in modern coins. Besides these elements, traces of Mn, Cr has been also observed which act as the strengthening elements. EDXRF spectra in Fig. 3 show the presence of major and minor elements in coins #1 and #7. The present study shows great consequence in archeological aspect of Indian coins and gives the clear view that what type of changes has been adopted for coin minting by government of India. EDXRF, being a way less complicated and cheaper analytical technique and regularly used for coins as compare to different technique like NAA, PIXE etc.

5. Acknowledgements

We are thankful to Dr. Rajesh Soni, Ms. Gayatri Sen, Mr. R. S. Puniya; FSL, Karnal (Haryana) India for their support in running EDX-720 instrument and suggestions regarding this study.

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