Preliminary Applications of the Surrey External Beam Facility

Prashant Mistry, Roger P Webb, Chris Jeynes and Karen J Kirkby

Surrey Ion Beam Centre, Advanced Technology Institute, School of Electronics and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH

Michael Merchant, Tony Clough and Geoffrey W Grime,
Dept. Physics, School of Electronics and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH

ABSTRACT

The new external microbeam at the University of Surrey is capable of mapping areas of 3mm x 3 mm. In this study it has been used to map the metal composition of 2 inks in a German 1920’s bank note. The major constituents of the red ink are mercury and barium, while those in the green ink, which was applied first, are lead and chromium. The analysis took 10 minutes and there was no detectable mark left on the paper as a result of the analysis. RBS and PIXE analysis of lines drawn on cartridge paper using a lead metalpoint enabled the fine structure and the depth distribution of lead in the paper to be determined.

Keywords: External microbeam, PIXE, RBS, Reichmark, metalpoint

Corresponding author name: Dr Karen J Kirkby, ATI, University of Surrey, k.kirkby@surrey.ac.uk

1. INTRODUCTION

External proton microbeam analysis using proton induced X-ray emission (PIXE), Rutherford Backscattering (RBS) and proton induced gamma emission (PIGE) have been successfully used on samples that are not compatible with analyses in vacuum. The technique has been shown to be particularly useful for the analysis of ancient manuscripts [1-4].

In this paper we report on preliminary analysis of paper using the new scanning external micro-beam which has recently been installed in the University of Surrey Ion Beam Centre after being moved from the University of Oxford. The Oxford system has already been described [5], however the new external beam capability at Surrey has been significantly upgraded and is now offers a mapping capability in addition to point analysis. A more detailed description of this new facility can be found in reference [6].

2. EXPERIMENTAL

Figure 1 shows a schematic of the exit nozzle for the new external beam facility which has recently been installed at the University of Surrey Ion Beam Centre. This allows the external beam to be scanned over an area of up to 3mm x 3mm.

The exit window is made of 8 micrometre Kapton foil which is surrounded by 4 detectors, these are as follows:

- an x-ray detector for light elements (with magnetic deflector to block recoiling protons)
- an x-ray detector for trace elements (with absorber to block x-rays from major elements, such as Si)
- a high purity Ge gamma ray detector
- a particle detector for recoiling protons (RBS and normalisation for PIXE)

FIGURE 1. Schematic of exit nozzle and detectors [5]
In order to test the way in which the new scanning external beam performed, two very different samples were selected. The first was a 100 Reichsmark note dating from 1920 bearing pictures of the Bamberg Horsemen and the Reich Eagle. The second was lines drawn with a lead point on a sheet of white cartridge paper, to simulate a metalpoint drawing.

3. RESULTS AND DISCUSSION

3.1 Analysis of 1920’s 100 Reichsmark note

January 1920 saw the beginning of rapid inflation in the German Weimar republic. In 1918, 1 US dollar could be exchanged for 5.21 Reichsmarks, by 1919 the exchange rate had increased to 8.2 Reichsmarks and by 1920 it had increased 8 fold to 64.8 Reichsmarks. There was then a year of relative stability but by Jan 1922 1 US $ was worth 191.81 Reichsmarks and by December 1923 this had risen to a massive 4,200,000,000,000 Reichsmarks to the US dollar. The 100 Reichsmark note used in this study predates the period of hyperinflation and bears a picture of one of the Bamberg horsemen (horseman of the apocalypse from a manuscript in Bamberg cathedral) and the Reich eagle. Despite extensive research we have been unable to find out anything about the printers of this banknote or the inks used. Figure 2 shows a photograph of the banknote and an enlargement of the area scanned by the external beam.

Fig 3 shows elemental maps (3mm x 3mm) for the red ink used for the head of the eagle and the green ink used to produce the wavy lines beneath and surrounding the eagle’s head. During the analysis, 10 elements were detected in the two inks, the beam was scanned for 10 minutes after which there was no visible mark on the paper of the banknote. The major constituents in the red ink were mercury and barium while those in the green ink were lead and chromium. Figure 4 shows the relative percentage of metals in red and green ink from German banknote determined using PIXE.
relative percentages of the metals found in the red and green inks. From the pattern of the green ink (in figure 3) it is apparent that the green ink was applied prior to the red ink.

3.1 Analysis of lead metalpoint lines

Figure 5 shows PIXE and RBS analysis of lines drawn on cartridge paper using a lead metalpoint. The beam was scanned over a 3mm x 3mm area in order to obtain the PIXE maps. One of the lead lines is finer than the other. The thicker of the two lines apparently consists of large particles of lead, which can be seen in the PIXE map. RBS analysis allows the depth distribution of the lead in the paper for each of the lines to be determined.

4. CONCLUSIONS

The new external beam facility at the University of Surrey has been successfully used to analyse the inks in a 100 Reichmark note and to analyse lead metalpoint lines on cartridge paper. The beam is capable of being scanned over a relatively large area (3mm by 3mm) enabling spatial changes in elemental composition to be mapped. For the Reichmark note the major elements found in the red ink were mercury and barium while those in the green ink are lead and chromium. From the PIXE maps it is apparent that the green ink was applied prior to the red. After 10 minutes analysis no visible mark was observed on the paper of the banknote. Lead metalpoint lines have been analysed using PIXE and RBS, this enables both the elemental composition of the lines and the depth profiles of the lead in the paper to be determined.

ACKNOWLEDGMENTS

The authors would like to thank the UK Engineering and Physical Sciences Research Council (EPSRC) and for their support. They would also like Mr F.B.D Kirkby for the loan of the banknote.

REFERENCES