



# Chemical characterization of soda-lime glass samples by in situ current normalised PIGE and conventional INAA methods for forensic applications

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## Abstract

Nuclear analytical methods namely in situ current normalised Particle Induced Gamma Ray Emission (PIGE) and conventional Instrumental Neutron Activation Analysis (INAA) were utilized for determining major, minor and trace concentrations of eighteen elements in five soda-lime (automobile) glass samples. Concentration of four major elements (Si, Na, Mg and Al) by PIGE and fourteen elements including ten trace elements by INAA were determined. For forensic application, major elements were used for confirming the class of glass samples, whereas concentration results of trace elements like transition and rare earth elements were utilized for finding similarity or differences among the glass samples.

**Keywords** Soda-lime glass · Automobile glass · PIGE · INAA · Trace element fingerprinting · Forensic applications

## Introduction

Provenance study is an important area in forensic science, in which various samples like glass, ceramics, archaeological objects, soil and food are analysed to obtain their source or origin [1, 2]. Archaeologists are keen to establish whether the set of similar objects/samples under investigation belong to same or different sources. Among the above samples, ceramics and glasses are often studied for finding their source of manufacture through their chemical composition at major as well as minor and trace concentration levels. In general, glass properties are not decayed or corroded with time due to its high stability and thus it acts as important forensic evidence. Provenance or grouping studies are carried out in glass and ceramic samples with higher

degree of confidence using minor and trace elemental concentrations instead of major elements, as major elements are found to be similar in same class of samples though they are obtained from different sources. Trace elements in particular are source specific in nature thus their concentrations are used in finding similarities or differences in a set of similar samples [3, 4]. With the recent developments in the glass manufacturing procedures it is possible to fabricate the glasses with same optical and physical properties, though it is prepared by different manufacturers, but, there are minor variations in the chemical composition especially at the minor and trace elemental concentration levels which are associated with the sources of the raw materials. After the invention and advancement in glass blowing technology during first century BC, glass had become a common material [5]. Glass is ubiquitously used in modern society including window, ornaments, automobile window and windshield, utensils and containers and laboratories [6]. This results into its involvement to most of the crimes such as hit and run accidents and murders. On the basis of major elemental concentrations, glasses can be commonly categorised into three broad classes namely soda-lime (CaO based), alumino-silicates (Al<sub>2</sub>O<sub>3</sub> based), and boro-silicates (B<sub>2</sub>O<sub>3</sub> based) glasses. Soda-lime glasses have Si, Na, Ca, Mg and Al as major elements along with varying amount of minor and trace elements like Fe, K, Ti, Mn and other trace elements depending on the source of the raw materials taken

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