TRACE DETERMINATION OF SILICON
BY HEAVY ION ACTIVATION ANALYSIS

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(Received August 30, 1983)

The Si(11B, x) $^{34}$Cl and Si(19F, x) $^{44}$Sc reactions have been studied in order to
work out their capabilities in determining traces of silicon. The first one has been tested
with beam energies ranging from 19 to 27 MeV $^{11}$B ; only Mg and Al have shown nuclear
interferences and a 30-min 27 MeV $^{11}$B irradiation yields a 14 ng detection limit. The
second reaction, investigated in between 35 and 46 MeV $^{19}$F, yields a 16 ng detection
limit with a 2 hrs 46 MeV $^{19}$F irradiation; at that energy only Al and P present nuclear
interferences.

Introduction

The use of silicon as a dopant in semiconducting materials,1 the part it plays in
the modification of some metals' physical properties,2 or the influence it exercises
over the growth of many higher plants,3 justify the interest of determining this non-
metal in different kinds of materials.

To this end, beyond the wet chemistry techniques, numerous nuclear methods
have been developed. The neutron activation analysis is extremely sensitive4 but its
use calls for a very selective radiochemical separation. The 14 MeV neutron activation
is relatively selective, but less sensitive and has been applied to determination of
silicon in the percent range of concentrations;5 it is the same with photon activation.6
The activation using a tritium beam seems to be both sensitive and selective7 but the
availability of such a beam is rather exceptional. Different on-line nuclear techniques
have been used for silicon determination as PIXE with a proton beam8 or even an
argon beam.9 This technique, though very sensitive, cannot be used when heavy
elements are the major component of the matrix to be analyzed. Finally, the deter-
mination of silicon by neutron-capture prompt γ-ray activation10 or by proton
induced γ-ray analysis11 is possible, in the low concentration range, only in some
specific materials.

The use of the heavy ion activation analysis technique has also been considered
using an oxygen-18 beam.12 This paper discusses the first results obtained from the
Si + $^{11}$B → $^{34}$Cl and Si + $^{19}$F → $^{44}$Sc reactions, whose characteristics are given
in Table 1.
Table 1
Nuclear characteristics of the reactions and products used in Si determination

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Threshold, MeV</th>
<th>Coulomb barrier, MeV</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{28}$Si($^{11}$B, α$^{34}$mCl)</td>
<td>Q &gt; 0</td>
<td>17.8</td>
<td>32 m 146 0.35</td>
</tr>
<tr>
<td>$^{29}$Si($^{11}$B, α2n$^{34}$mCl)</td>
<td>8.8</td>
<td>17.5</td>
<td>511 2.00</td>
</tr>
<tr>
<td>$^{30}$Si($^{11}$B, α3n$^{34}$mCl)</td>
<td>23.8</td>
<td>17.2</td>
<td></td>
</tr>
<tr>
<td>$^{31}$Si($^{19}$F, α$^{44}$mSc)</td>
<td>0.2</td>
<td>35.6</td>
<td>2.44 d 272 0.86</td>
</tr>
<tr>
<td>$^{32}$Si($^{19}$F, α$^{44}$mSc)</td>
<td>Q &gt; 0</td>
<td>34.9</td>
<td></td>
</tr>
<tr>
<td>$^{33}$Si($^{19}$F, αn$^{44}$mSc)</td>
<td>Q &gt; 0</td>
<td>34.2</td>
<td></td>
</tr>
<tr>
<td>$^{44}$mSc → $^{44}$Sc</td>
<td>3.92 h</td>
<td>511</td>
<td>1156 0.99</td>
</tr>
</tbody>
</table>

Both beams have been chosen by the following criteria:
- character of the radionuclides produced (half-lives and decay schemes),
- reaction threshold energies and Coulomb barriers,
- nuclear interference probabilities,
- availability of the beams (energies and intensities).

The first irradiations have been used to sketch the activation curves, to calculate the detection limits and to estimate the relative importance of the nuclear interferences.

Experimental

Irradiation

The 19 to 27 MeV $^{11}$B$^{n+}$ and 35 to 46 MeV $^{19}$F$^{m+}$ beams were produced with the tandem Van de Graaff accelerator at the Swiss Federal Institute of Technology in Zürich. The experimental set-up has been described in an earlier paper. Targets were mounted on a holder and irradiated for 30 min in a 120-250 nA cm$^{-2}$ beam. The current was monitored using a small wire mesh ($\approx 57\%$ transmission) placed approximately 15 cm in front of the target. Prior to the sample irradiation, the mesh transmission ($I_{mesh}/I_{target}$) was determined with a Faraday cup placed at the point of target mounting. The beam current was monitored and integrated during irradiation.