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Analysis of Impactor Residues in Tray Clamps from the Long Duration Exposure Facility

Part 1: Clamps from Bay "A" of the Satellite

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Contents

Figures

Acronyms

EDXA	energy dispersive X-ray analysis
FOILS	Facility for Optical Inspection of Large Surfaces
JSC	NASA/Lyndon B. Johnson Space Center
LDEF	Long Duration Exposure Facility
LEO	low Earth orbit
M&D SIG	Meteoroid & Debris Special Investigation Group
SEM	scanning electron microscopy

Introduction

The Long Duration Exposure Facility (LDEF) was placed in low Earth orbit (LEO) in 1984 and was recovered 5.7 years later. The LDEF hosted several individual experiments that were specifically designed to characterize critical aspects of meteoroid and debris environment in LEO. It was realized from the beginning, however, that the most efficient use of the satellite would be to examine the entire surface for impact features. In this regard, particular interest has centered on common exposed materials that faced in all LDEF pointing directions. Among the most important of these materials is the tray clamps. Therefore, in an effort to understand the nature of particulates in LEO and their effects on spacecraft hardware better, we are analyzing residues found in impact features on LDEF tray clamp surfaces. This catalog presents all data from clamps from Bay A of the LDEF. Subsequent catalogs will include clamps from succeeding bays of the satellite.

All LDEF experiment trays were held in place by a series of aluminum clamps (fig. 1). Each clamp had an exposed area of approximately 58 cm^2. One-half of the LDEF tray clamps have been archived at the NASA/Johnson Space Center (JSC) by the Meteoroid & Debris Special Investigation Group (M&D SIG). These archives are available for study by qualified investigators. For more information regarding these materials, contact the JSC Curatorial Facility. The remaining half of the clamps are being studied by the LDEF Materials Space Investigation Group.

Optical scanning of clamps—beginning with Bay A Row 01 and working through the entire satellite—is being documented in the Facility for Optical Inspection of Large Surfaces (FOILS) at JSC to locate and document impact features that are as small as 30 microns. These impacts are then examined by scanning electron microscopy/energy dispersive X-ray analysis (SEM/EDXA) to characterize further those features that contain appreciable impactor residue. Based upon the bulk composition of those residues and using criteria developed at JSC[2], we have made a preliminary discrimination between micrometeoroid- and space debris-containing impact features. These data are in a catalog format that includes (1) an optical photograph of each clamp, (2) a secondary electron image of the impact, (3) associated parameters such as impact feature size, (4) an EDXA plot of the residue, (5) impactor origin (if applicable), and (6) a curatorial number that will facilitate requests for specific impact features by interested investigators. All results are being input into the M&D SIG computerized database, which documents all LDEF meteoroid and debris results and is accessible to investigators via SPAN, Internet, or modem.[2]

LDEF Tray Clamps

LDEF experiment trays were held in place by a series of chromic-anodized aluminum (6061-T6) clamps (fig. 2). Eight clamps were used to attach the experiment trays on each of the 12 sides of the LDEF, while experiment trays on the Earth and space ends were held in place by 12 clamps. Each clamp was fastened to the spacecraft frame using three stainless-steel hex bolts. Clamps exposed an area of approximately 58 cm^2 each (4.8 cm $\times$ 12.7 cm $\times$ 0.45 cm, minus the bolt coverage). All 774 LDEF clamps were surveyed for impact features greater than 0.5 mm in diameter during experiment tray deintegration at the NASA/Kennedy Space Center. Some 337 out of 774 LDEF tray clamps have been archived by the M&D SIG in the Curatorial Facility at JSC and are available for scientific examination by qualified individuals.

A clamp numbering scheme was devised that would provide hardware location information with respect to its position within a particular bay (fig. 2). From the labeling scheme, it can be seen that a clamp occupying position 1 of Bay A02 would be identified by the label A02-C01, with A02 indicating the experiment location of Bay "A" and Row "02," and with C01 interpreted as "C" for the clamp and "01" being the clamp number. Each clamp uses a Cartesian coordinate system to reference impact locations on exposed surfaces. The X and Y coordinates were measured in millimeters using a standard origin assigned by the M&D SIG at the lower left corner of each clamp (fig. 3).

Results

Each of the clamps was optically scanned. All impact features greater than 40 microns (and some as small as 30 microns) were labeled and their position was documented. After scanning, an optical photograph was taken of the clamp illustrating each of the impact features located optically. Clamps that contained no detectable impact features are not included in this catalog. These clamps are A02-C01, -C03, -C05, -C06, and A03-C06 and A04-C06, which are still available to individuals for further analysis. SEM/EDXA was then conducted on each feature that has been identified optically. Not all features identified are high-velocity impacts. In some cases, because of resolution limits during optical inspection, clamp manufacturing flaws, handling flaws, and contamination spots were mistakenly identified as impact features. During SEM/EDXA analysis, these features were properly identified and labeled as such (figs. 4 through 7). These features include craters and pits caused during the manufacturing and handling of the clamps. When clamp edges were ground

smooth, abrasive grit could become trapped between the clamps when they were stacked one upon the other. Movement caused these grains to roll and leave tracks and pits.[1] The secondary electron images were obtained at 30 deg from normal. Because the initial intent of this survey was to identify only those impacts that contained large amounts of micrometeoritic residue, a minimal amount of time was spent analyzing for small or unobvious projectile remnants. The EDX spectra obtained were qualitative but served to provide a basic classification of either "natural" or "manmade" for residues, although many of the impacts are classified as having no definite origin. Clamp impacts that have no detectable residues by techniques were used to display a composition typical of the clamp aluminum alloy. Although the exact composition differed slightly from example to example, these spectra were recogniz ibly the same. For this reason, a standard clamp aluminum alloy spectrum is displayed in figure 8. Throughout the catalog, features containing no detectable residue will reference this spectra. The criteria used to determine impactor origin are described at length in another publication.[2] Figure 9 summarizes the survey residue classification results for our clamp analyses in histogram form. We believe that further, more detailed analyses will undoubtedly uncover evidence of impactor residues in many of the presently unclassified impact craters. The support of such subsequent analysis is our primary objective in publishing this catalog. A factor hindering our analyses is the fact that the clamps have all been anodized, a process that deposits a surface layer of Si, Mg, and S—all of which are important elements for the discrimination of natural from manmade materials. This contamination has been properly considered as background, but in many instances its presence makes characterization of the residues extremely difficult.

References

[1] Redd, Cecil; and Zolensky, Mike E. (1991) *Too exposed* (Scientific correspondence). *Nature 352*, page 289.

[2] Zolensky, M. E.; Zook, H.; Atkinson, D.; Coombs, C.; Dardano, C.; See, T.; Simon, C.; and Kinard W. (1993) *Interim report of the Meteoroid and Debris Special Investigation Group*. From *Proceedings of the 2nd LDEF Post-Retrieval Conference*, eds., A. Levine and W. Kinard. In press (available from the LDEF Project Office at NASA/Langley, mail stop 404).

FIGURE 1. A photograph taken of the trailing/Earth edge of the Long Duration Exposure Facility (A03) during the STS-32 retrieval mission. The arrows placed on the photograph show the location of clamps used to hold experiment trays in place during their exposure in low Earth orbit. The circles or round patches on some of the clamps are test paint coupons. Several possess impact craters but, because of surface contamination impact residues, these were not characterized here.

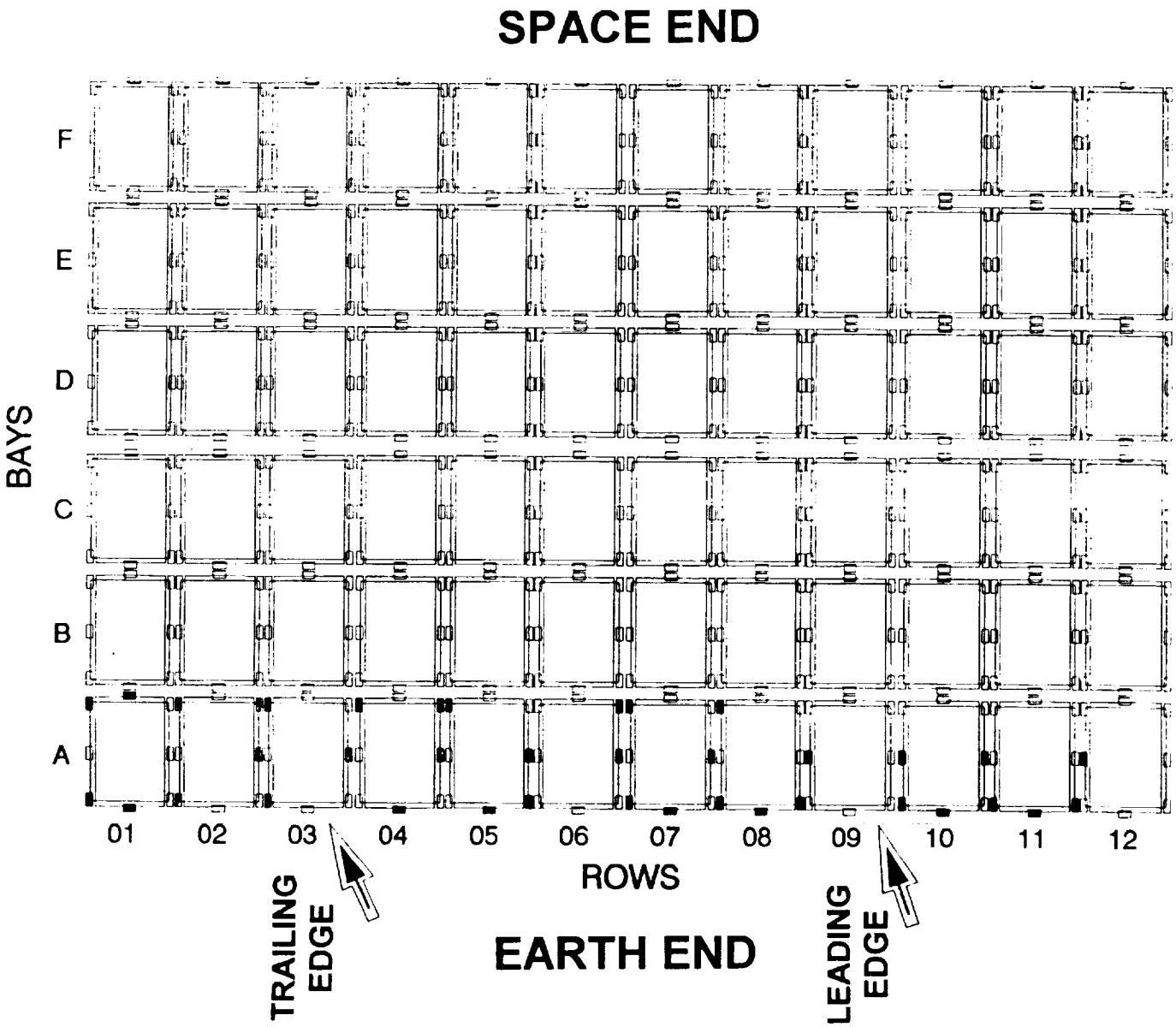


FIGURE 2. This diagram illustrates the numbering scheme used to label LDEF experiments by Bay and Row location. LDEF was a cylinder-shaped satellite with Row 1 being adjacent to Row 12, Bay A being on the Earth end and Bay F positioned on the space facing end. While in orbit, Row 9 was in the ram direction or the leading edge, with Row 3 being on the trailing edge of motion. Clamps examined for this report are designated by dark fill.

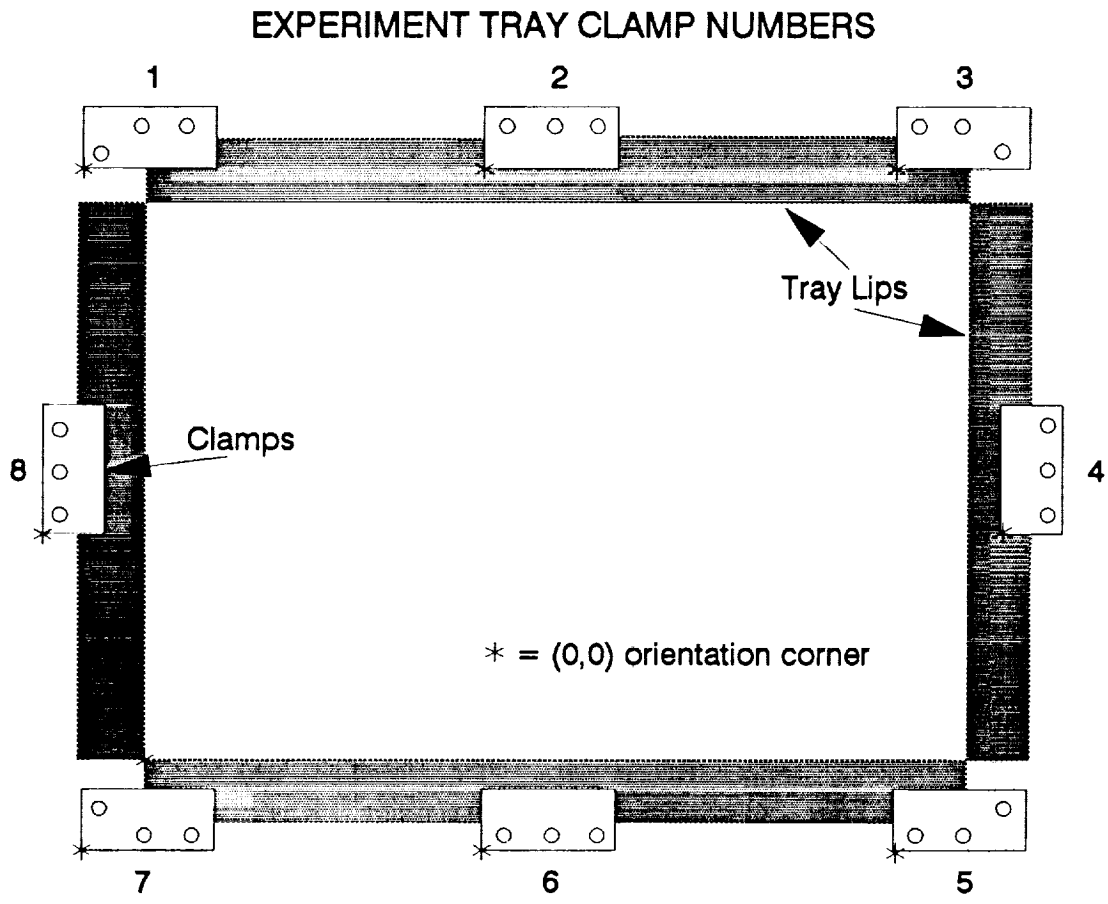


FIGURE 3. This schematic illustrates the numbering plan and positioning layout of tray clamps and bolt holes on the LDEF satellite. The bolt hole locations help to align the clamp to find the lower left orientation corner (0,0).

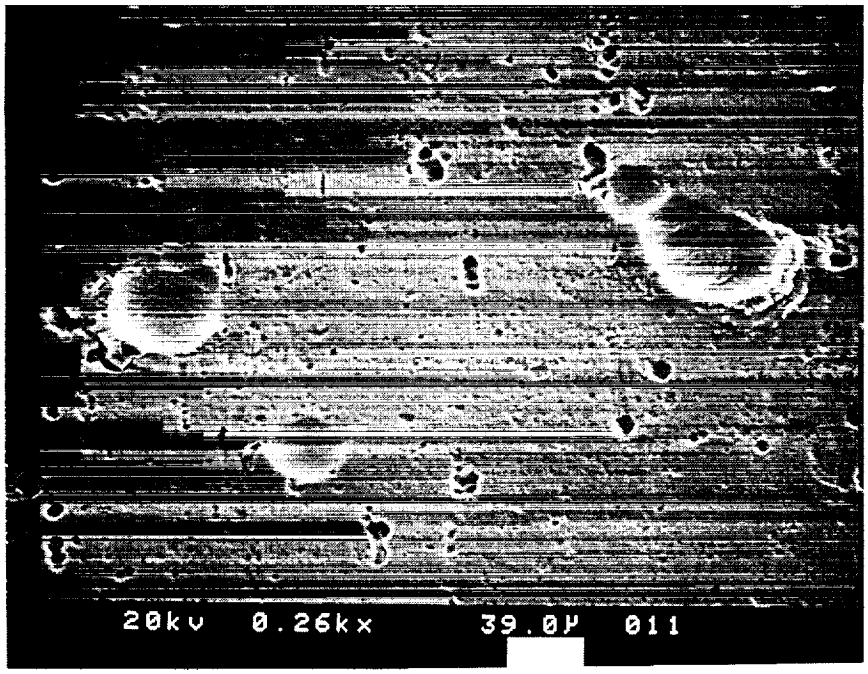


FIGURE 4. Secondary electron image of several impact-like flaws detected on the clamp surface. Features like these are quite abundant and are thought to be flaws acquired during the manufacturing and handling of the clamps.

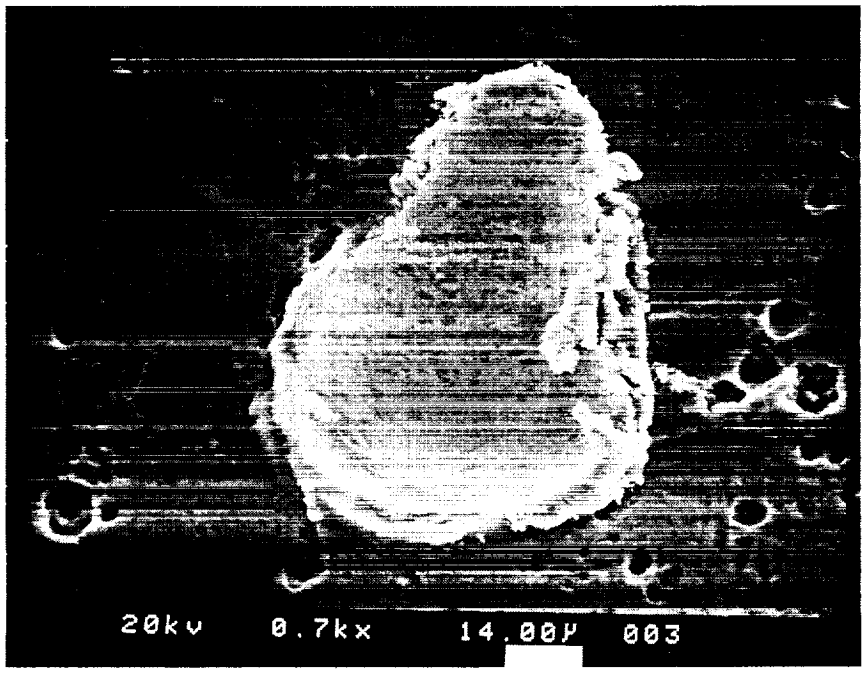


FIGURE 5. This very low velocity feature is similar to that in figure 3. During high magnification optical examination, this specimen appeared to be a typical hypervelocity impact crater. SEM examination determined its probable origin to be a handling flaw.

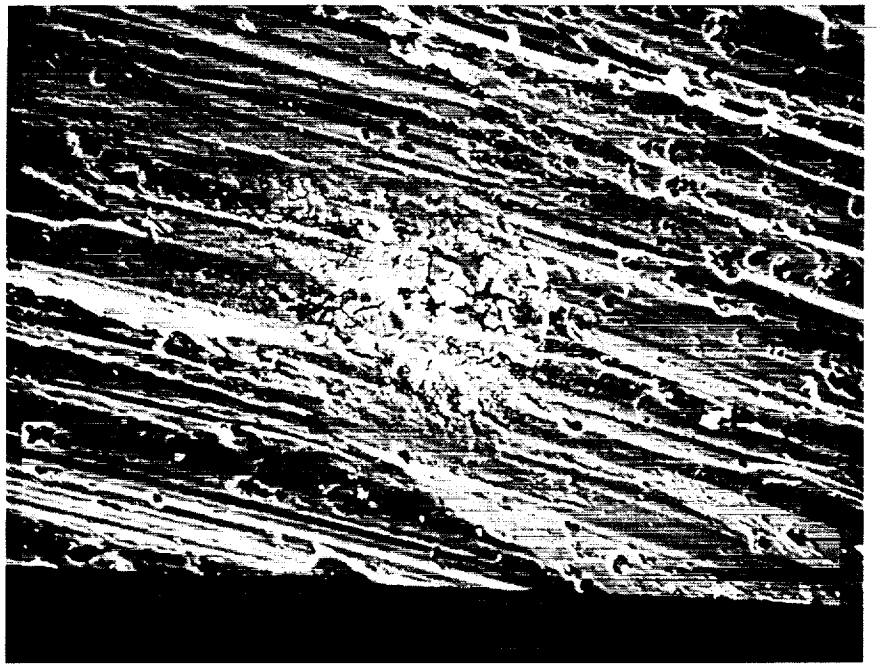


FIGURE 6. Surface flaws from chromic-anodization were also present on many of the clamps. The chemistry of such a flaw shows high levels of Si, Mg, Cl, and S, which are easily recognized by SEM/EDX analysis.

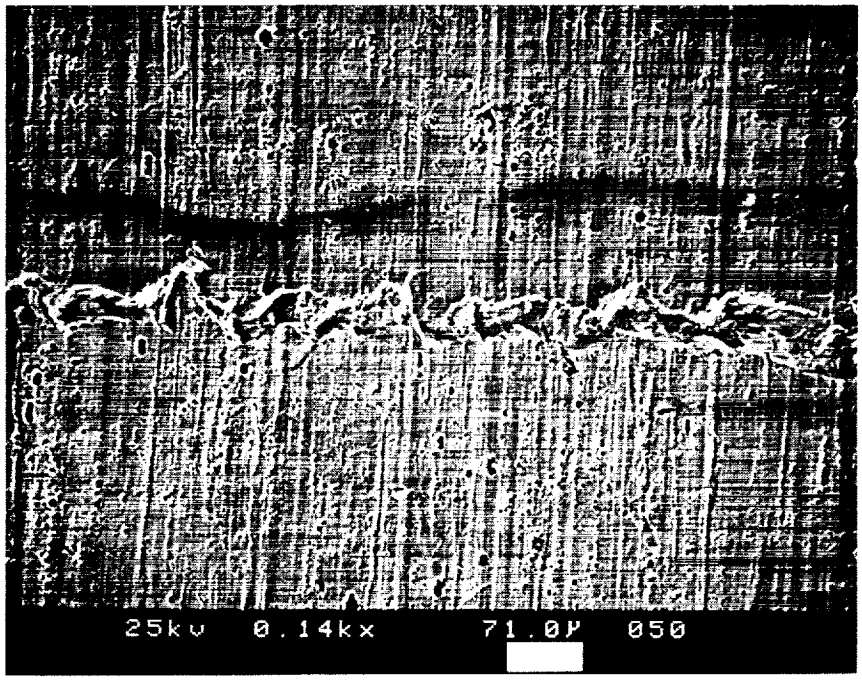


FIGURE 7. An example of a linear, repetitive-type pattern that occurred during the fabrication or preflight handling of clamps and other LDEF hardware.[1]

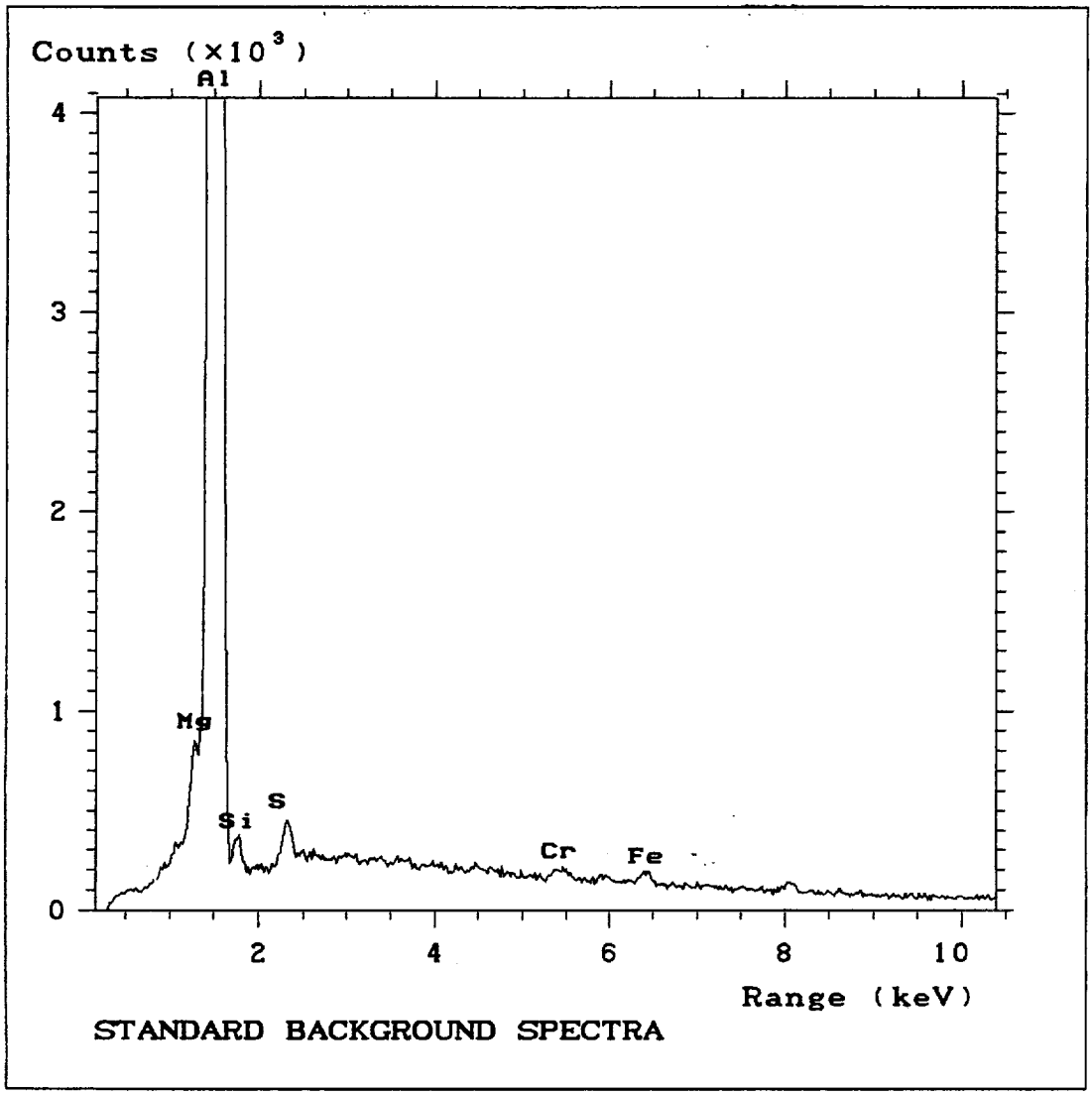


FIGURE 8. Many of the impacts analyzed by SEM/EDXA had no residue detected. These impact features are categorized as being unknown in origin. During analysis, no peaks above background were discernible; only the typical clamp materials were present. This spectra illustrates the typical composition of impacts with no detectable residue found.

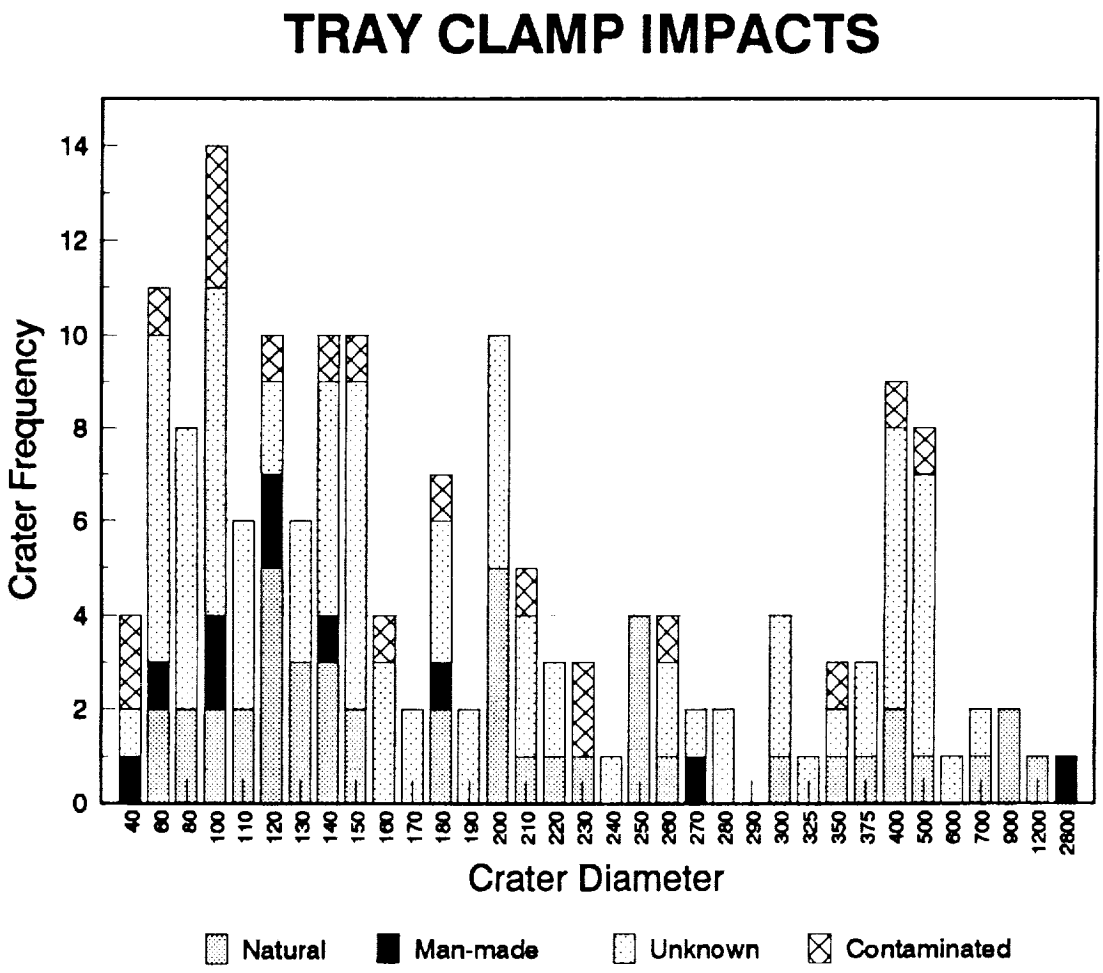
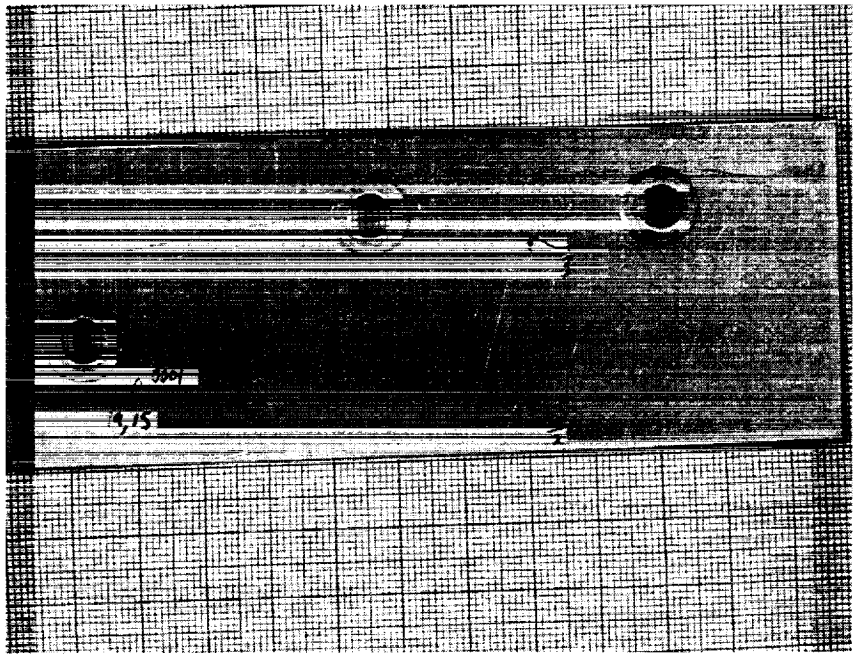


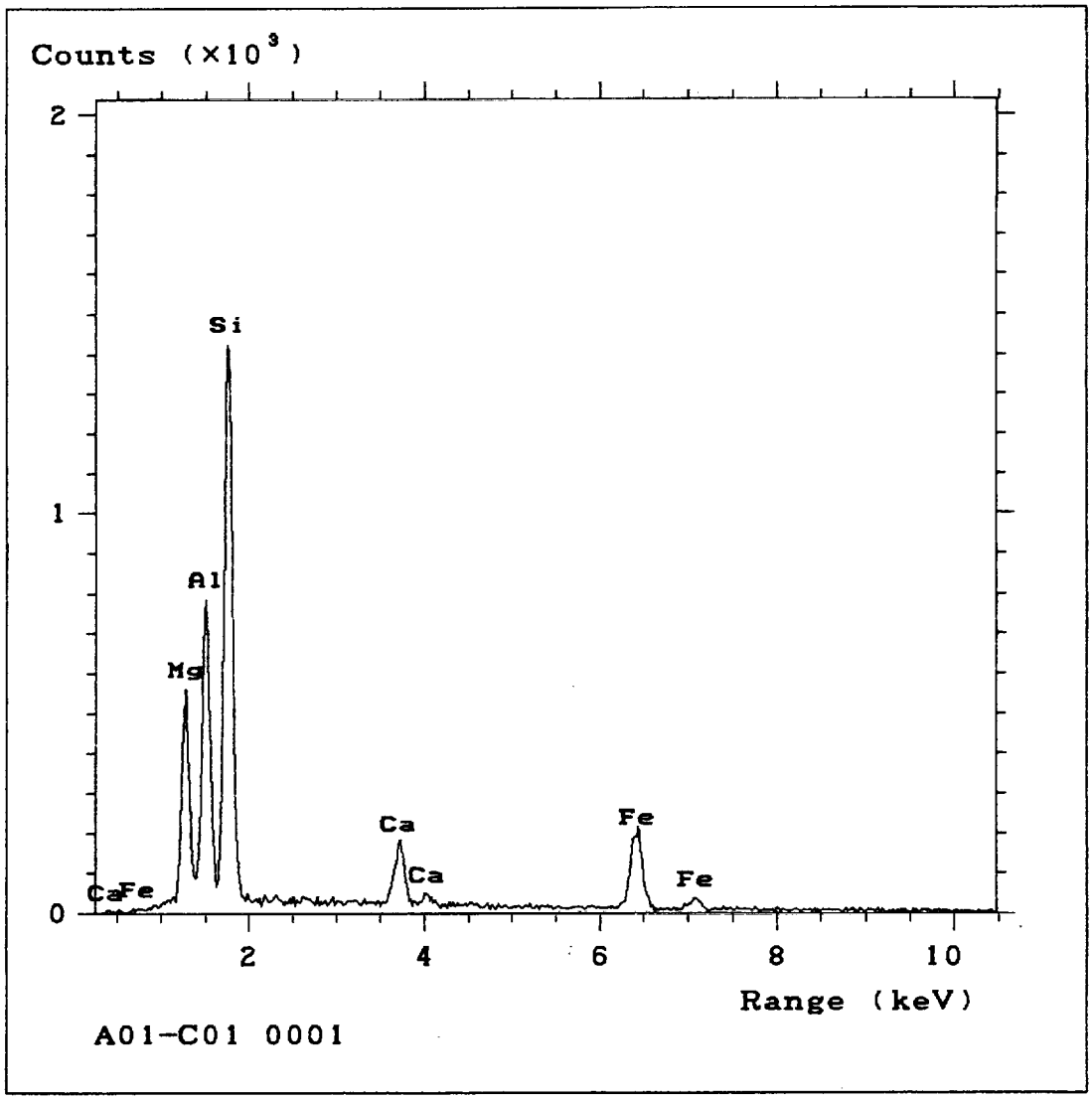
FIGURE 9. Histogram illustrating the determined impactor type versus the impact crater diameter. Samples listed as being contaminated contain significant amounts of foreign material and projectile remnants that are not easily identified.

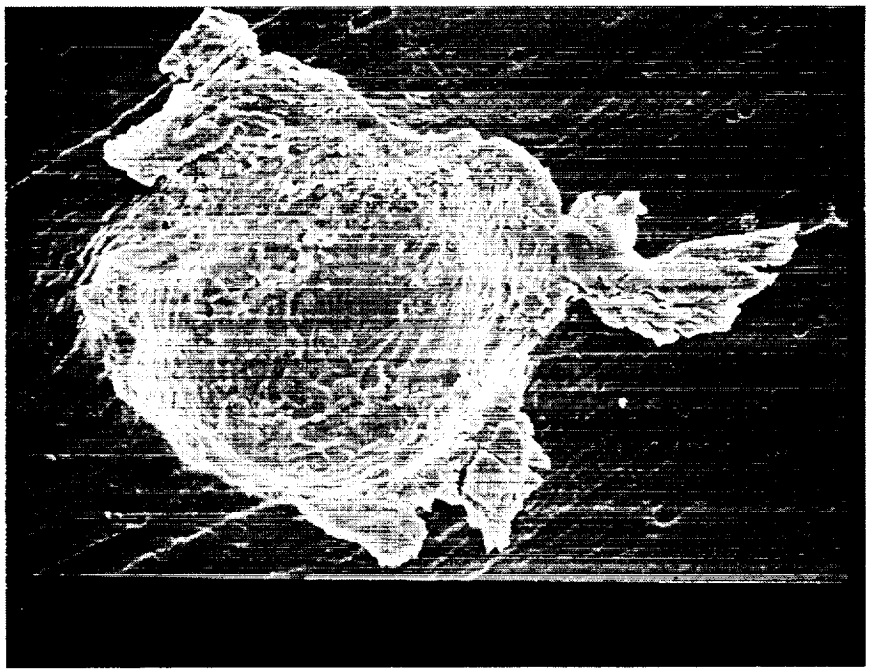
Appendix A

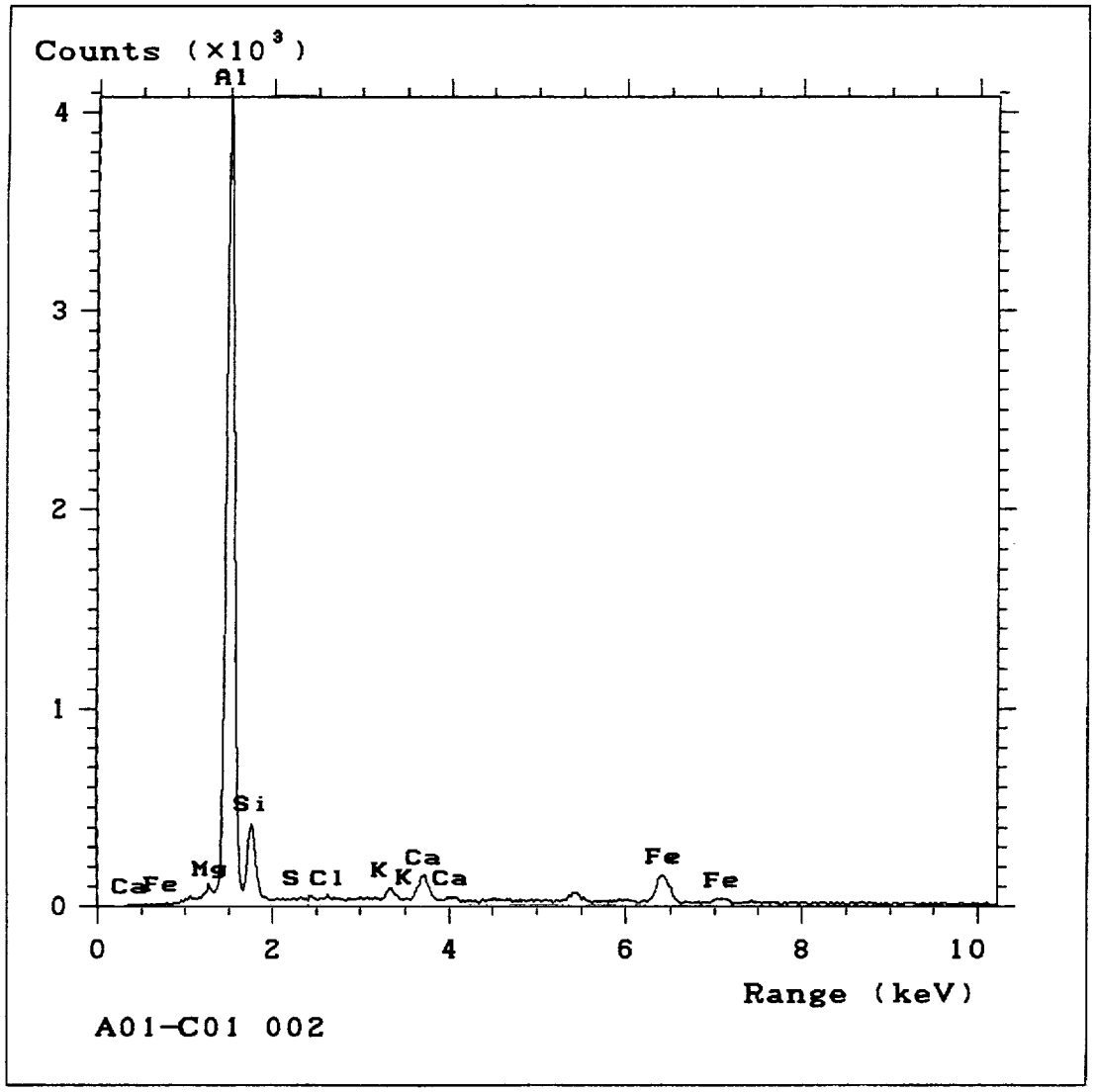
CLAMP NUMBER A01 C01

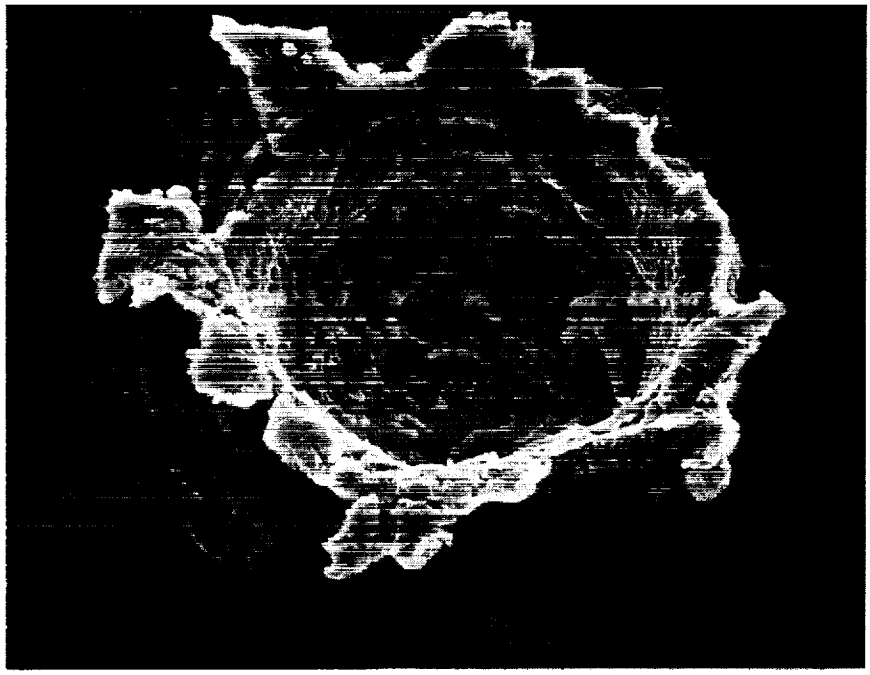
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	200	Mg, Si, Ca, Fe
002	100	Trace
003	100	Unkown

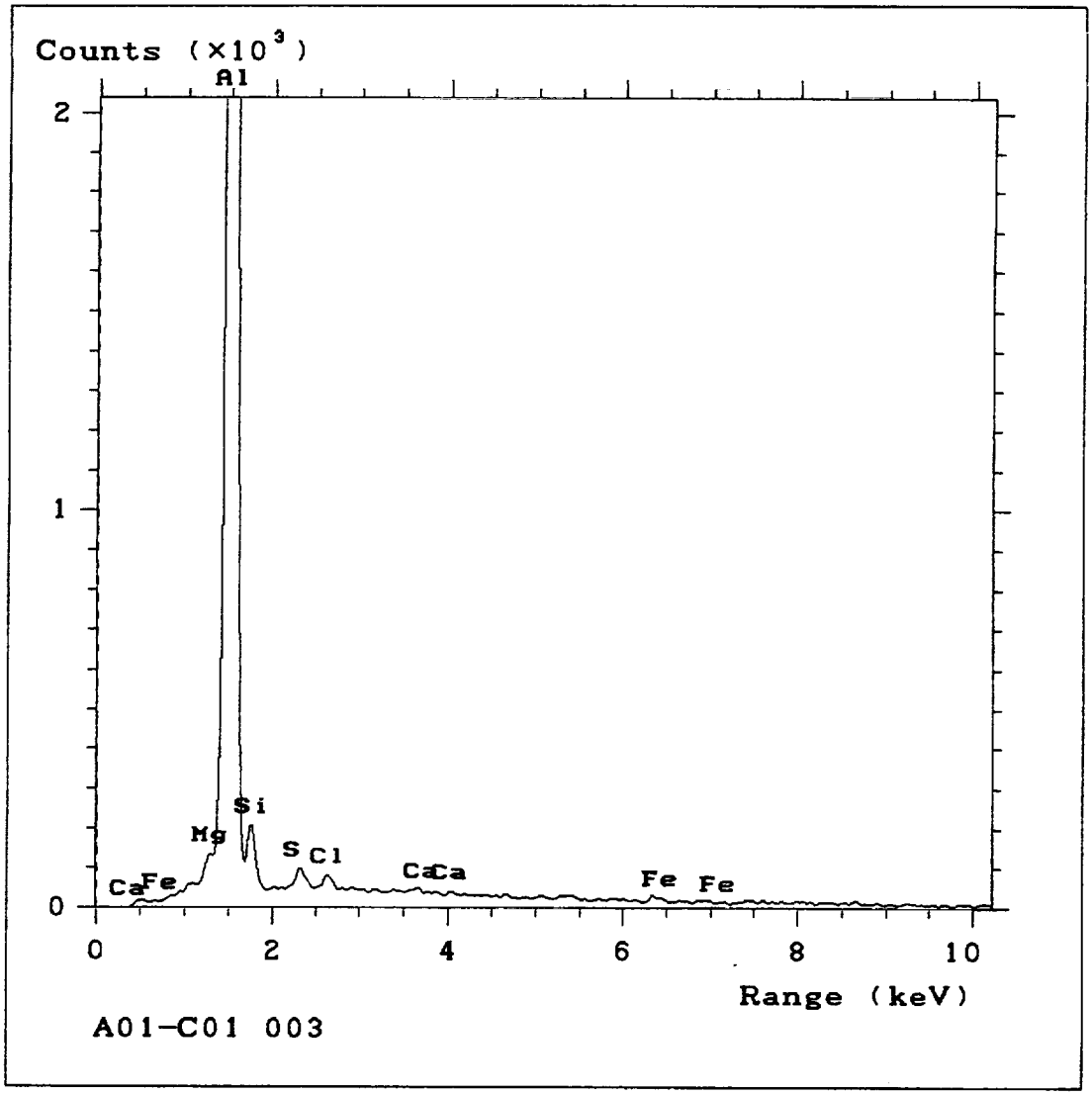


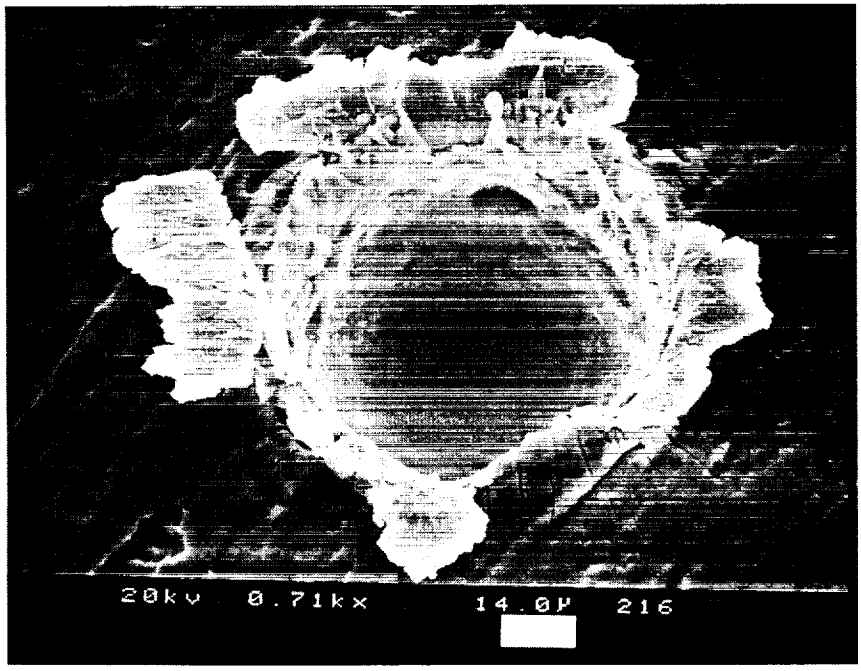

Counts (×10³)
2
1
0
Si
Al
Mg
Ca
Fe
Ca
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A01-C01 0001




Counts (×10³)
Al
Si
Ca
Fe
Mg
S Cl
K
K
Ca
Ca
Fe
Fe
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
A01-C01 002

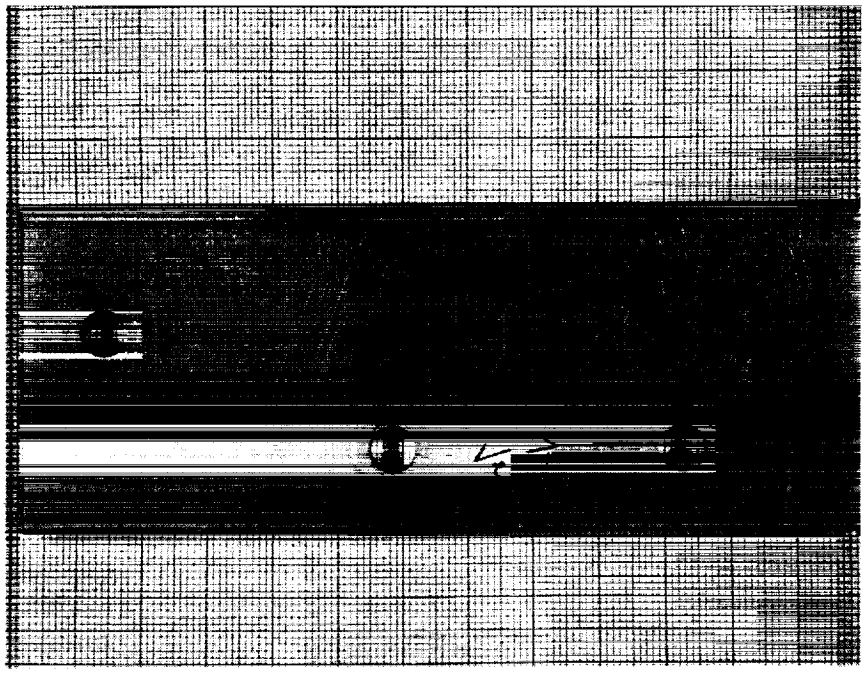


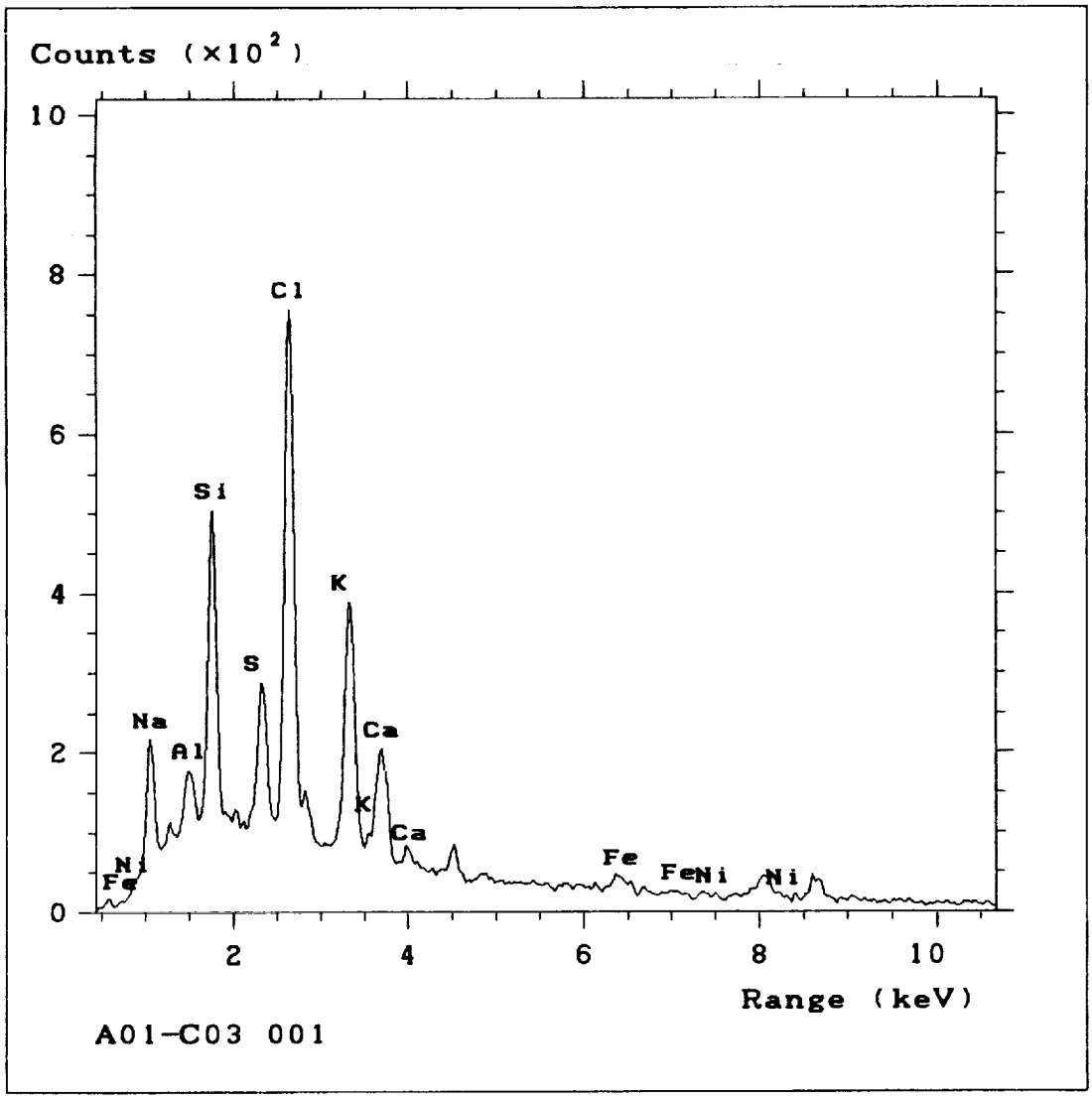

Counts (×10³)
Al
2
1
0
Si
Mg
S
Cl
Ca
Fe
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A01-C01 003

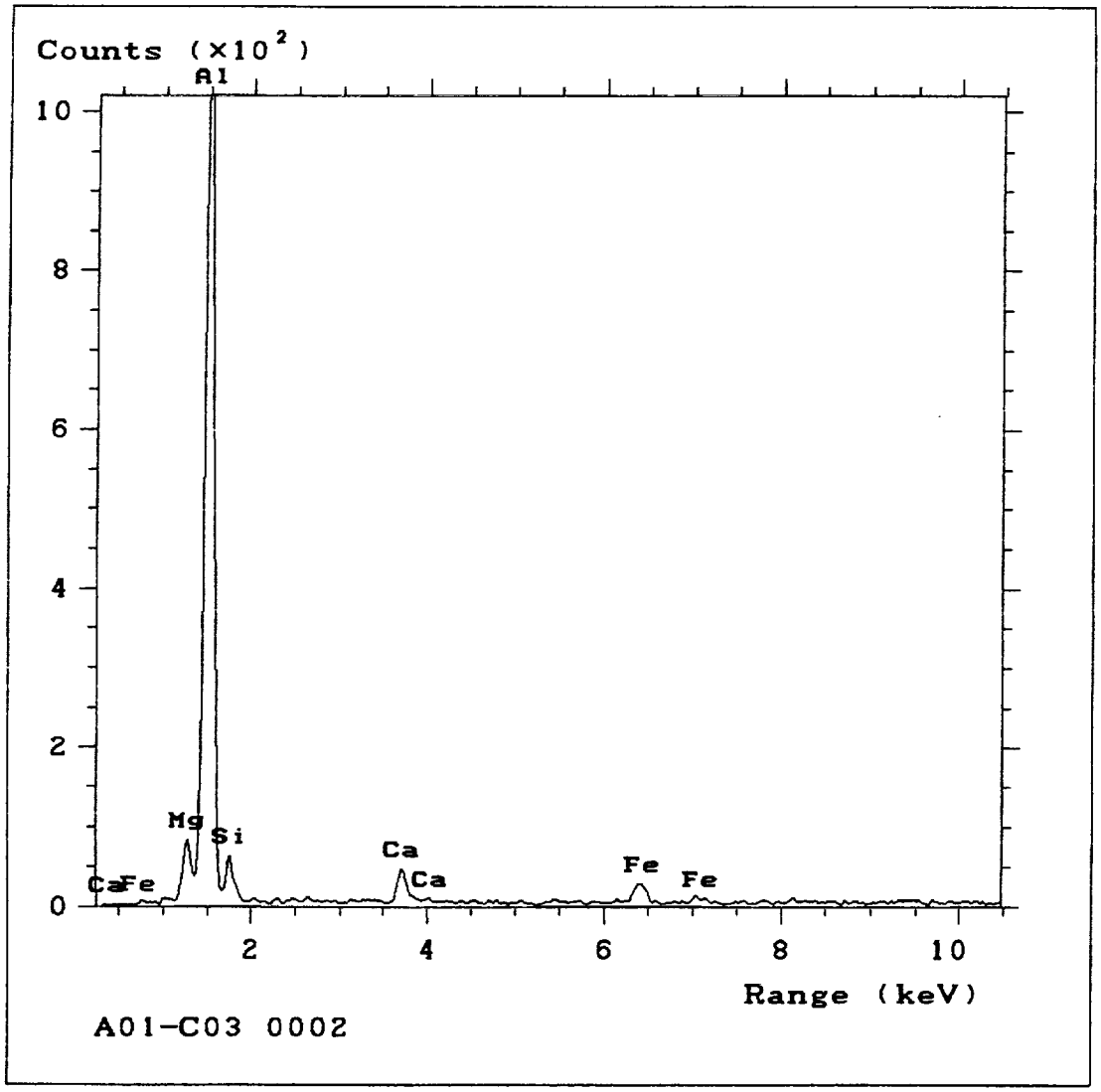

20kv 0.71kx 14.0μ 216

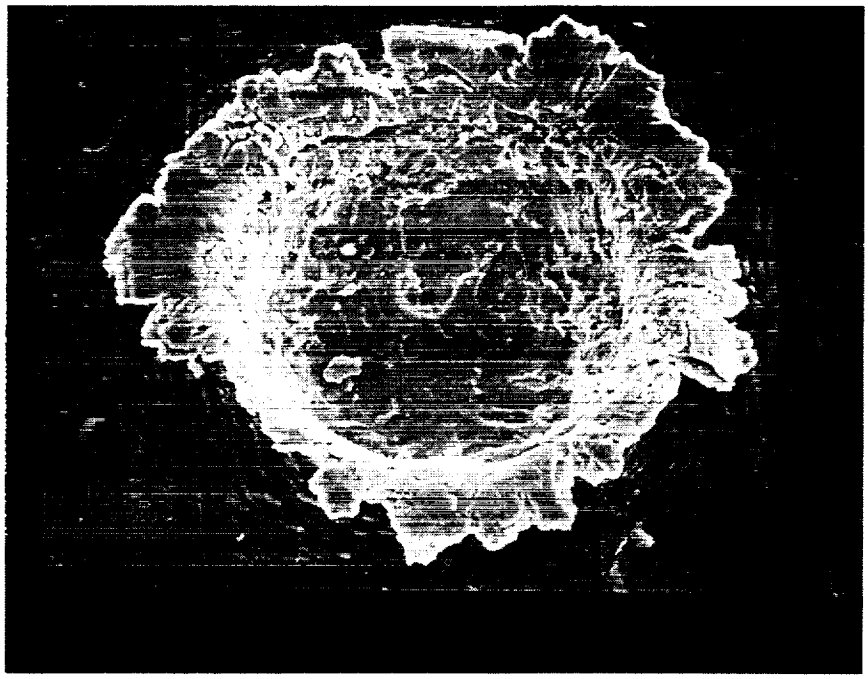
CLAMP NUMBER A01 CO3

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	120	Contamination
002	230	Mg, Si, Ca, Fe



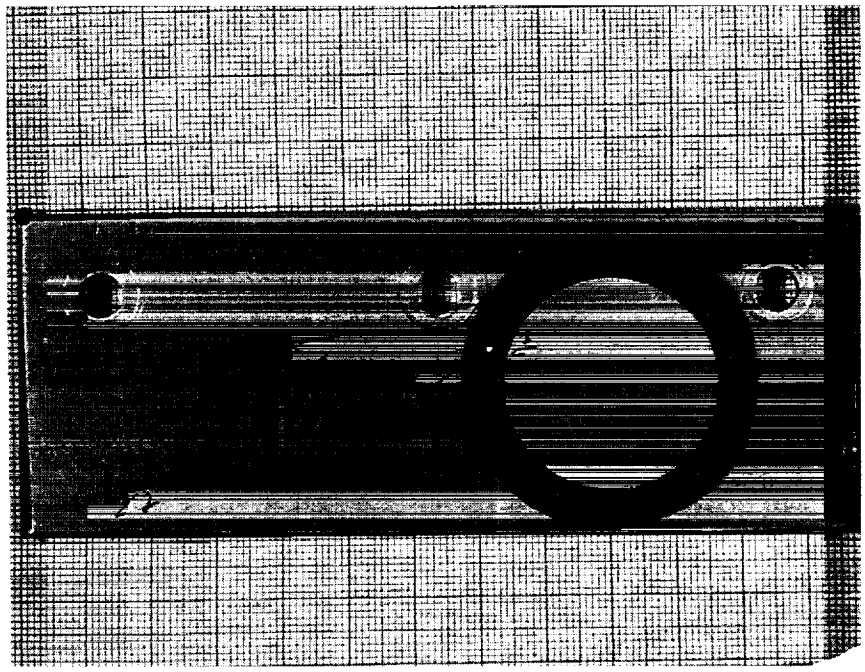

Counts (×10²)
10
8
6
4
2
0
Cl
Si
K
S
Na
Al
Ca
K
Ca
Fe
Ni
Fe
FeNi
Ni
2
4
6
8
10
Range (keV)
A01-C03 001

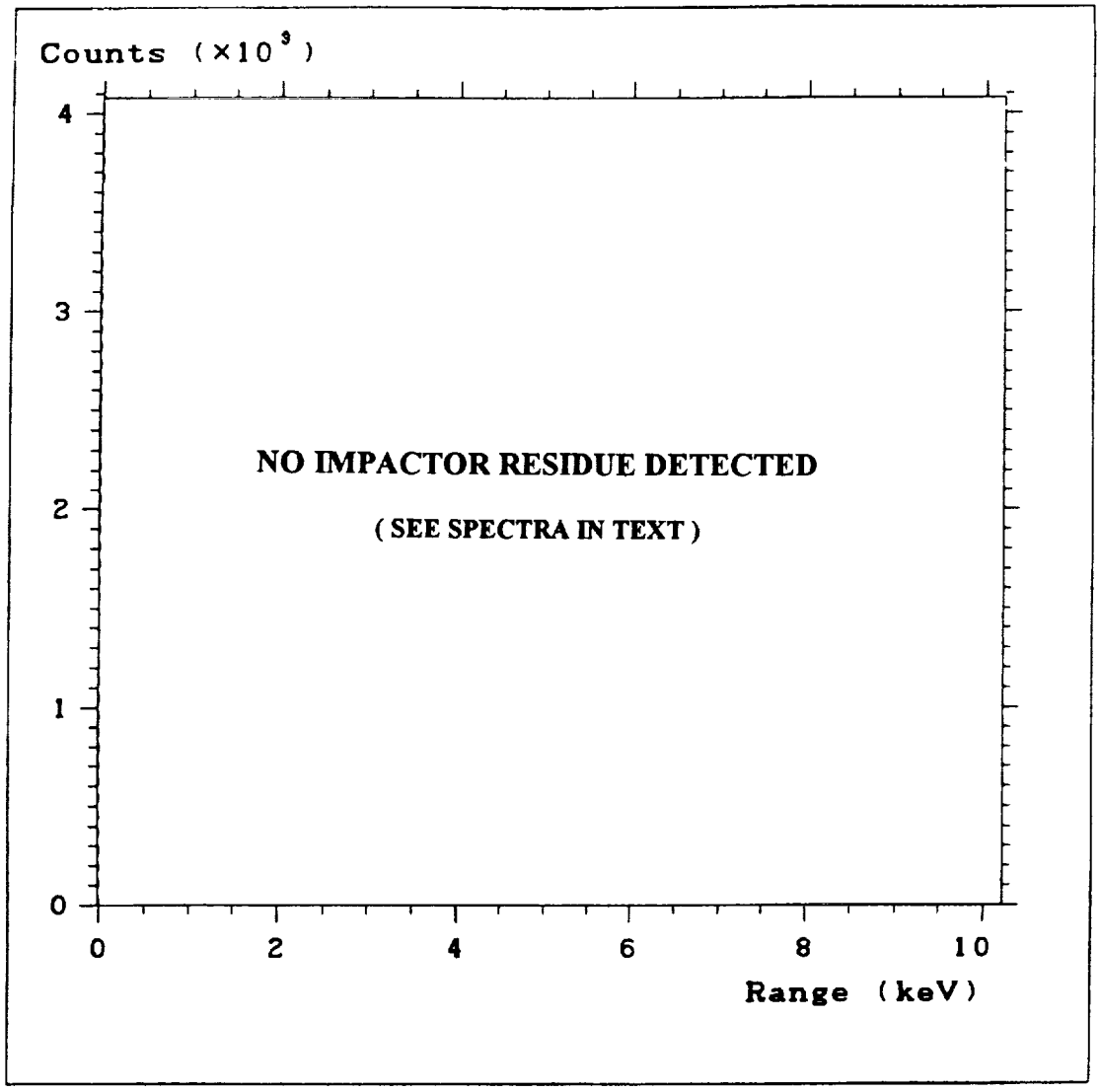

Counts (×10²)
Al
10
8
6
4
2
0
Mg
Si
Ca
Fe
Ca
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A01-C03 0002

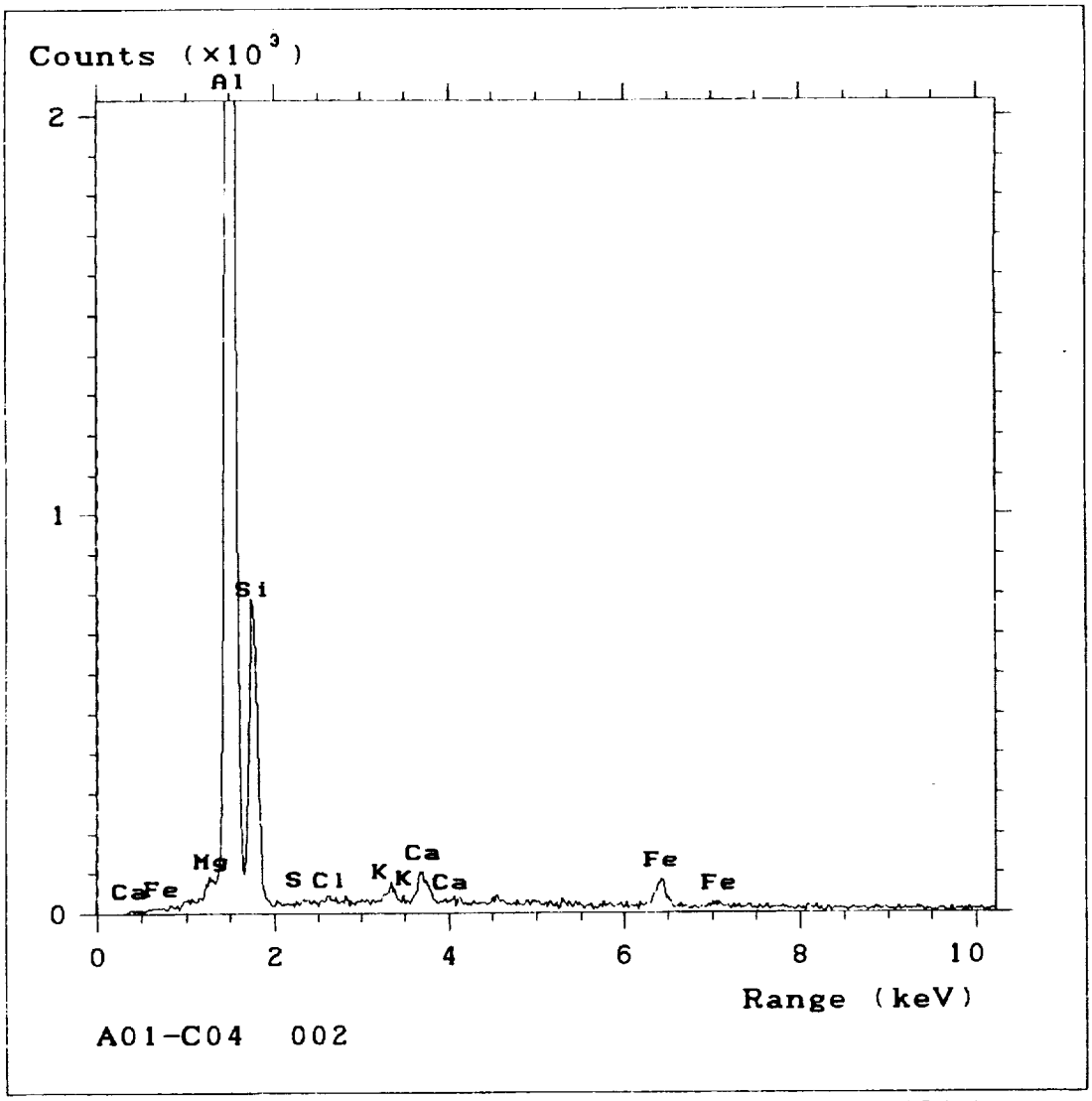


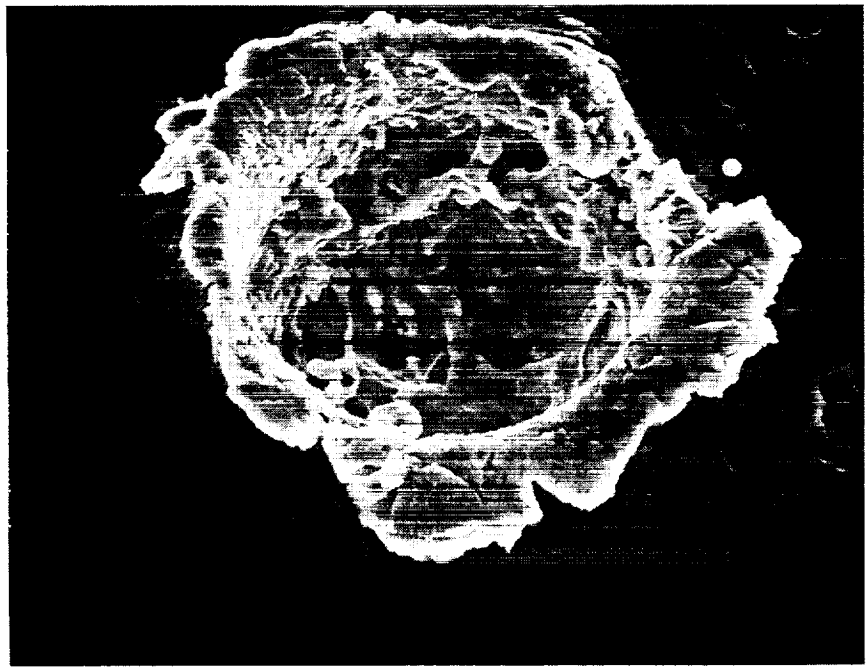
CLAMP NUMBER A01 C04

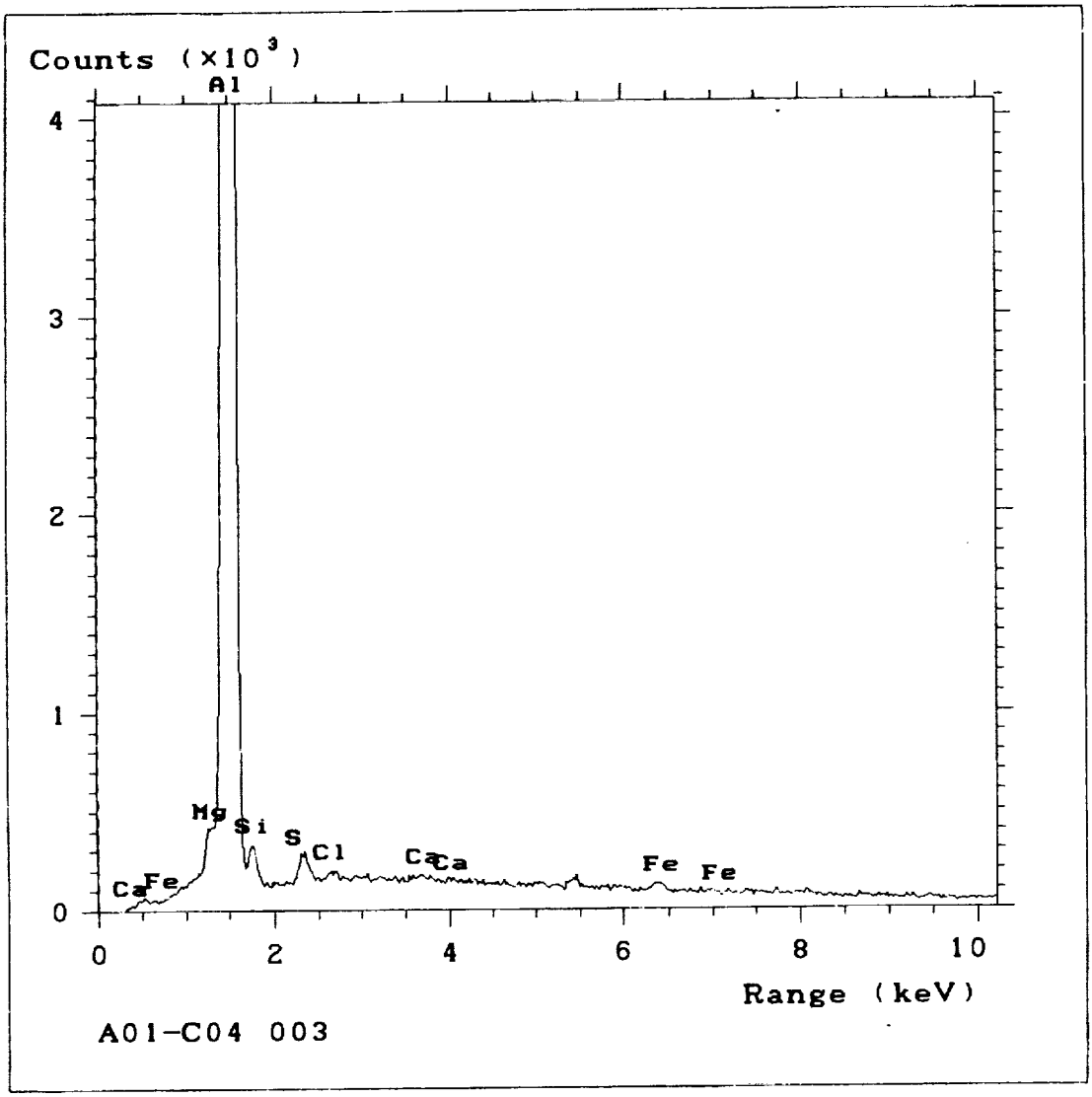
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	100	Paint Patch
002	180	Trace
003	140	Unknown

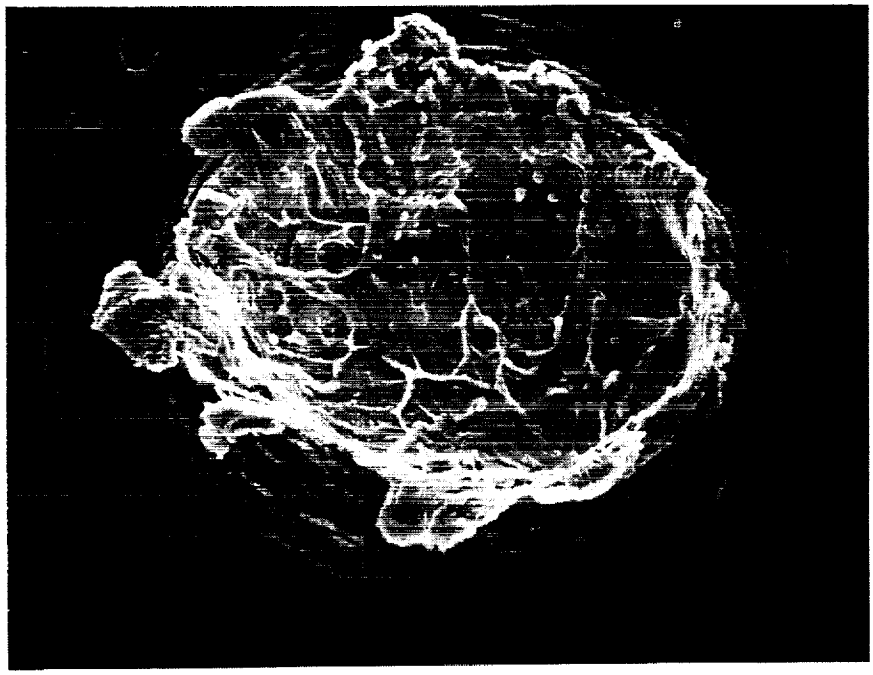



Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


Counts (×10³)
Al
Si
Mg
Ca
Fe
S Cl
K K
Ca
Fe
Fe
Ca
2
1
0
0
2
4
6
8
10
Range (keV)
A01-C04 002

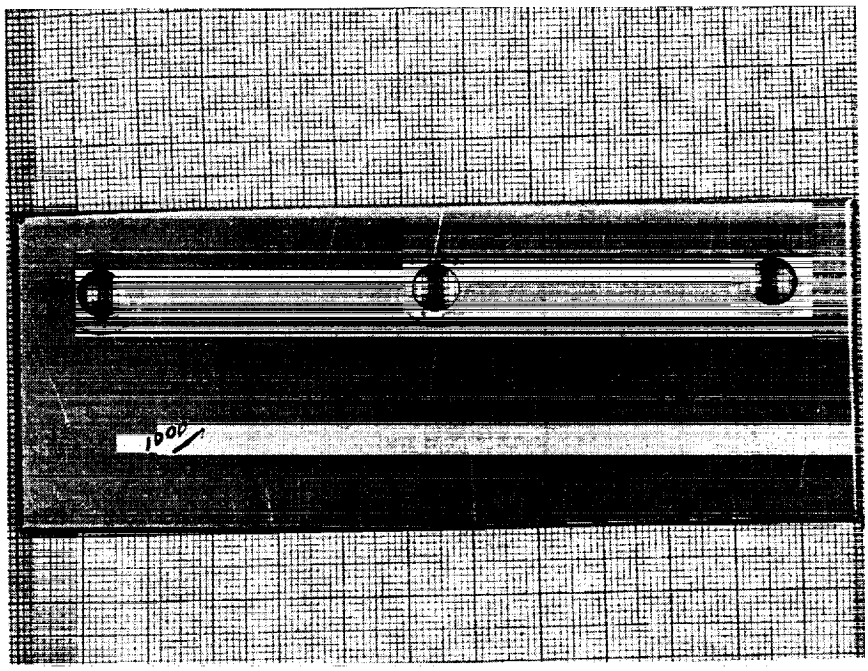


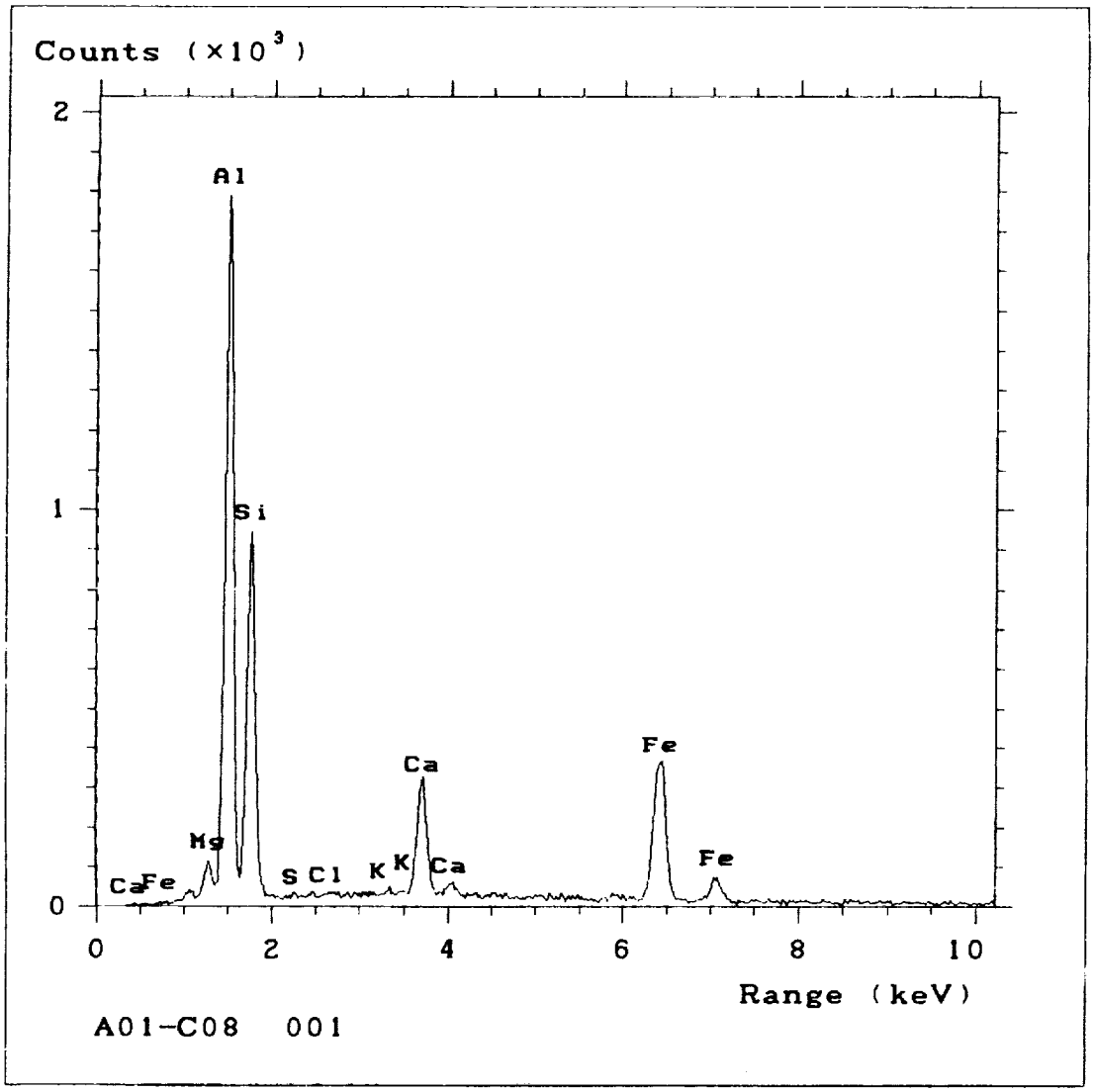

Counts (×10³)
Al
Mg
Si
S
Cl
Ca
Ca
Ca
Fe
Fe
Fe
0
1
2
3
4
0
2
4
6
8
10
Range (keV)
A01-C04 003

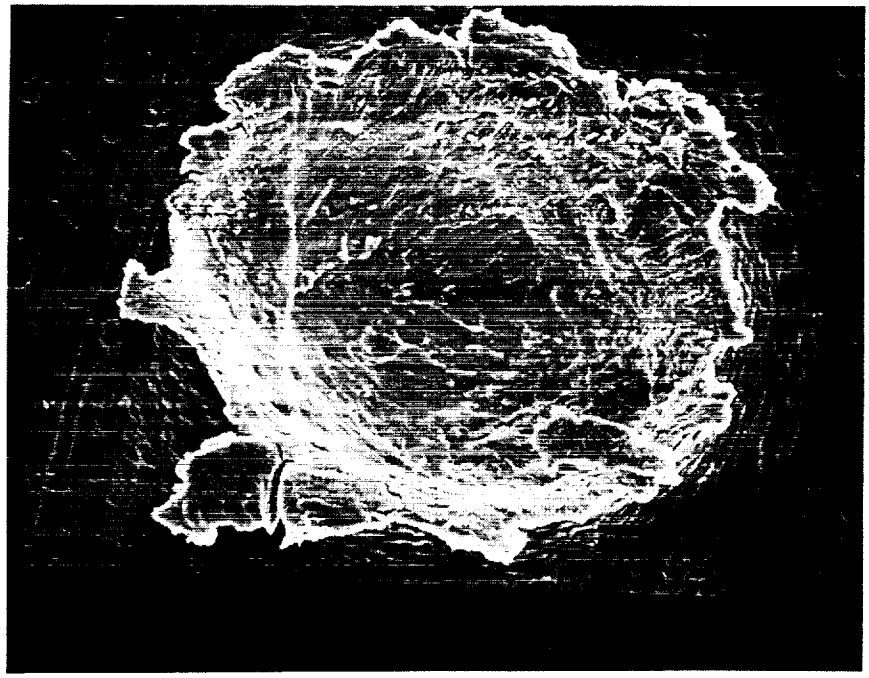


CLAMP NUMBER A01 CO8

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	370	Mg, Si, Ca, Fe

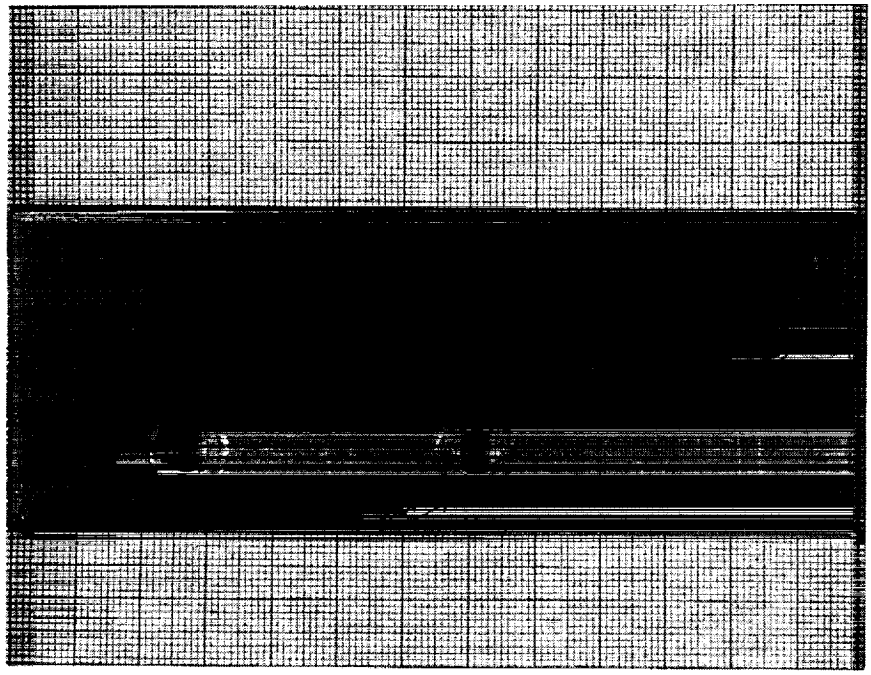


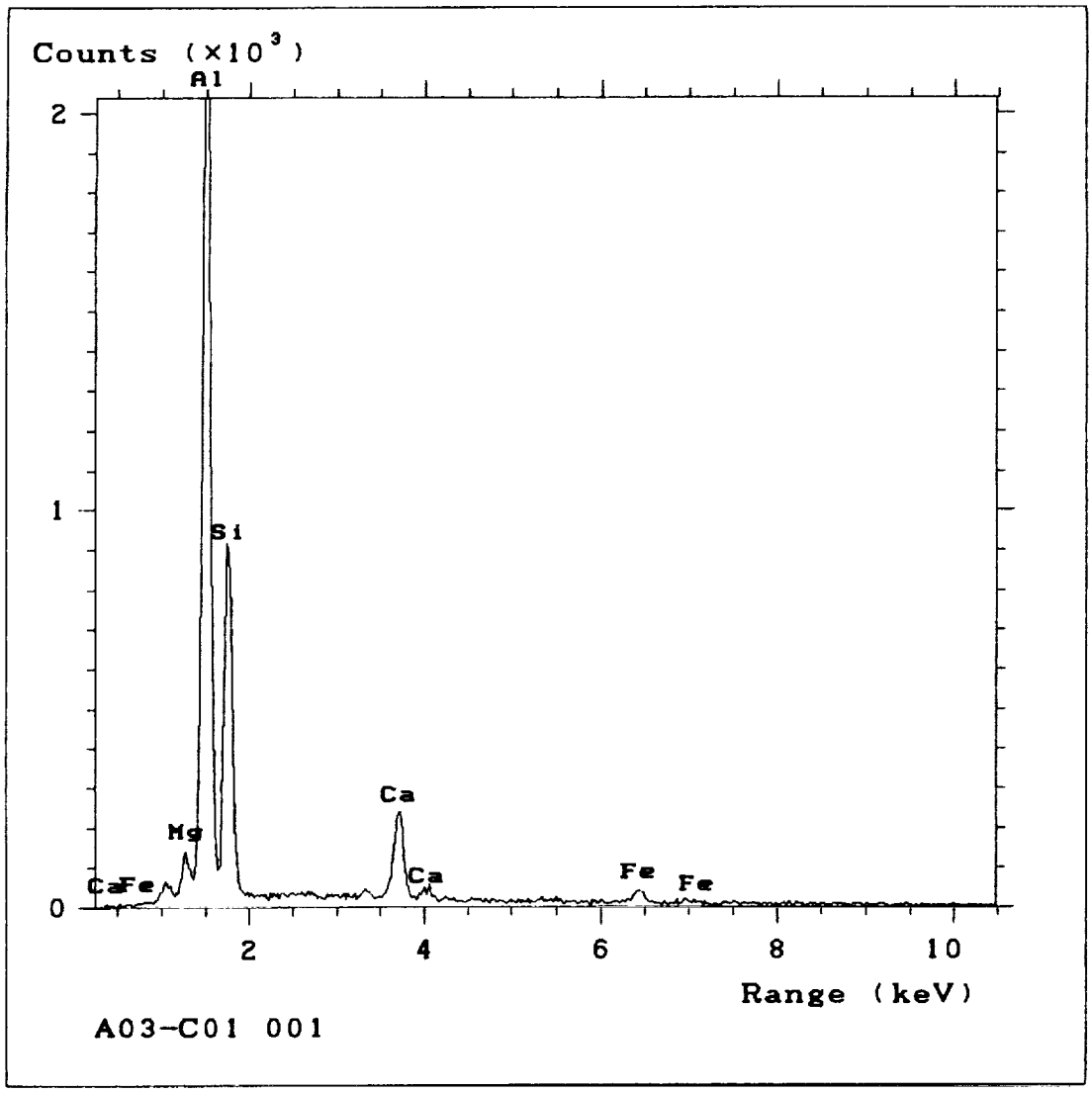

Counts (×10³)
2
1
0
Al
Si
Mg
Ca
Fe
S Cl
K K
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A01-C08 001

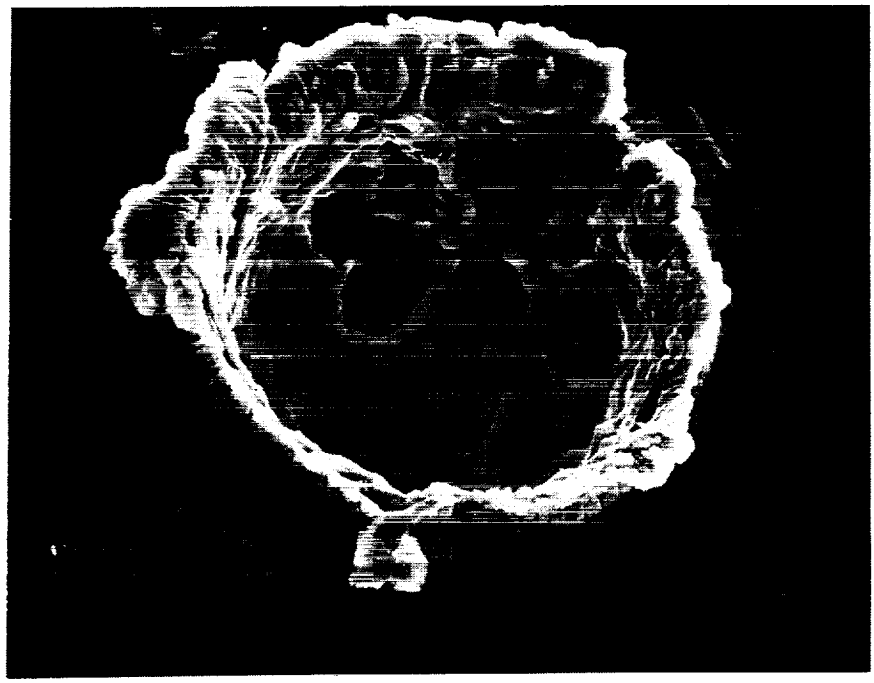


CLAMP NUMBER A03 CO1

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	150	Mg, Si, Ca, Fe

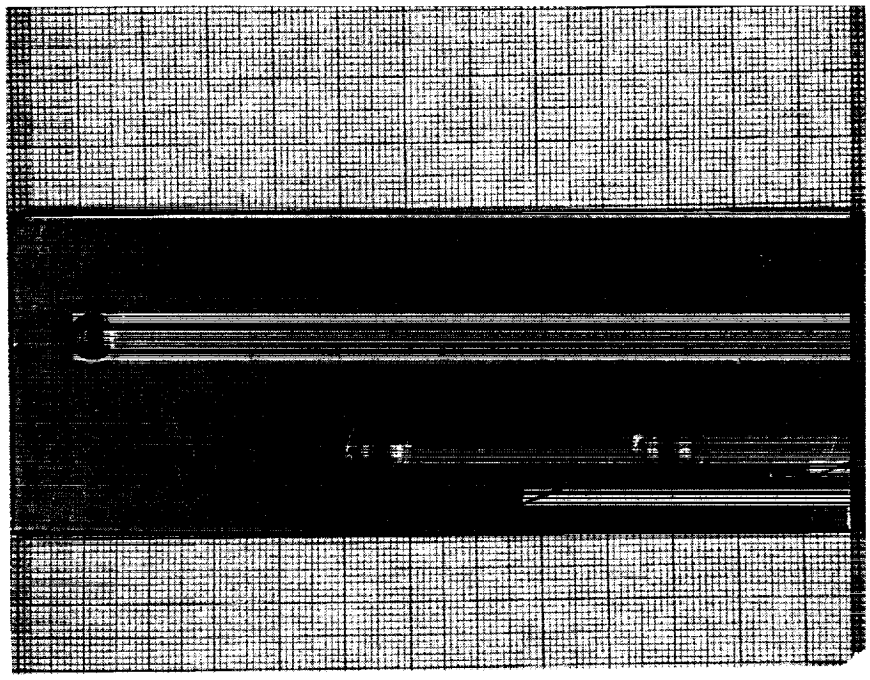


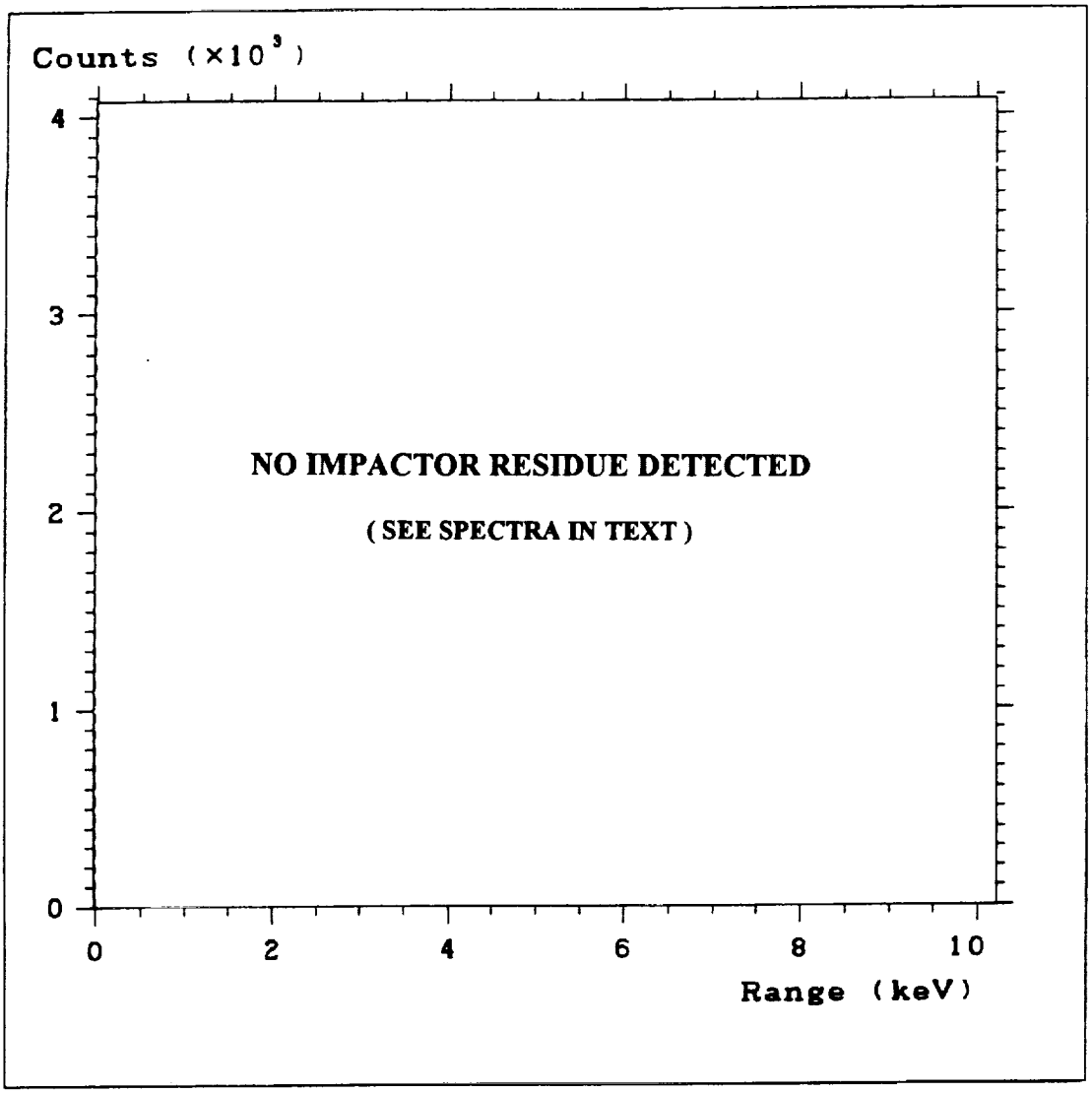

Counts (×10³)
Al
Si
Mg
Ca
Ca
Fe
Fe
Fe
2
1
0
2
4
6
8
10
Range (keV)
A03-C01 001

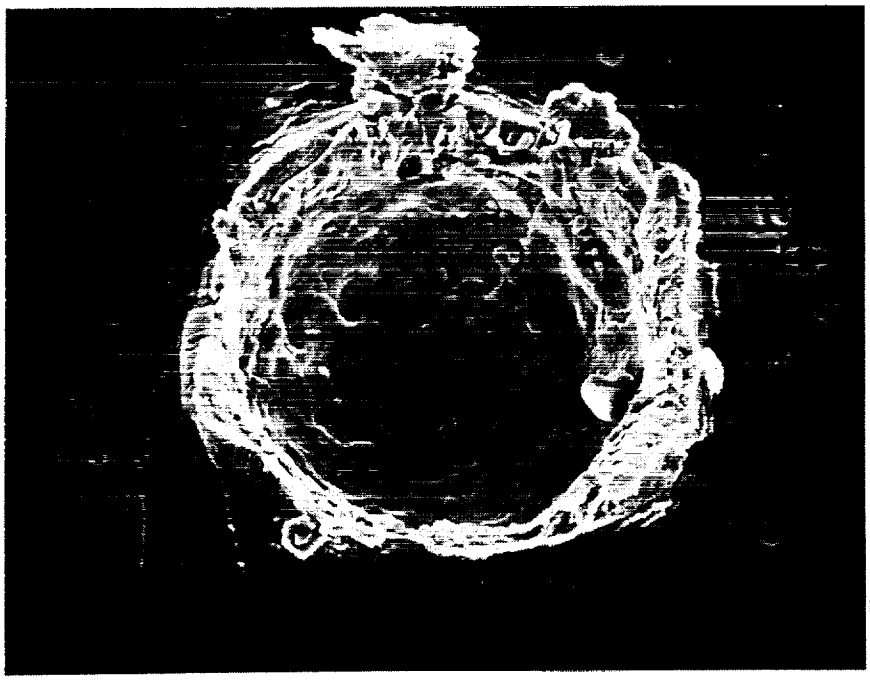


CLAMP NUMBER A03 CO3

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	220	Unkown




Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)



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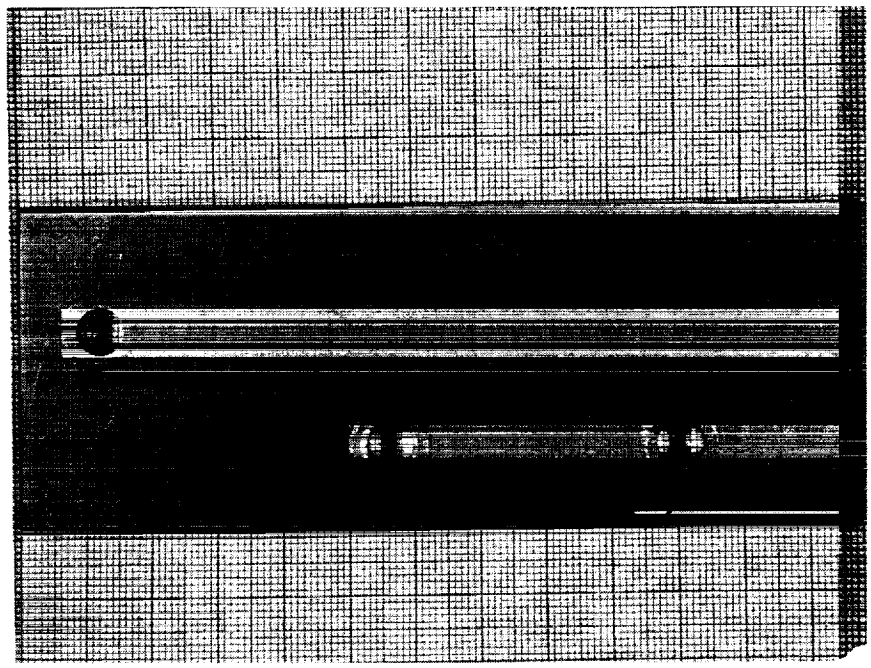
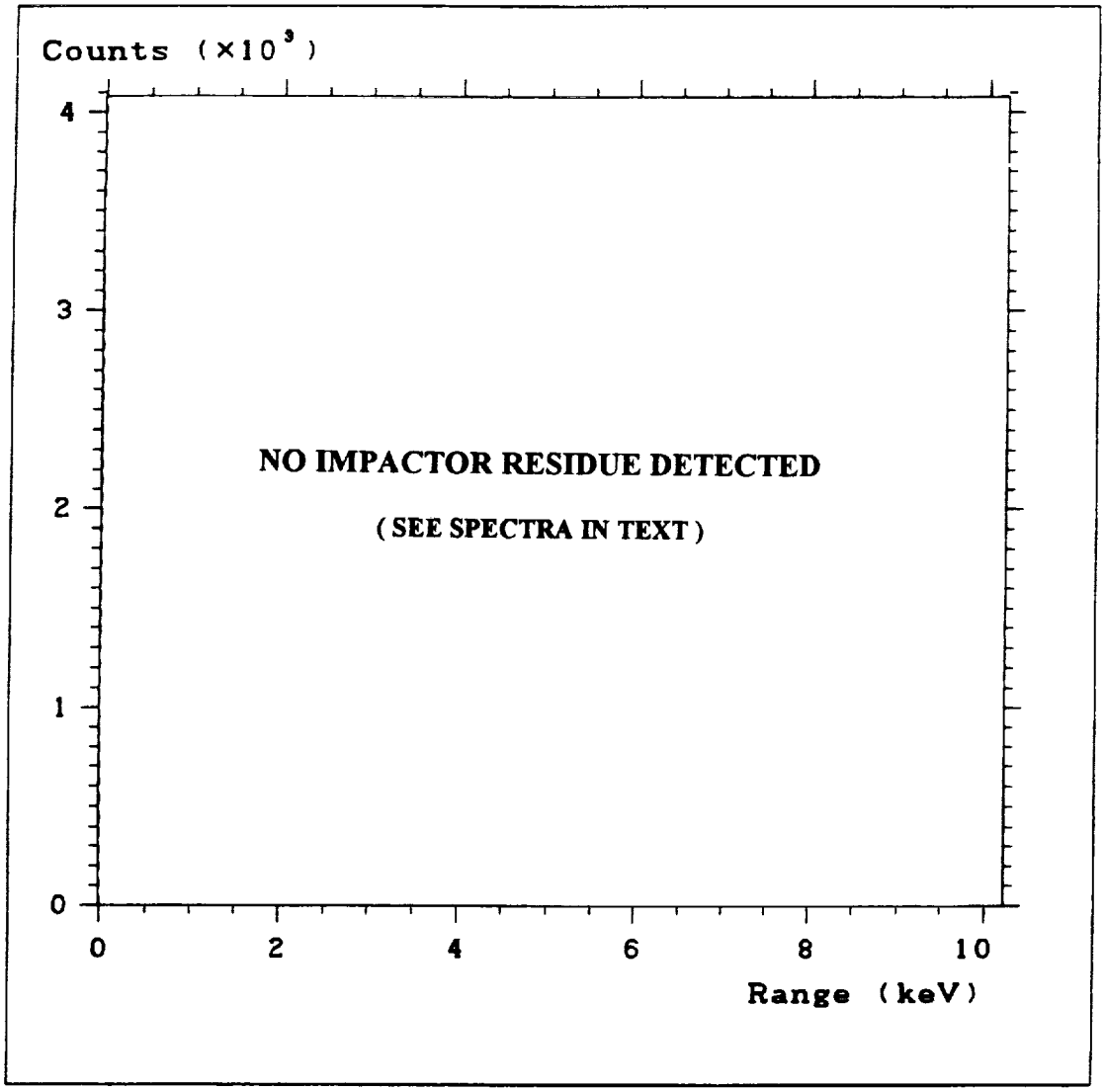
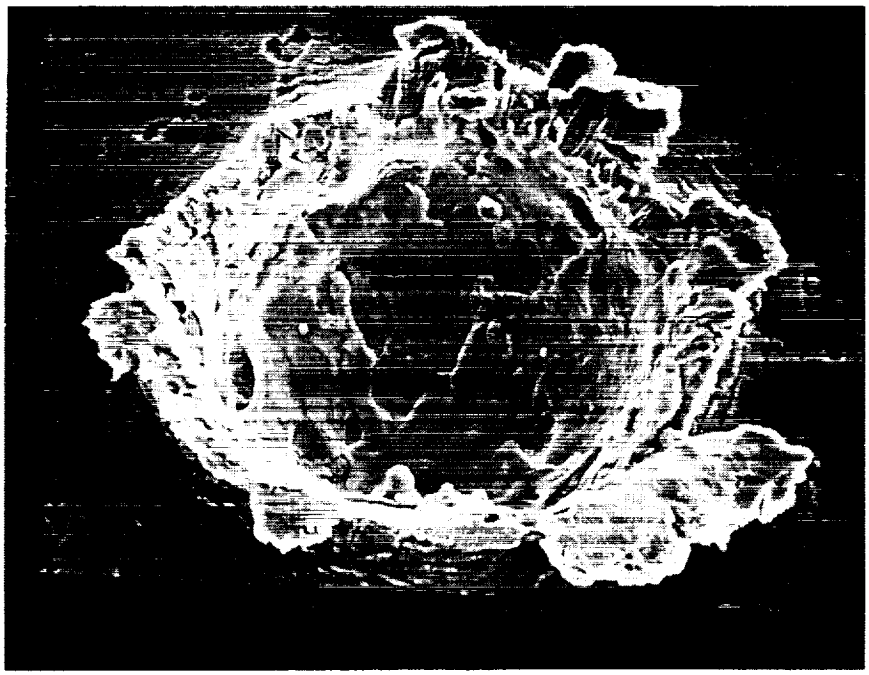
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	260	Unkown

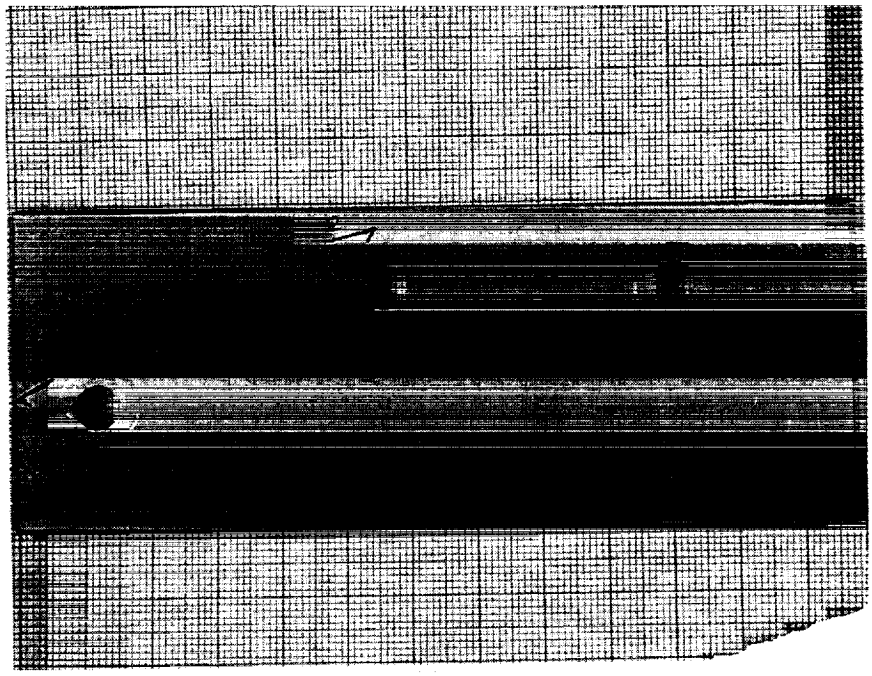


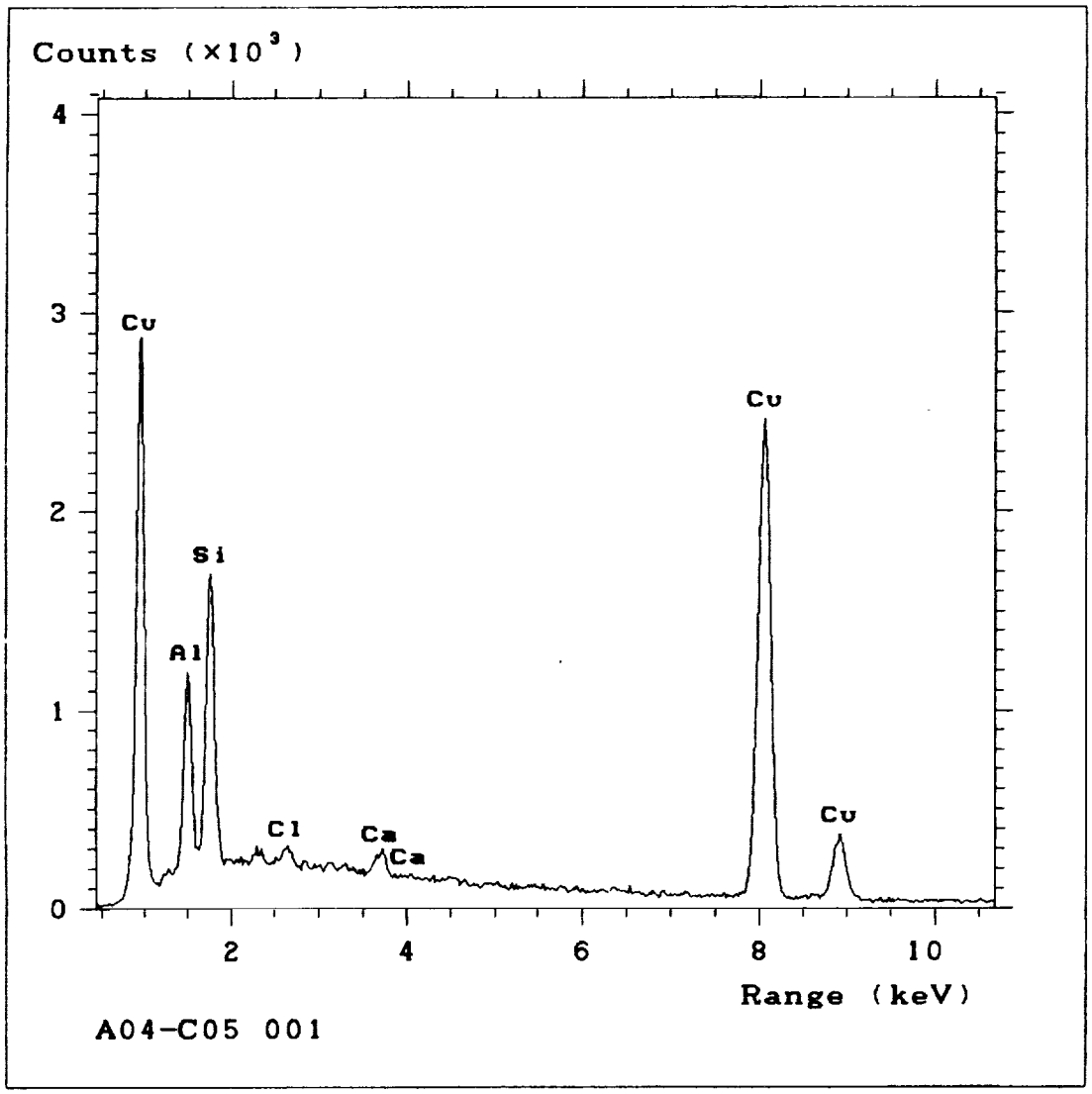

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

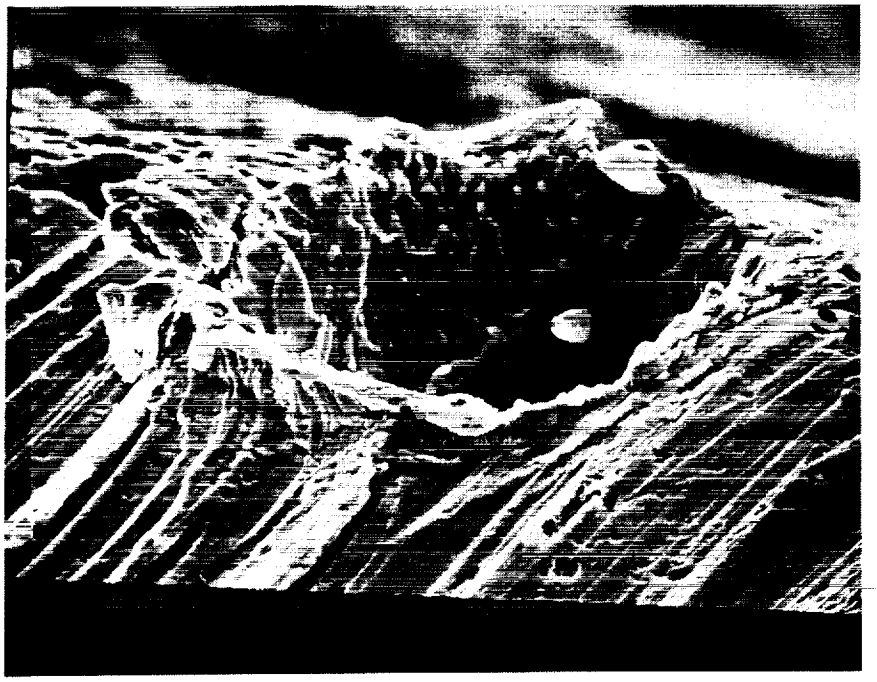


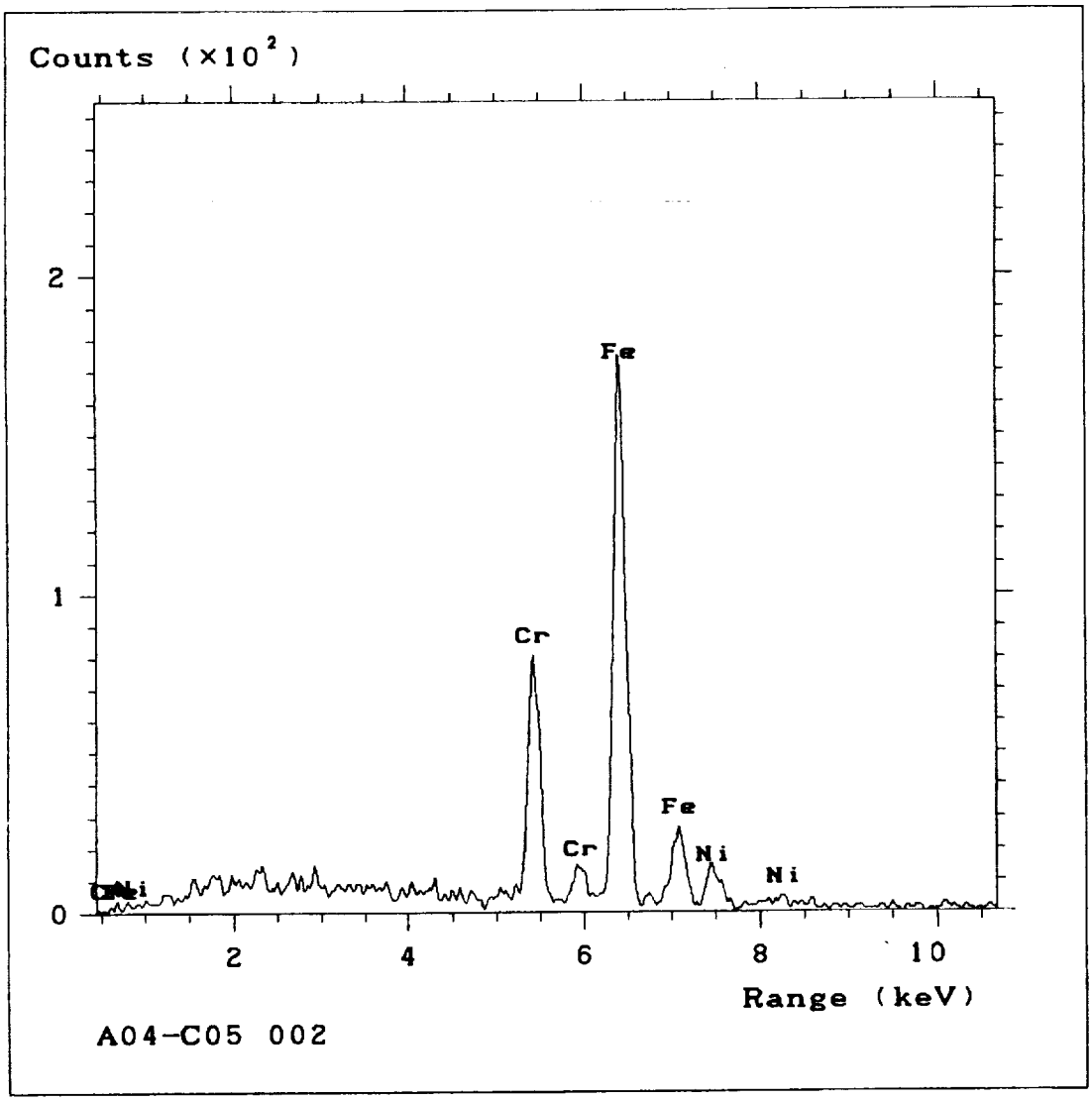
CLAMP NUMBER A04 CO5

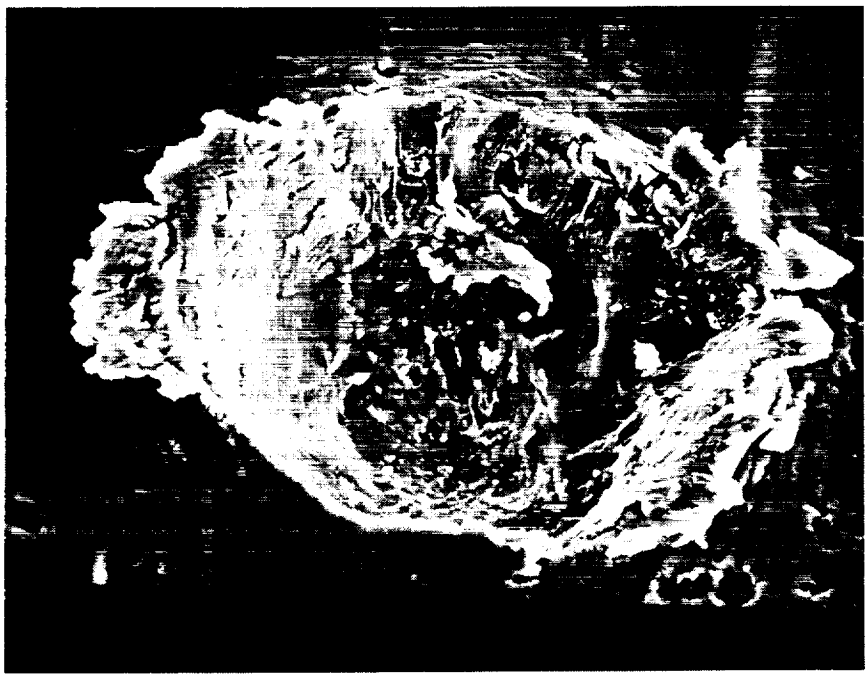
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	210	Contamination
002	120	Fe, Ni, Cr




Counts (×10³)
4
3
2
1
0
Cu
Si
Al
Cl
Ca
Ca
Cu
Cu
2
4
6
8
10
Range (keV)
A04-C05 001

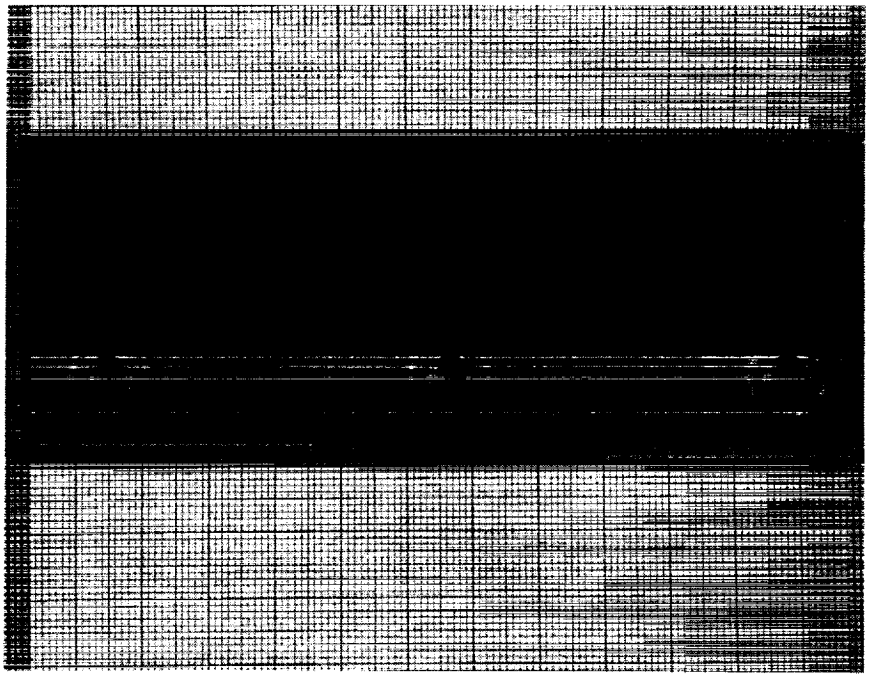


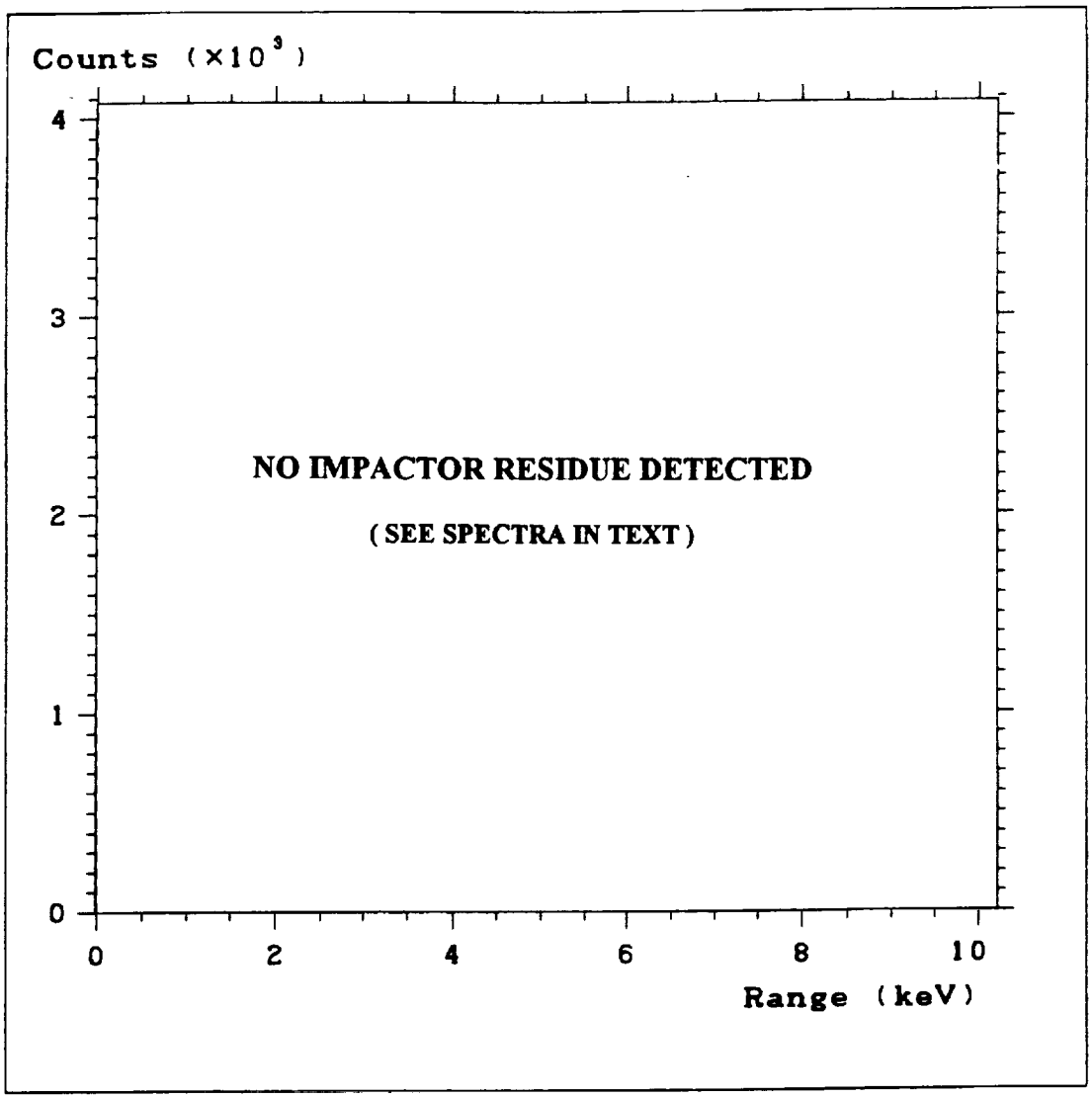

Counts (×10²)
2
1
0
Fe
Cr
Cr
Fe
Ni
Ni
Ni
2
4
6
8
10
Range (keV)
A04-C05 002

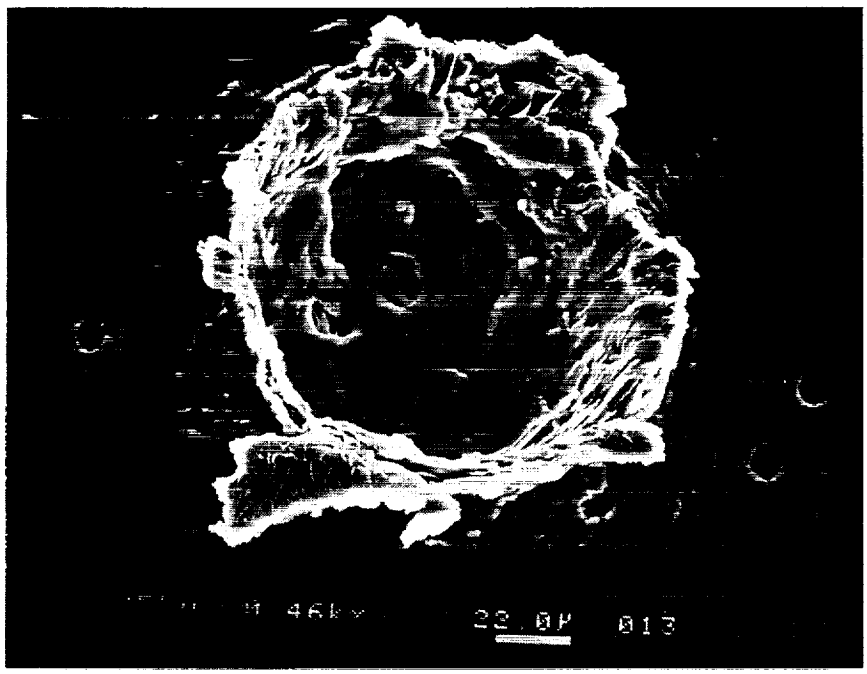


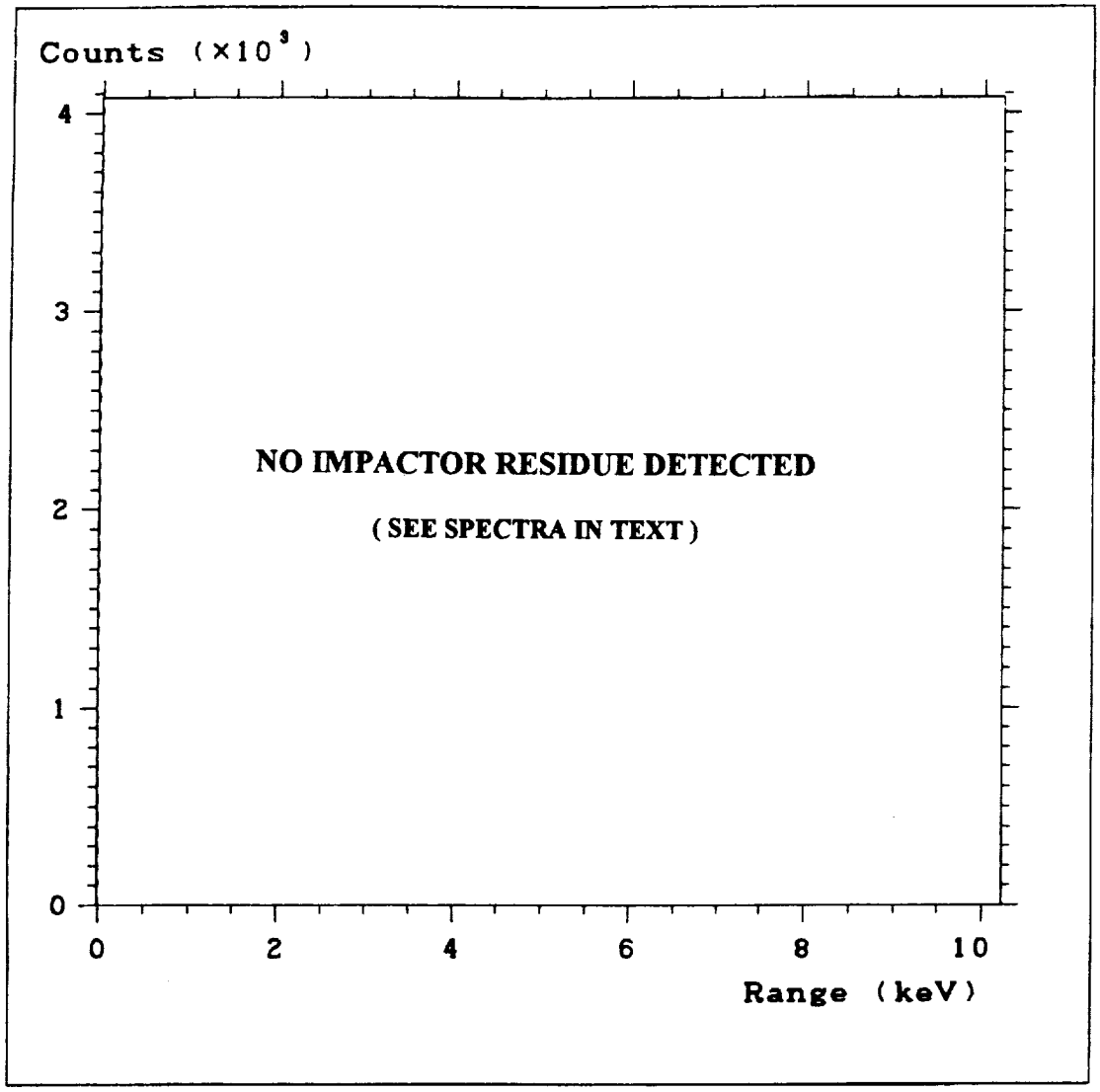
CLAMP NUMBER A04 CO8

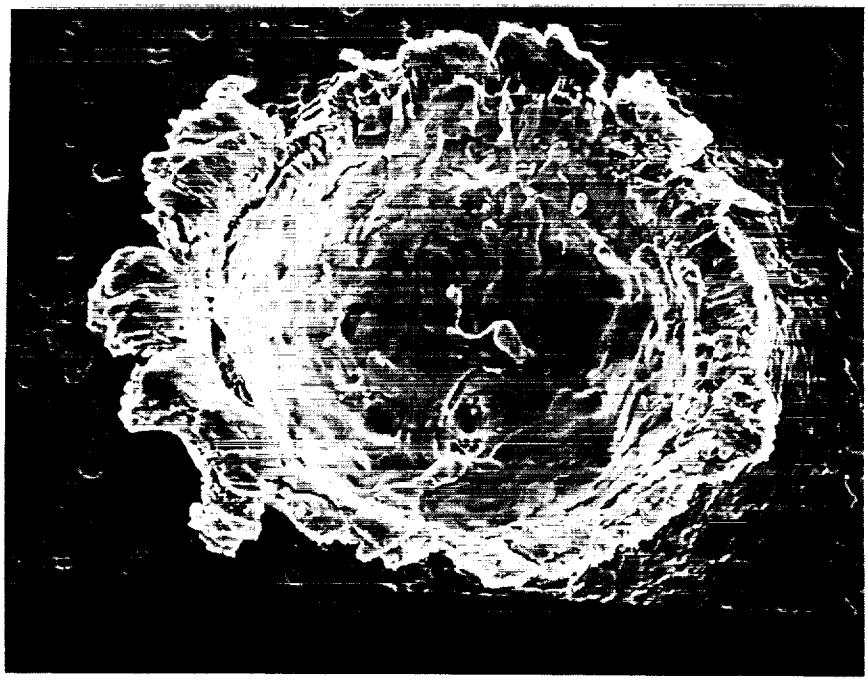
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	160	Unkown
002	400	Unkown




Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

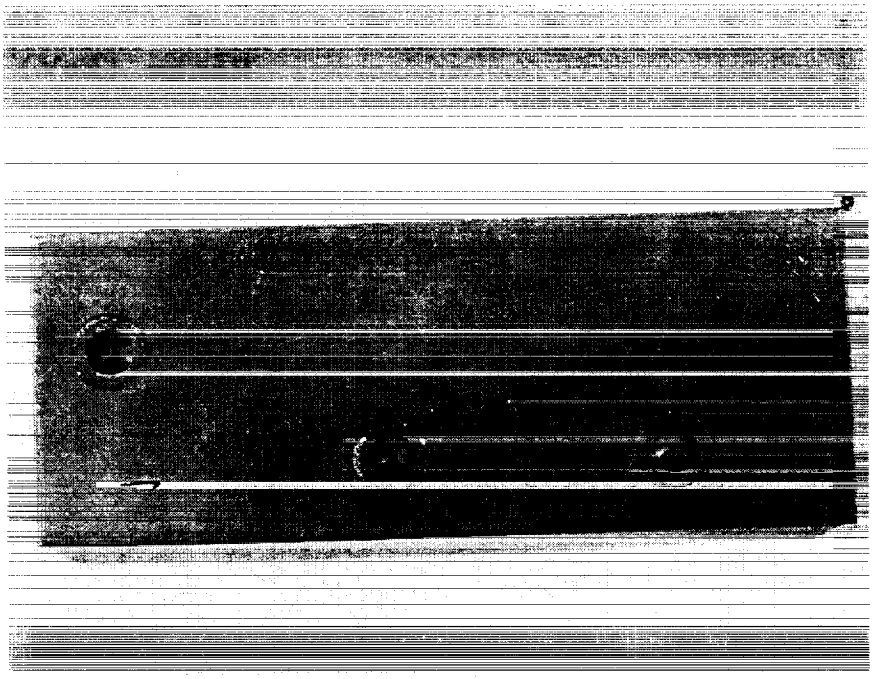

23.0P 013

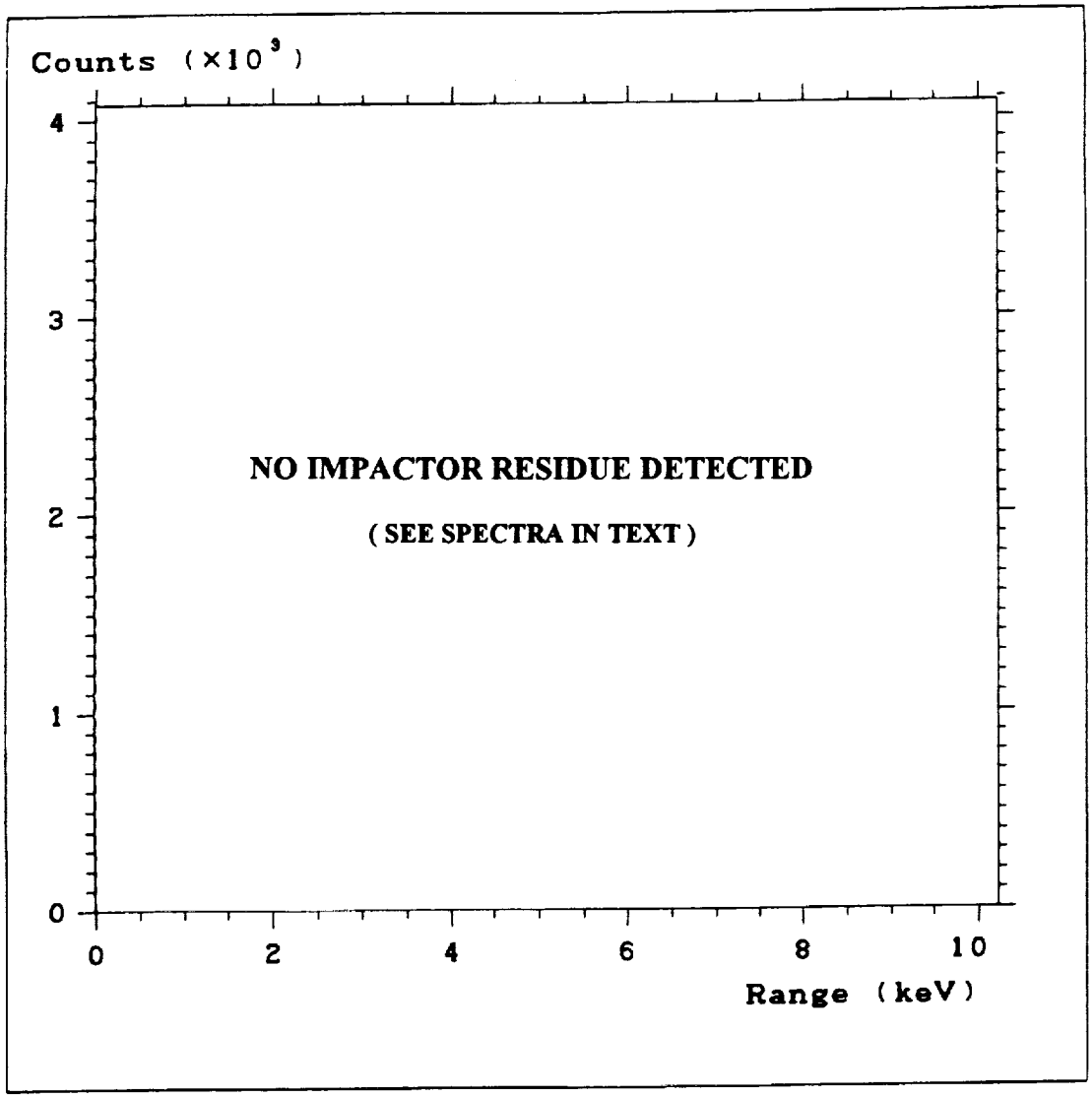

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

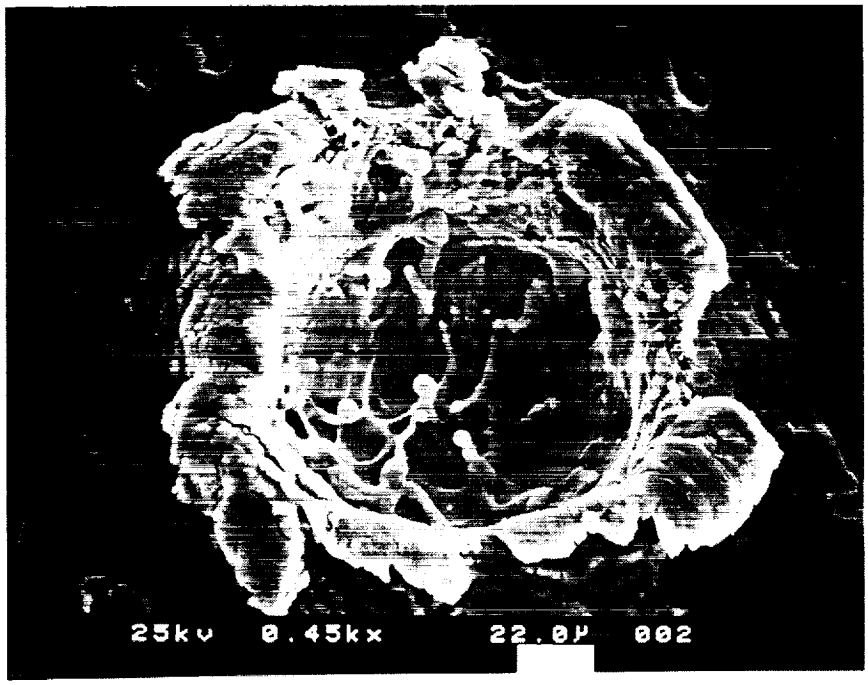


CLAMP NUMBER A05 CO3

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	180	Unkown

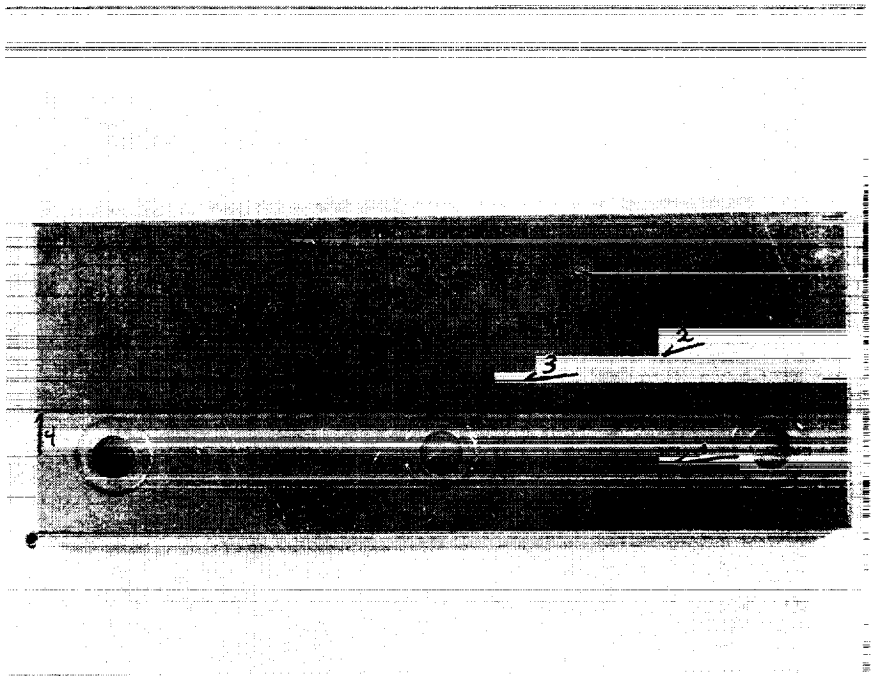


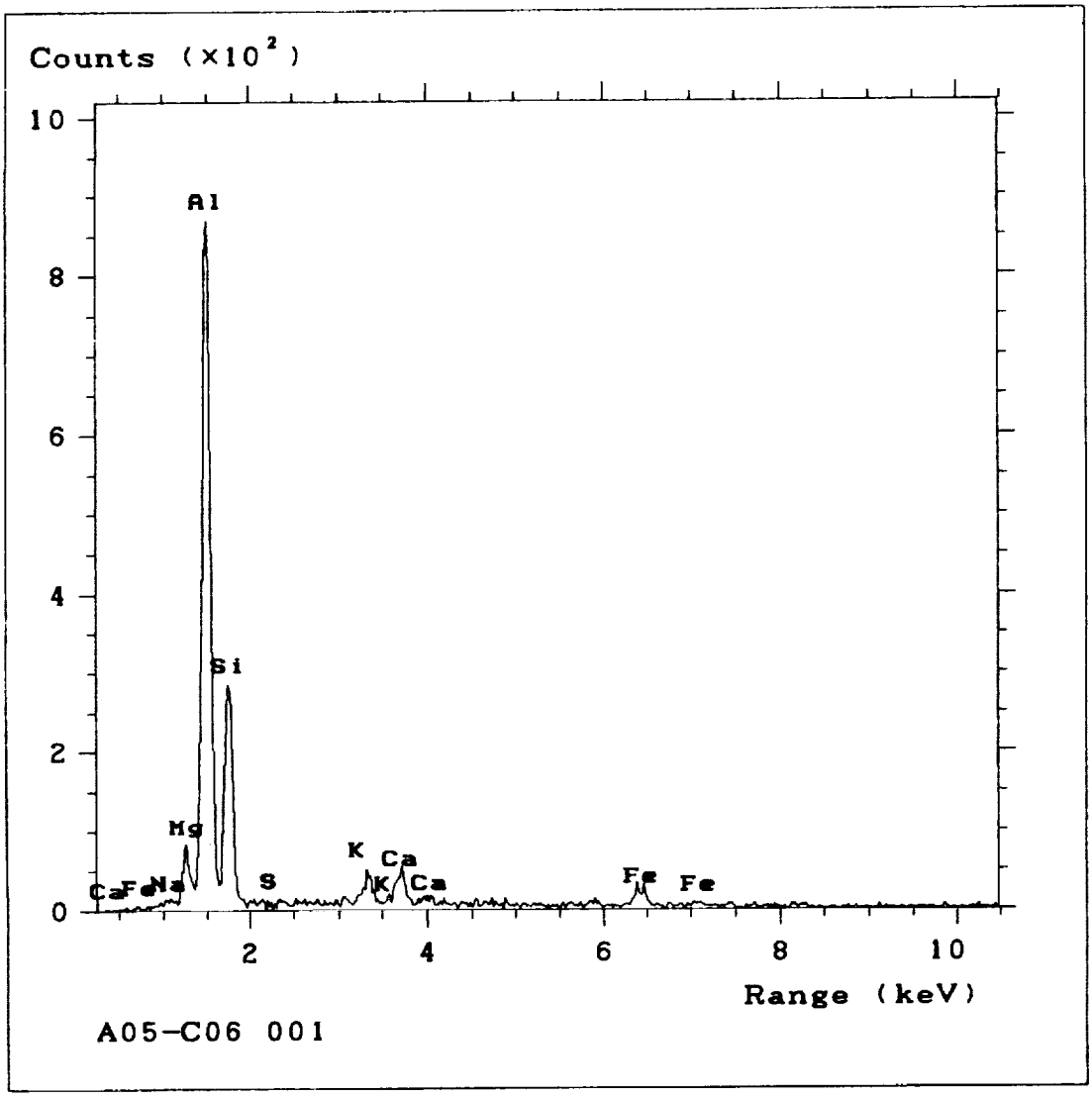

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

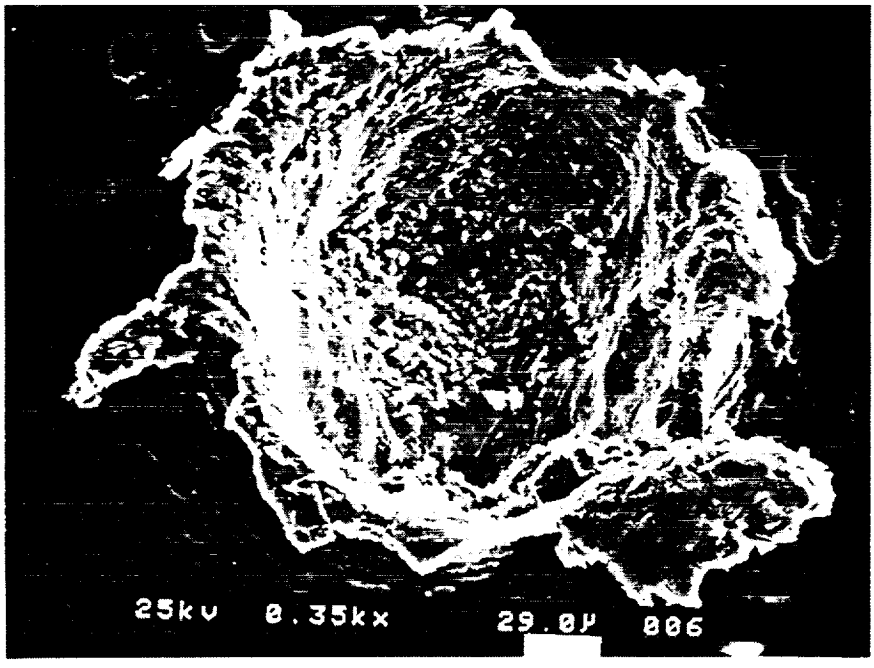

25kv 0.45kx 22.0µ 002

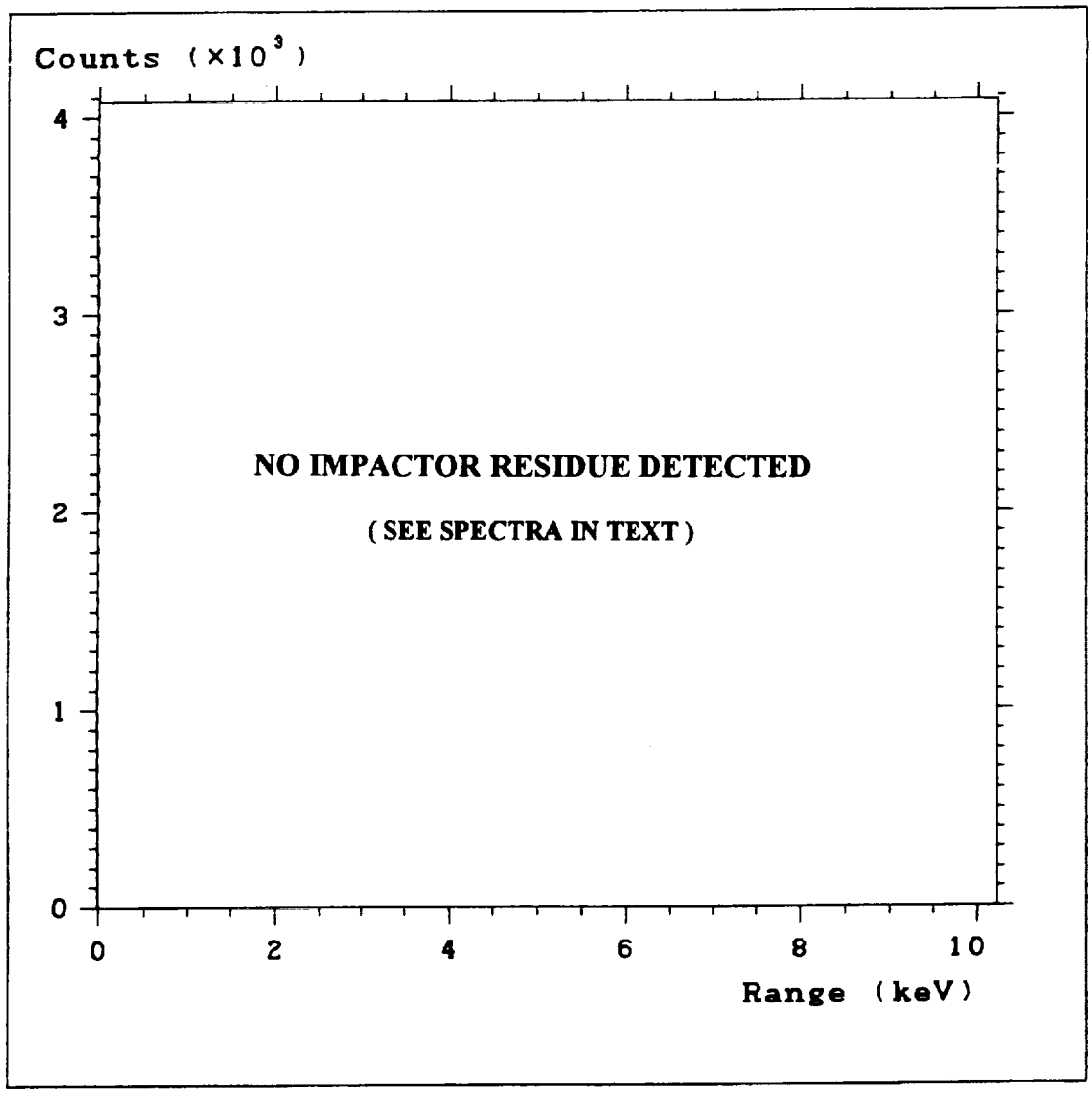
CLAMP NUMBER A05 CO6

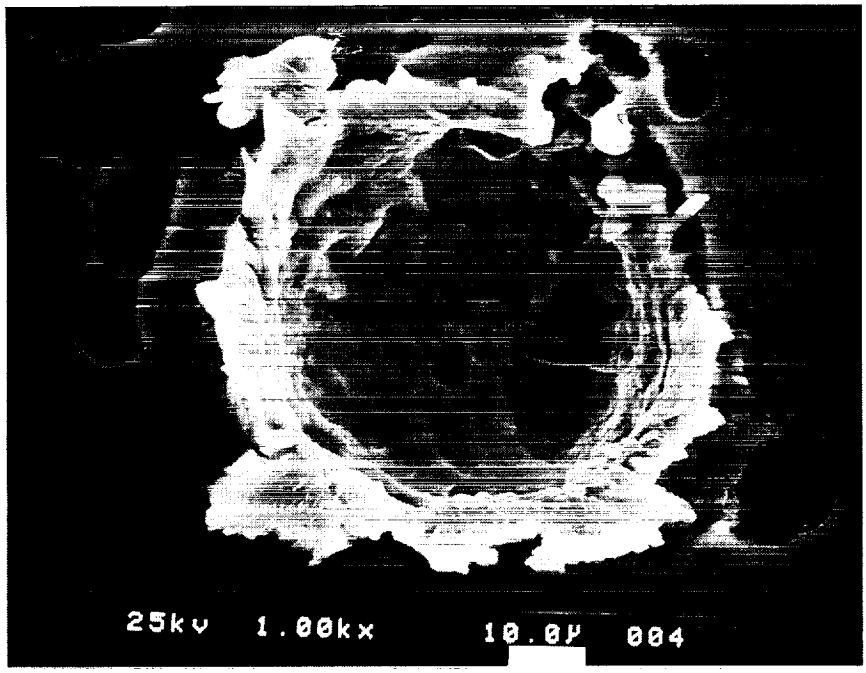
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	250	Si, Ca, S, K, Fe
002	70	Unkown
003	140	Trace
004	50	Unkown
005	90	Unkown

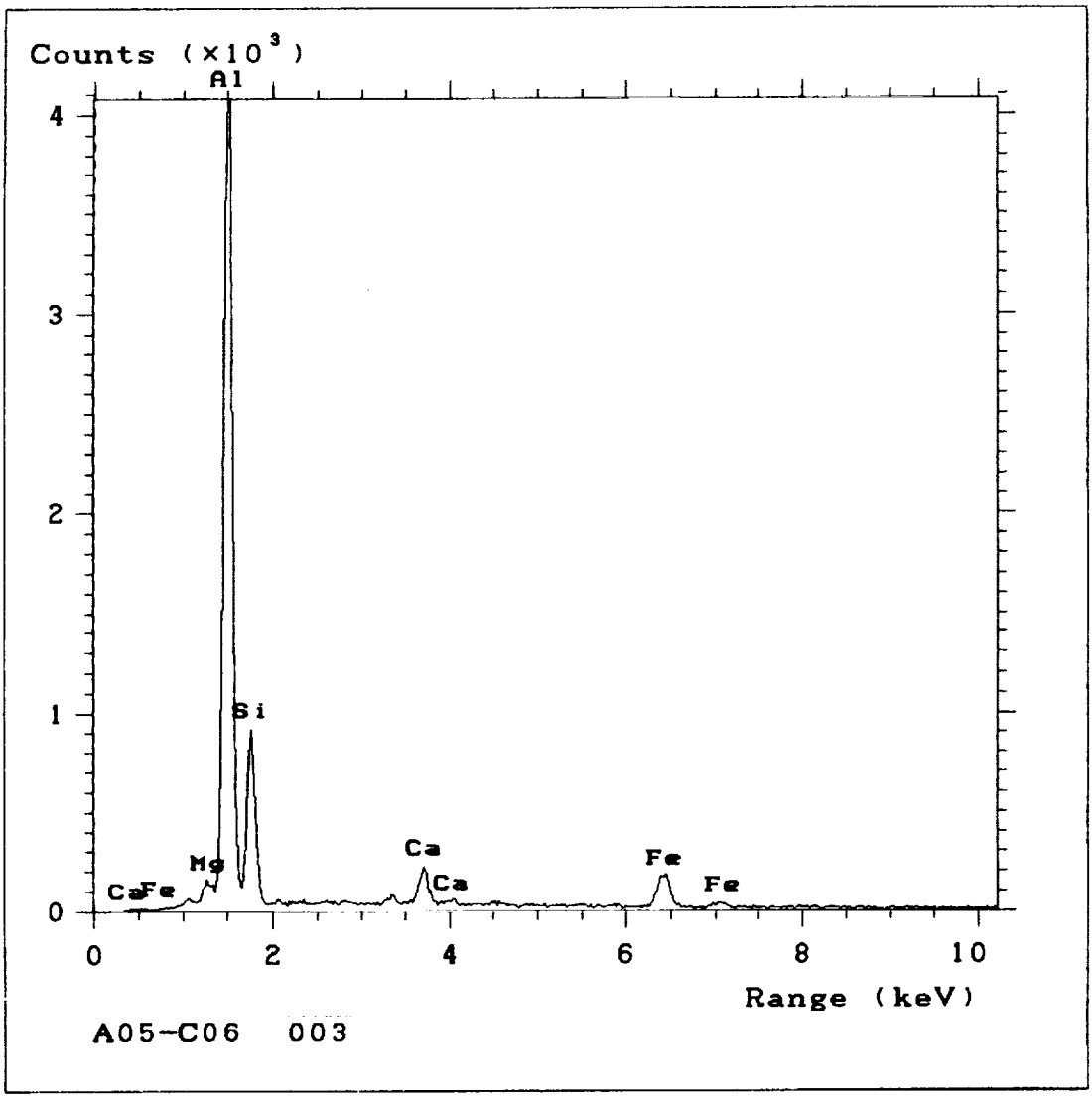


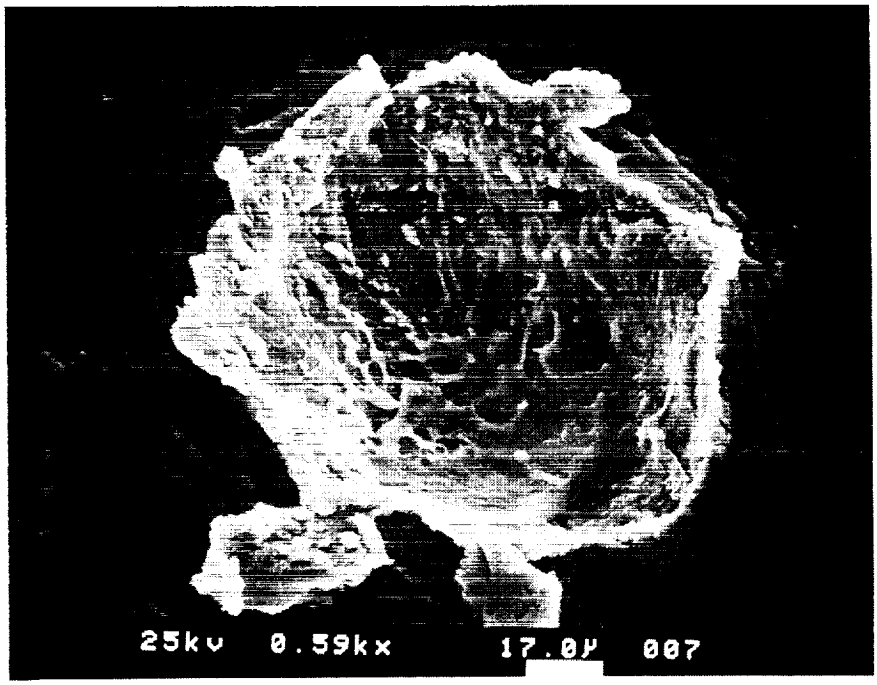

Counts (×10²)
10
8
6
4
2
0
Al
Si
Mg
Ca
Fe
Na
S
K
Ca
K
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A05-C06 001


25kv 0.35kx 29.0µ 006


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

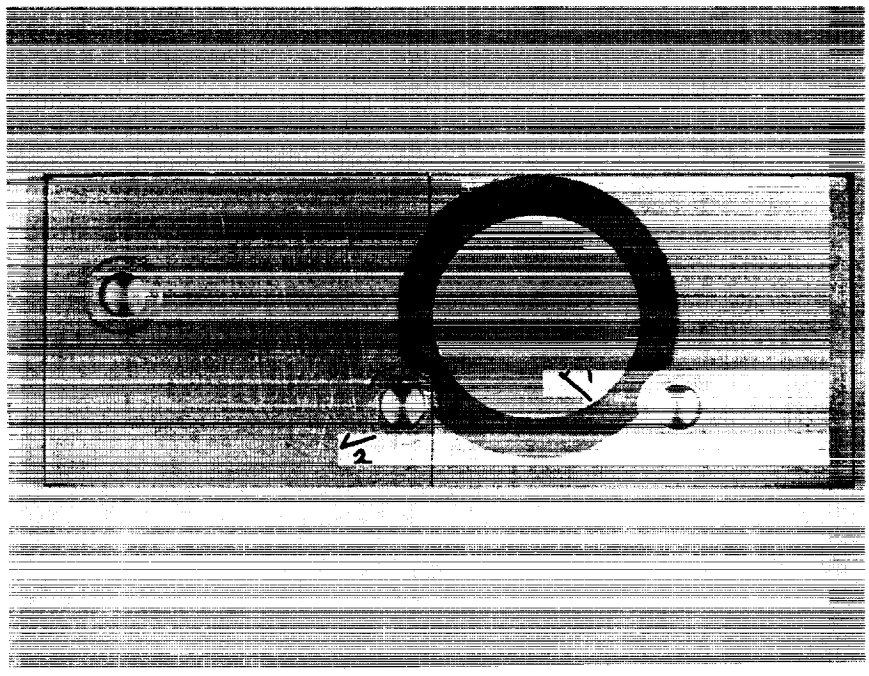

25kv 1.00kx 10.0µ 004

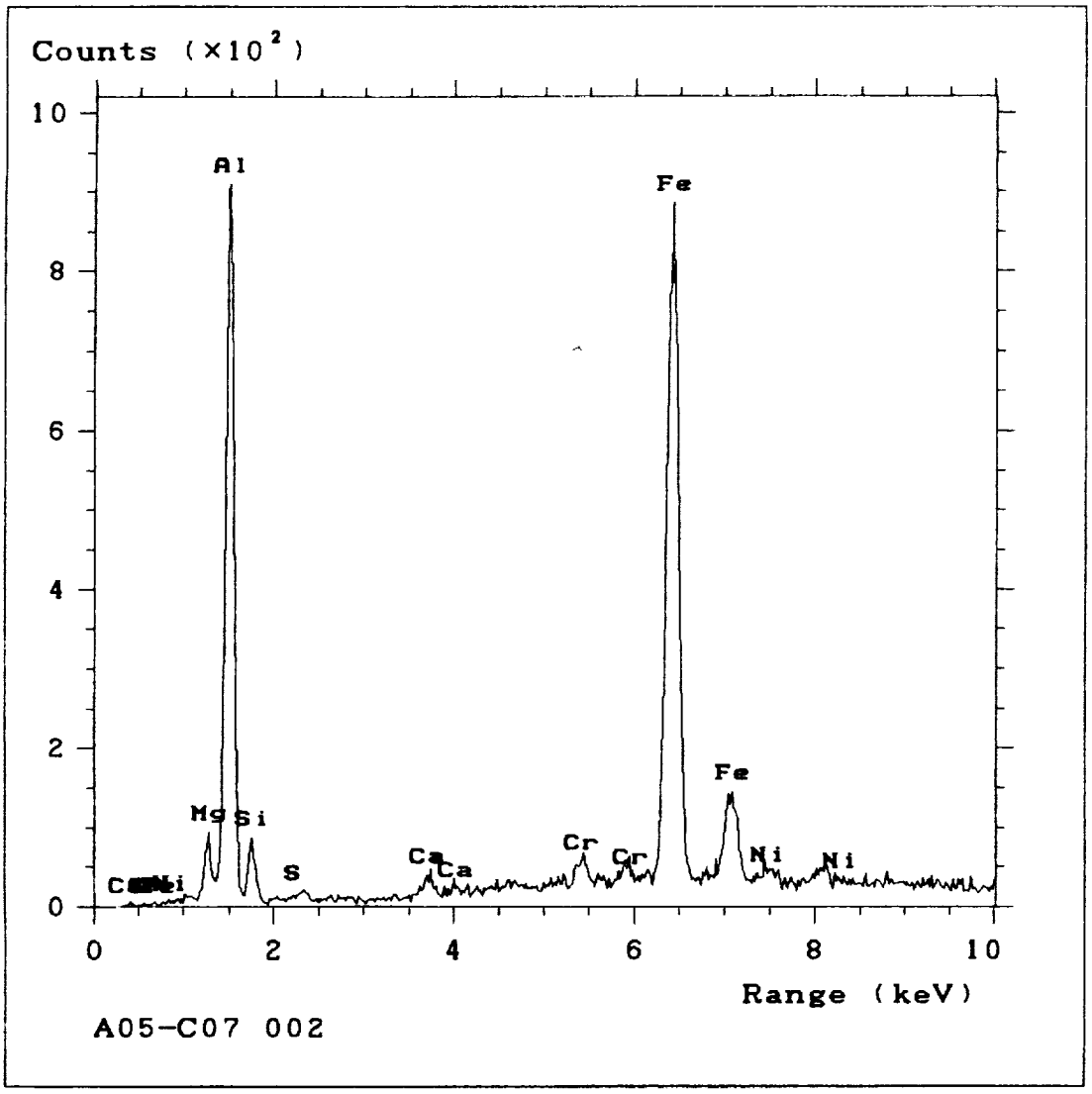

Counts (×10³)
Al
Si
Mg
Ca
Ca
Fe
Ca
Fe
Fe
0
1
2
3
4
0
2
4
6
8
10
Range (keV)
A05-C06 003

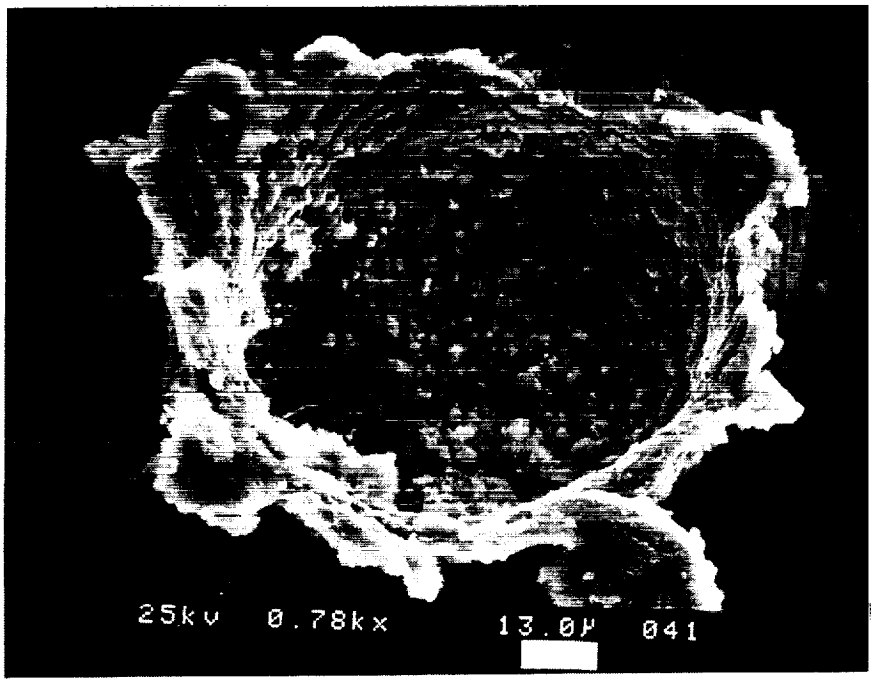

25kv 0.59kx 17.0µ 007

CLAMP NUMBER A05 CO7

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	400	Paint Patch
002	100	Mg, Si, Ca, Fe, S

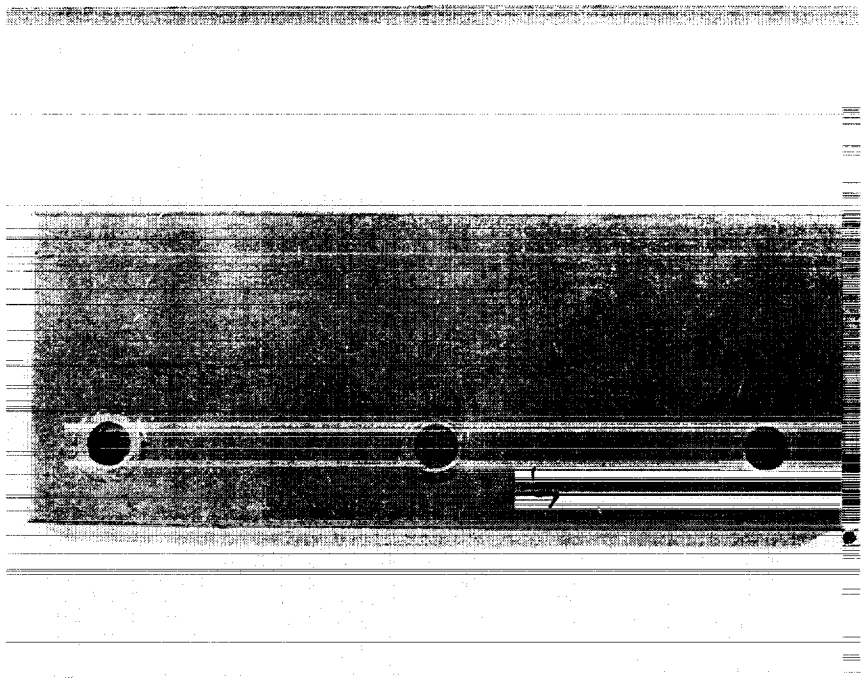


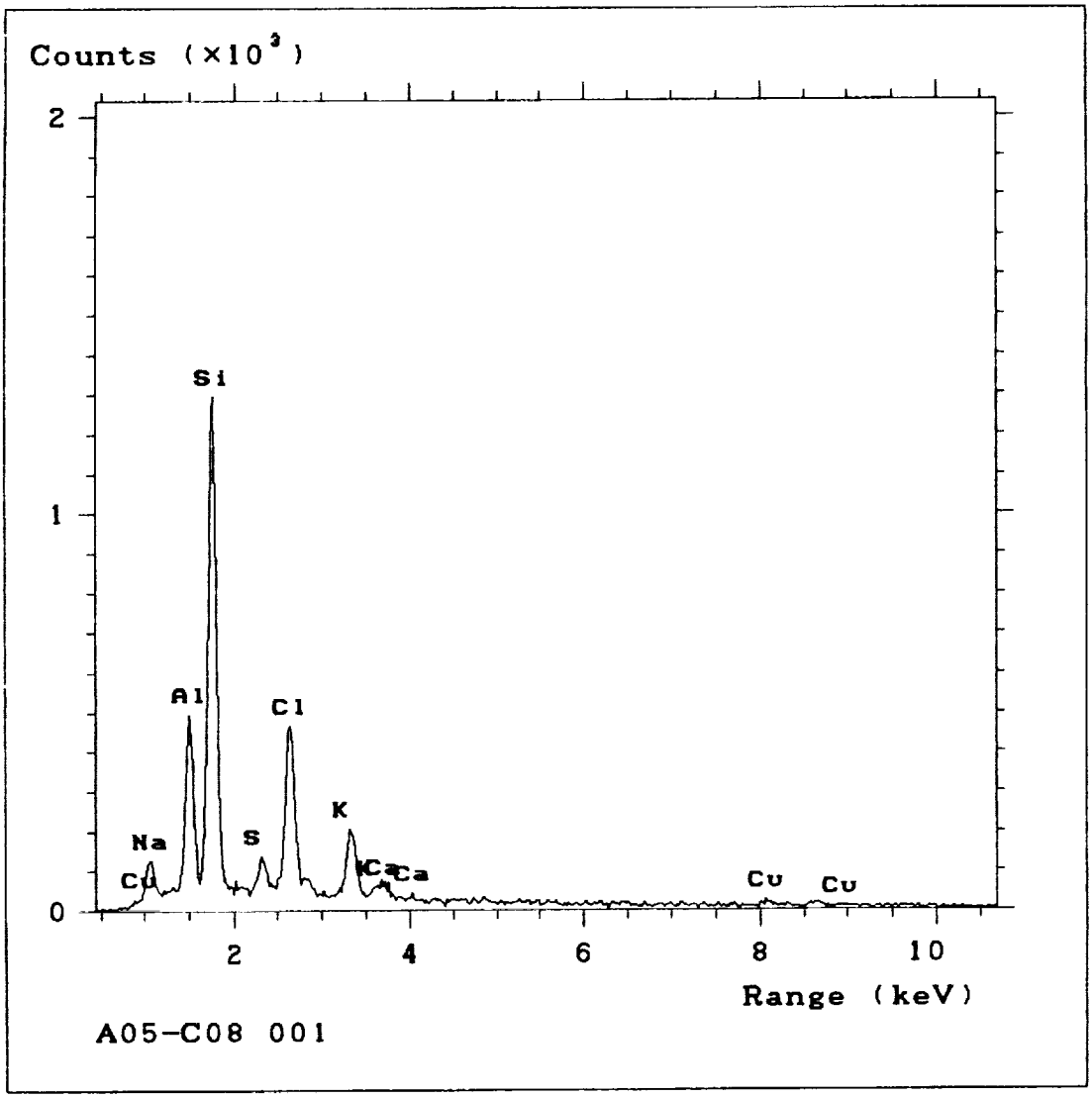

Counts (×10²)
10
8
6
4
2
0
Al
Fe
Mg
Si
S
Ca
Ca
Cr
Cr
Fe
Ni
Ni
0
2
4
6
8
10
Range (keV)
A05-C07 002

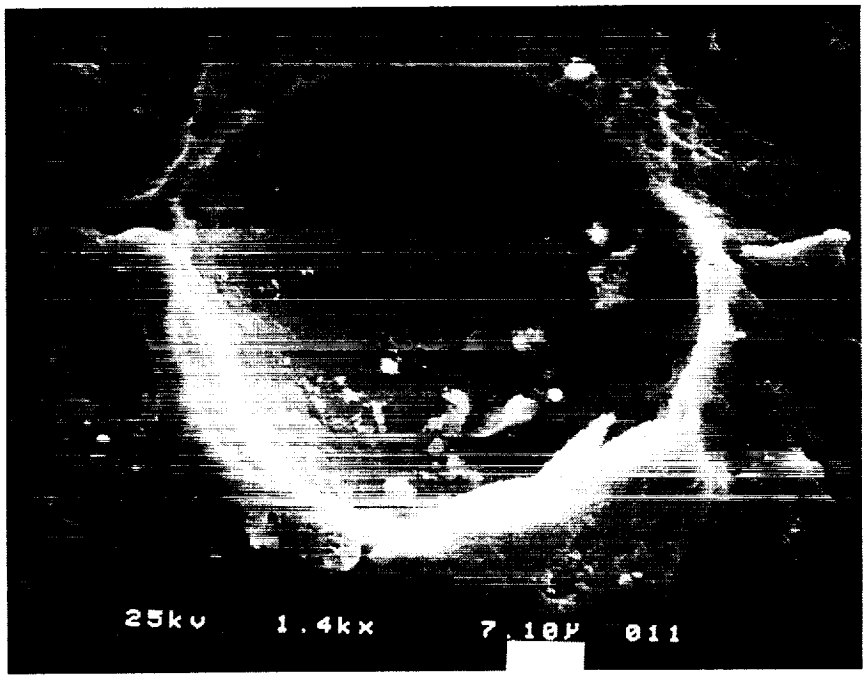

25kv 0.78kx 13.0μ 041

CLAMP NUMBER A05 CO8

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	180	Contamination

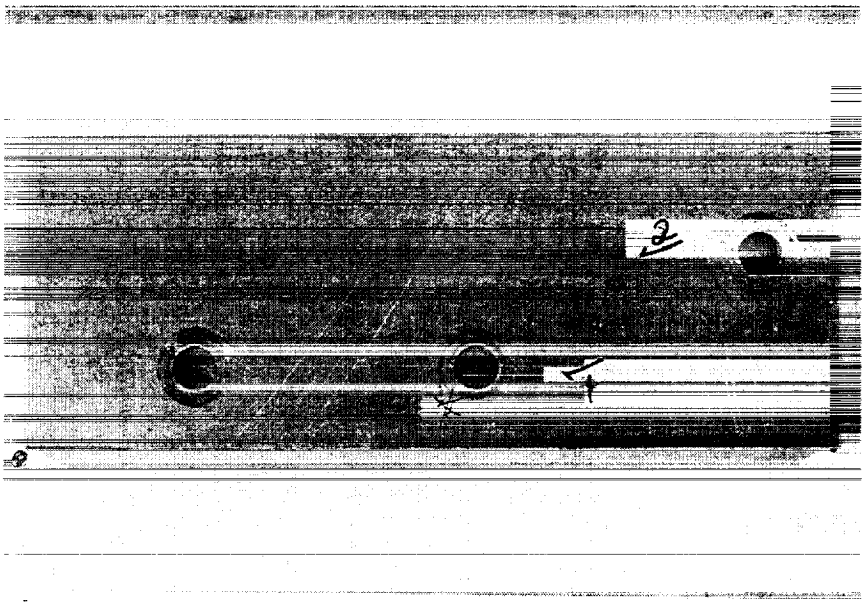


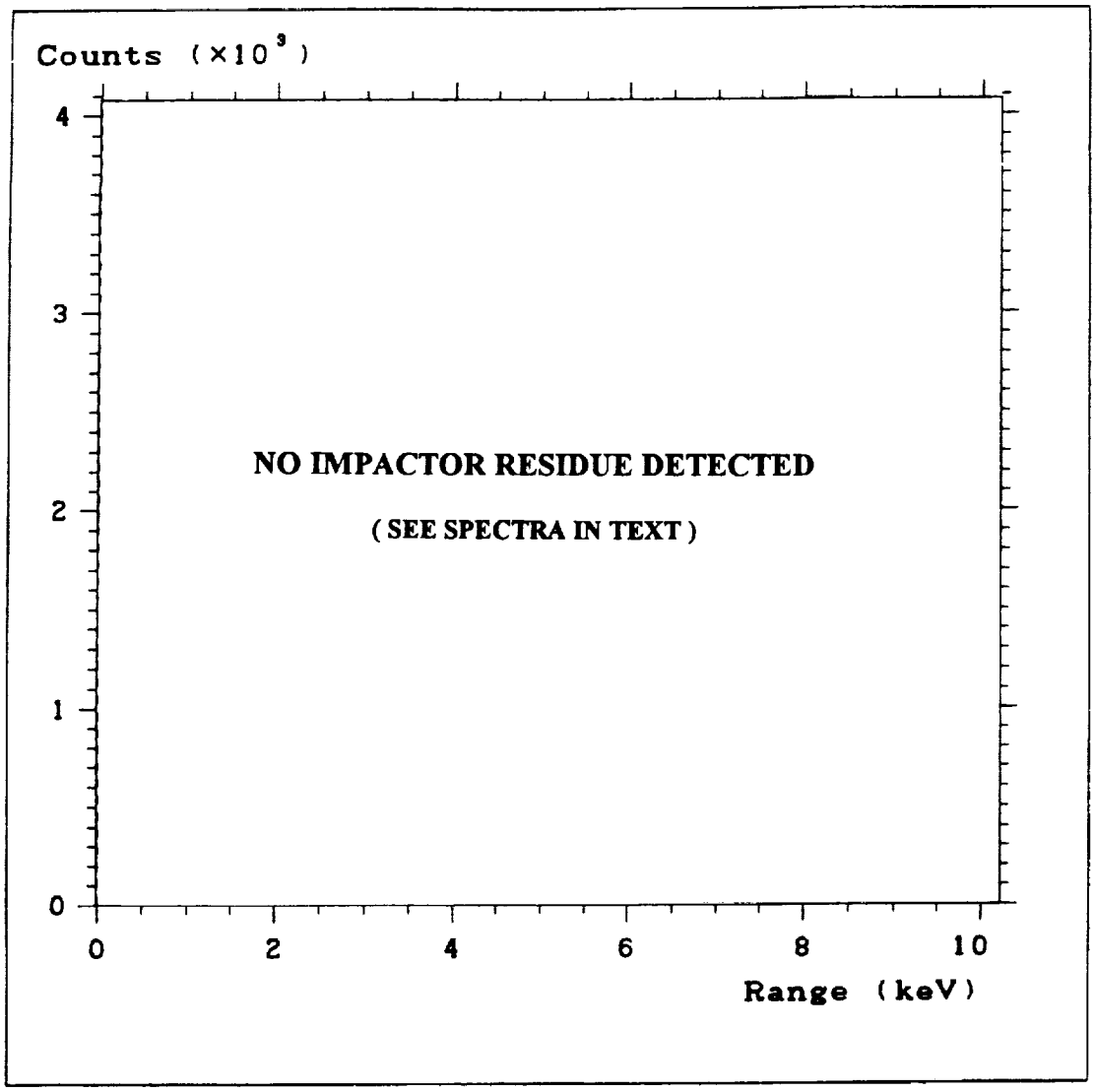

Counts (×10³)
2
1
0
Si
Al
Cl
K
Na
S
Ca
Ca
Cu
Cu
Cu
2
4
6
8
10
Range (keV)
A05-C08 001

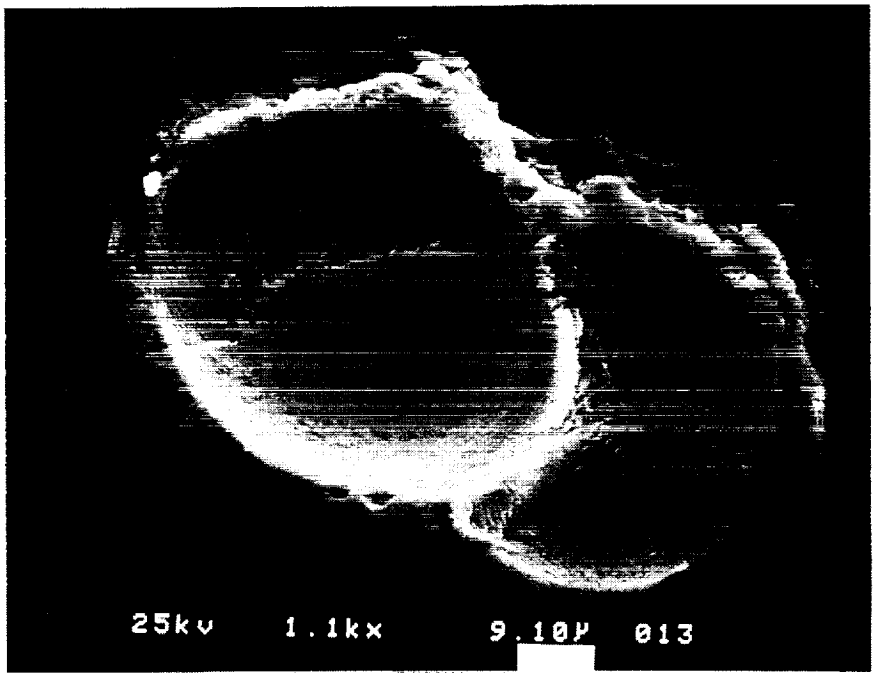

25kv 1.4kx 7.10μ 011

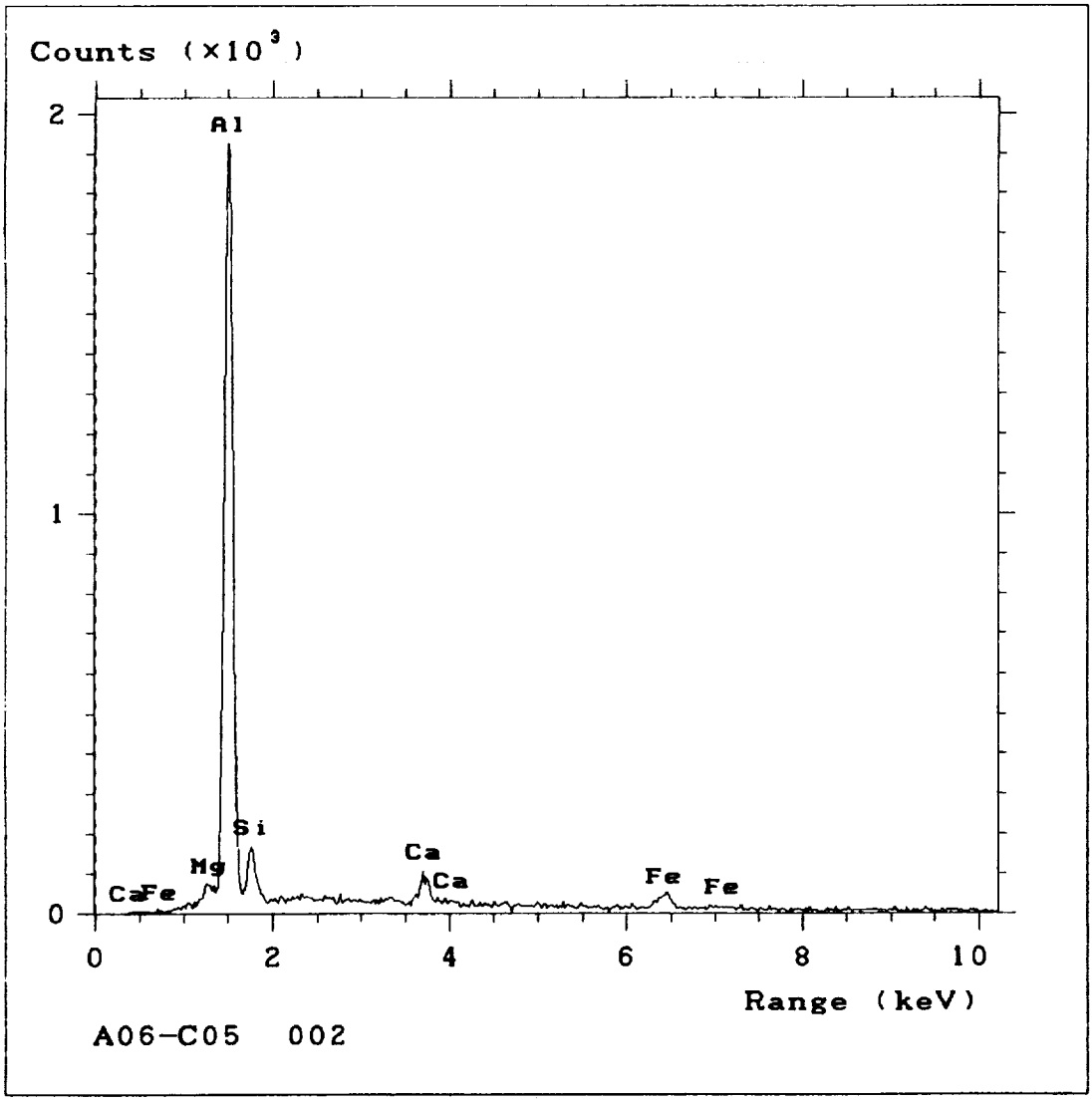
CLAMP NUMBER A06 CO5

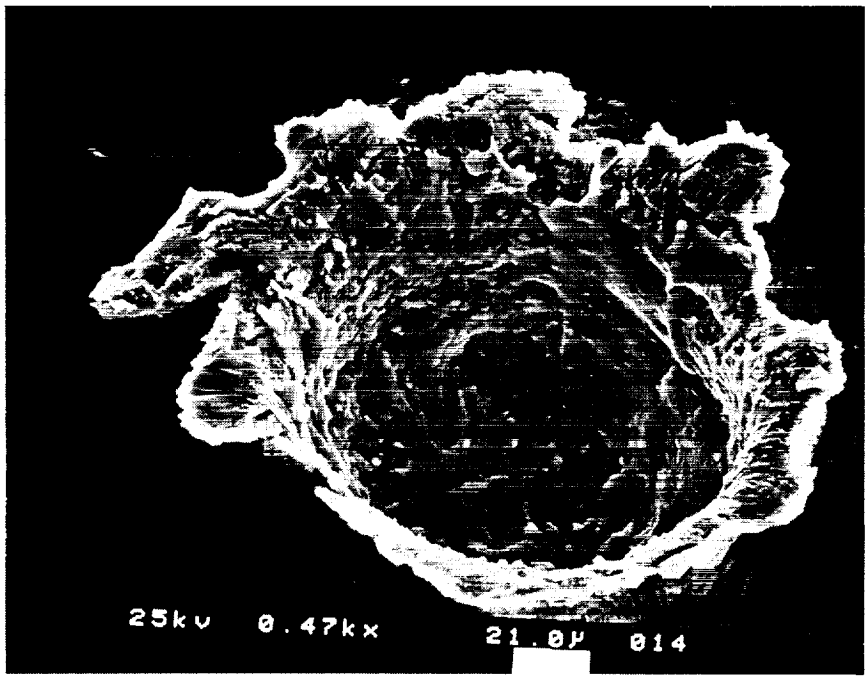
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	70	Clamp Flaw
002	200	Trace




Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

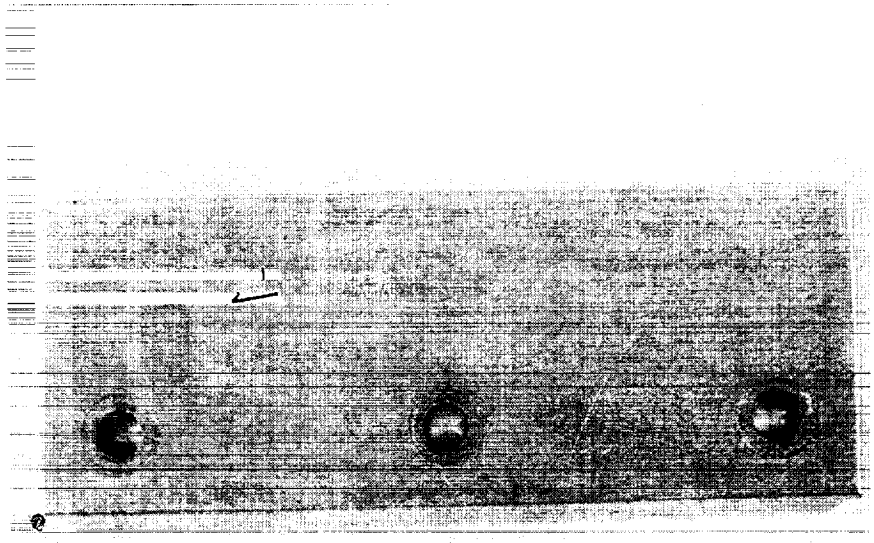

25kv 1.1kx 9.10µ 013

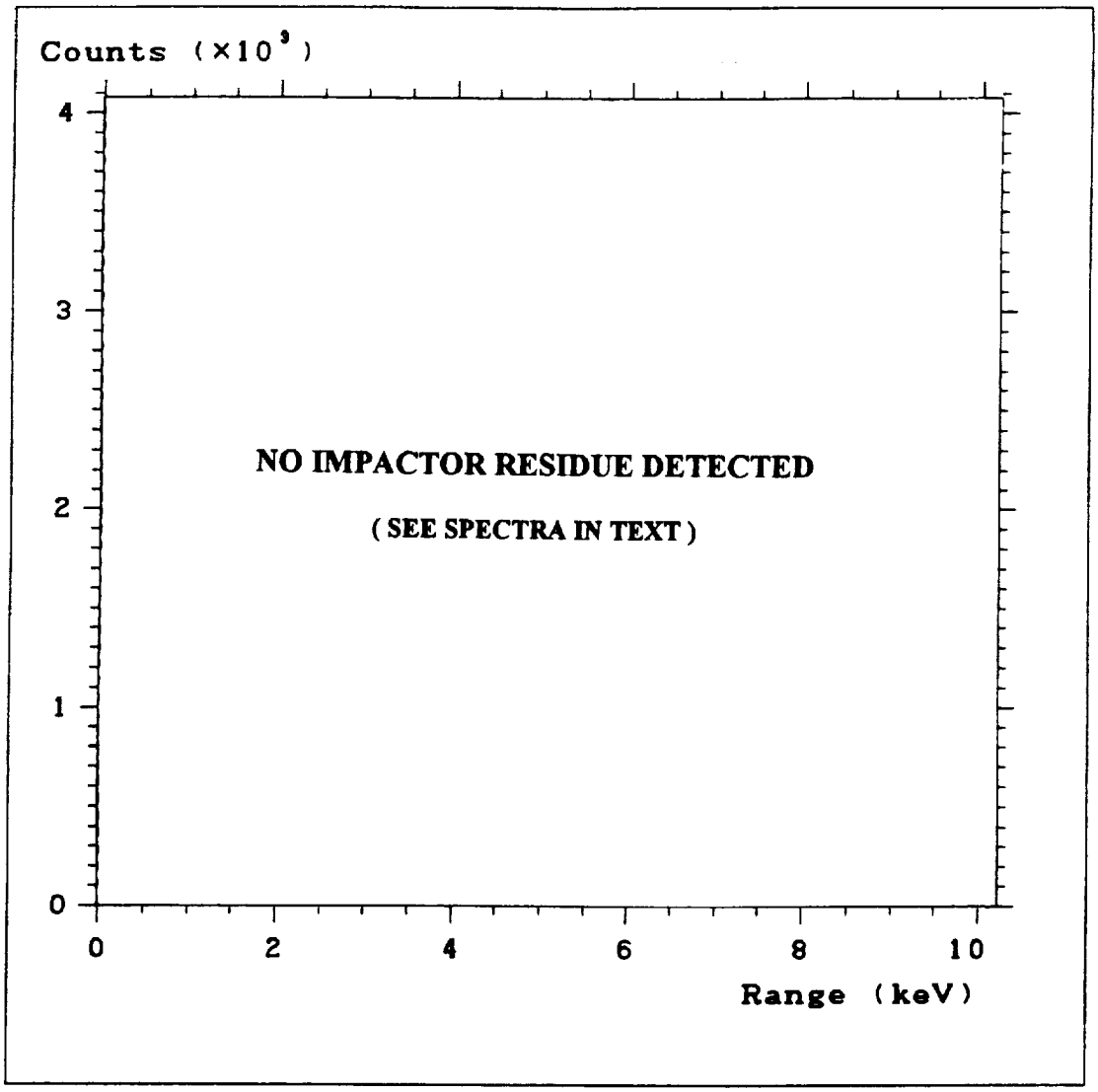

Counts (×10³)
2
1
0
Al
Si
Mg
Ca
Ca
Fe
Fe
Fe
0
2
4
6
8
10
Range (keV)
A06-C05 002

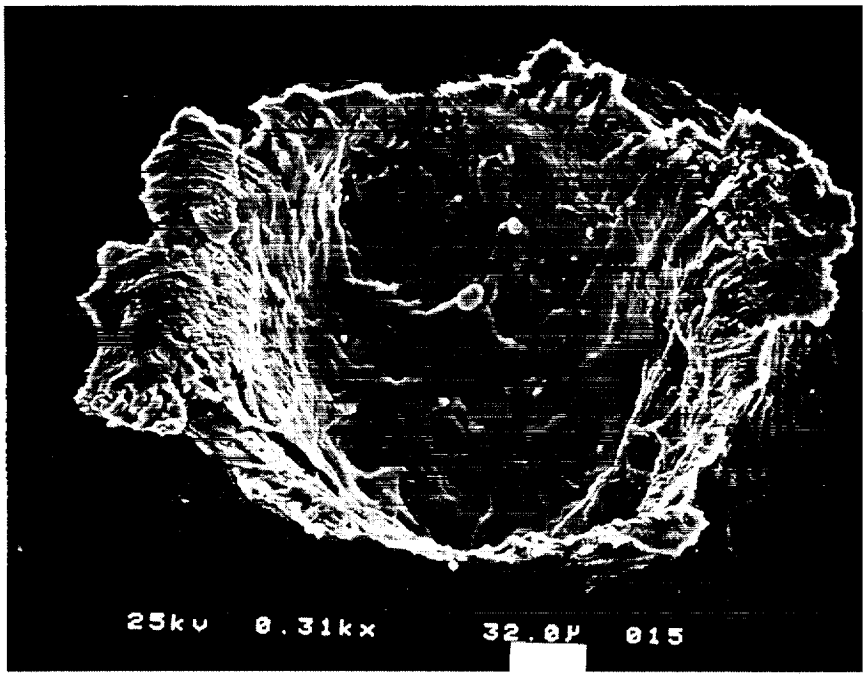

25kv 0.47kx 21.0μ 014

CLAMP NUMBER A06 CO6

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	320	Unkown

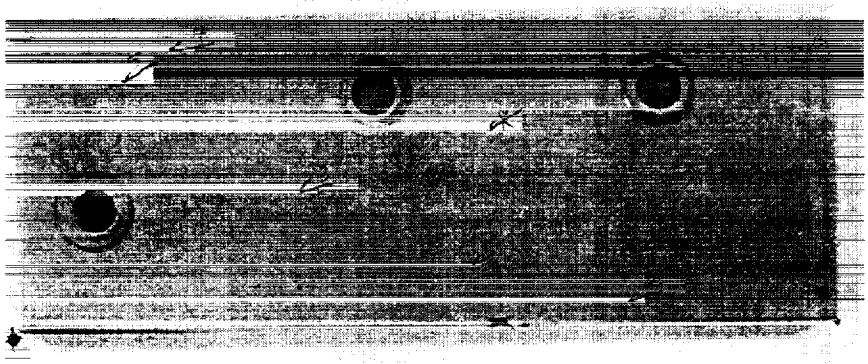


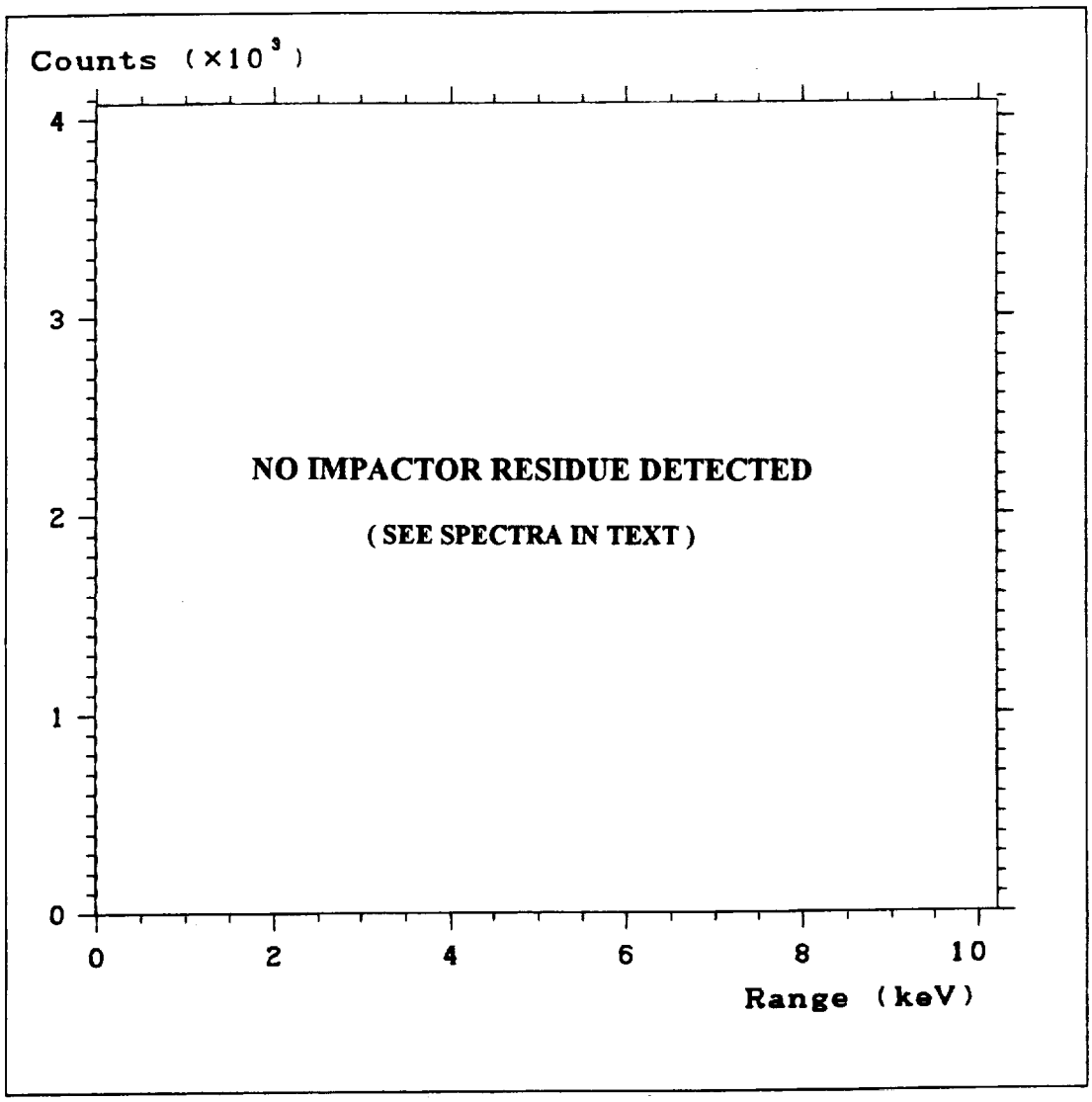

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

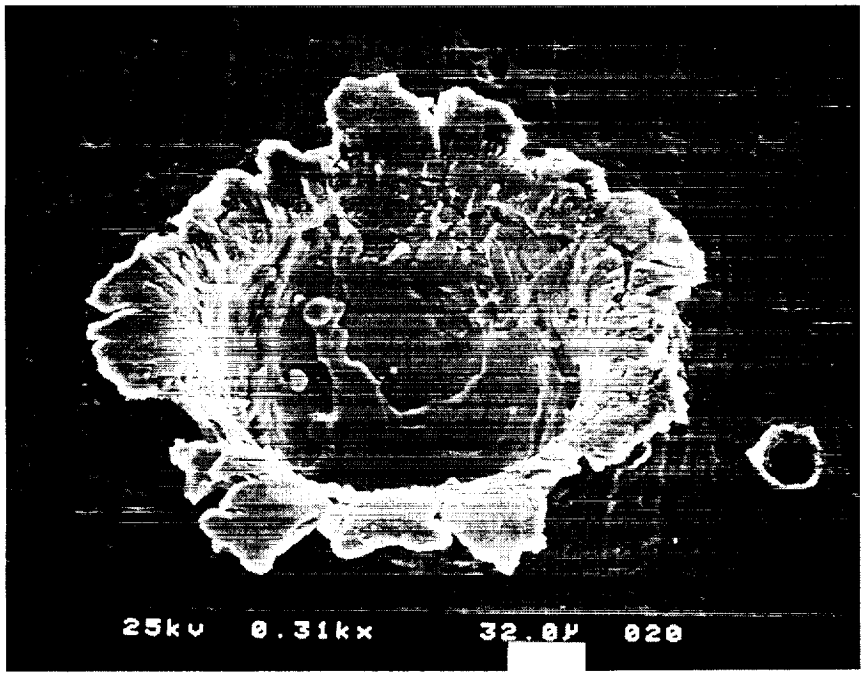

25kv 0.31kx 32.0µ 015

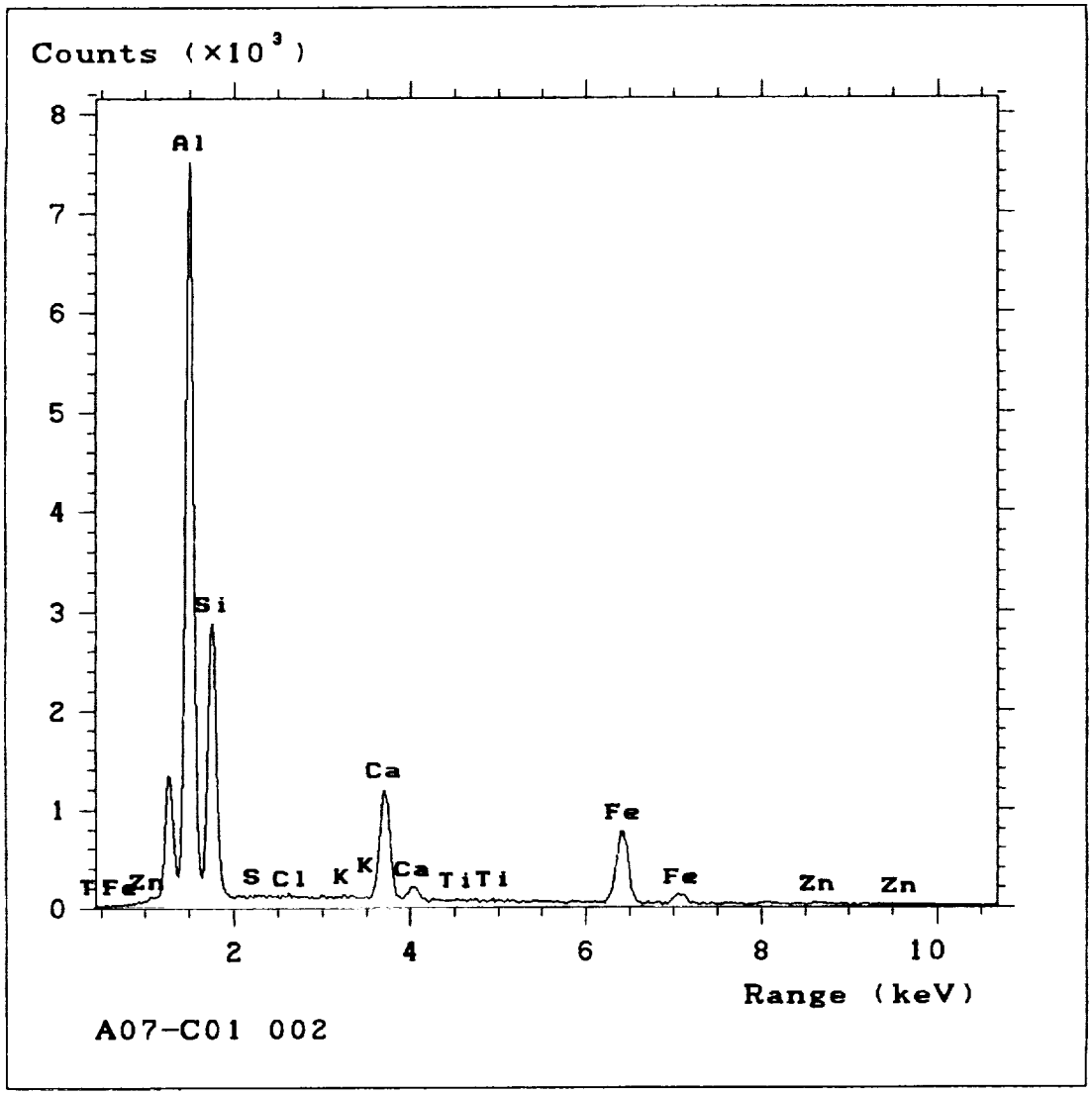
CLAMP NUMBER A07 CO1

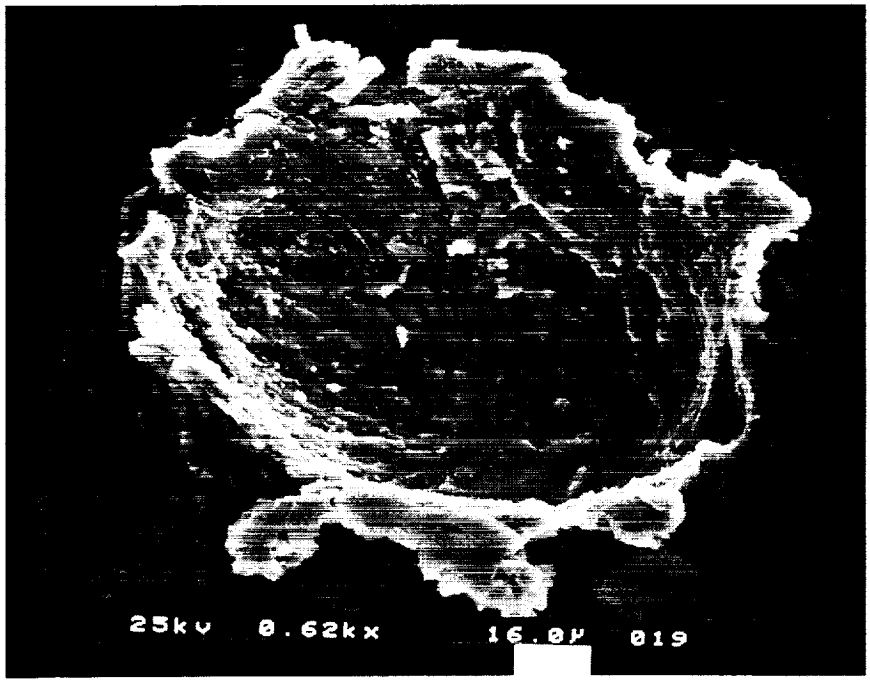
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	210	Unkown
002	120	Si, Ca, Fe
003	110	Si, Ca, S, Fe
004	210	Unkown
005	130	Trace

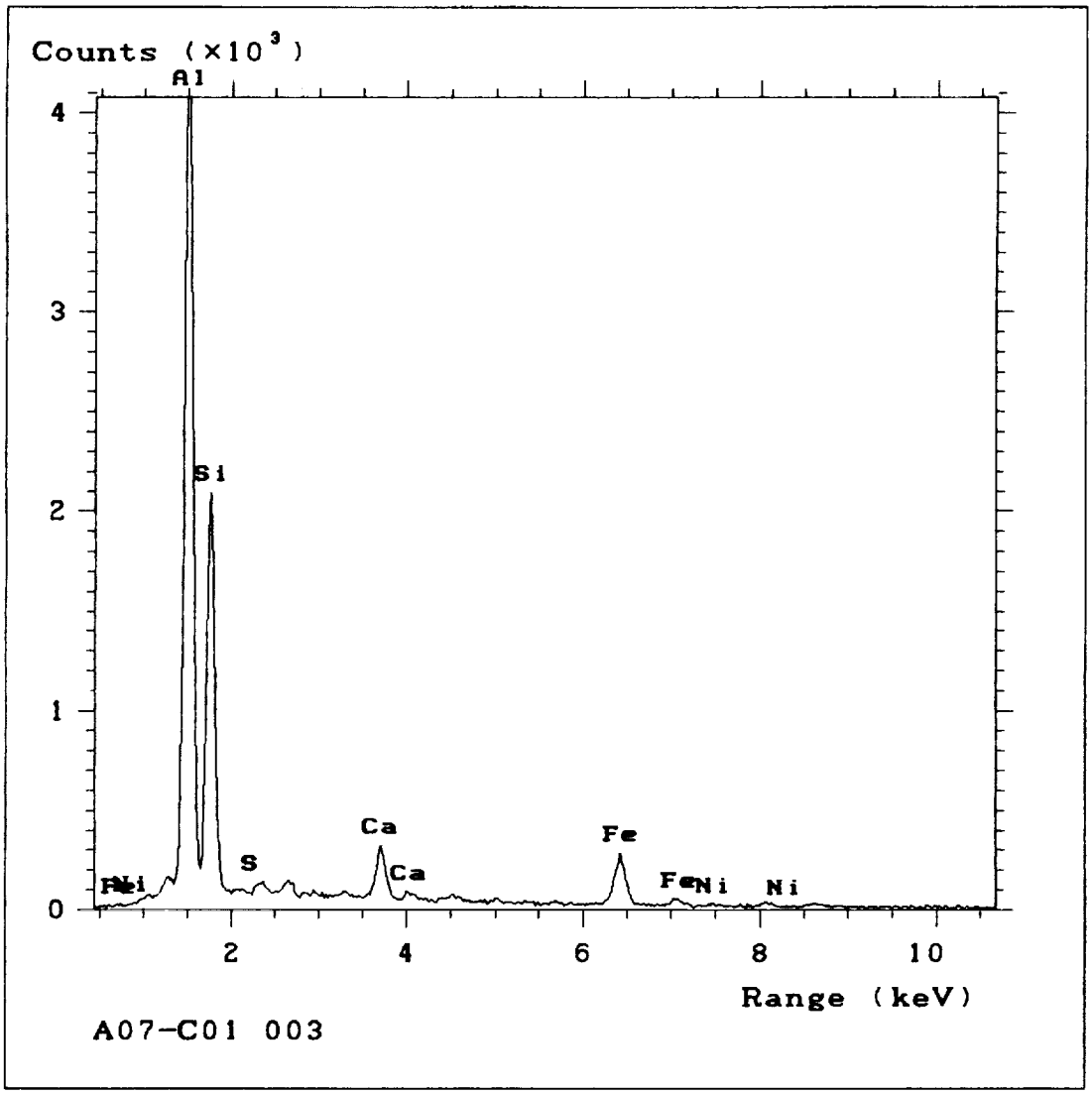


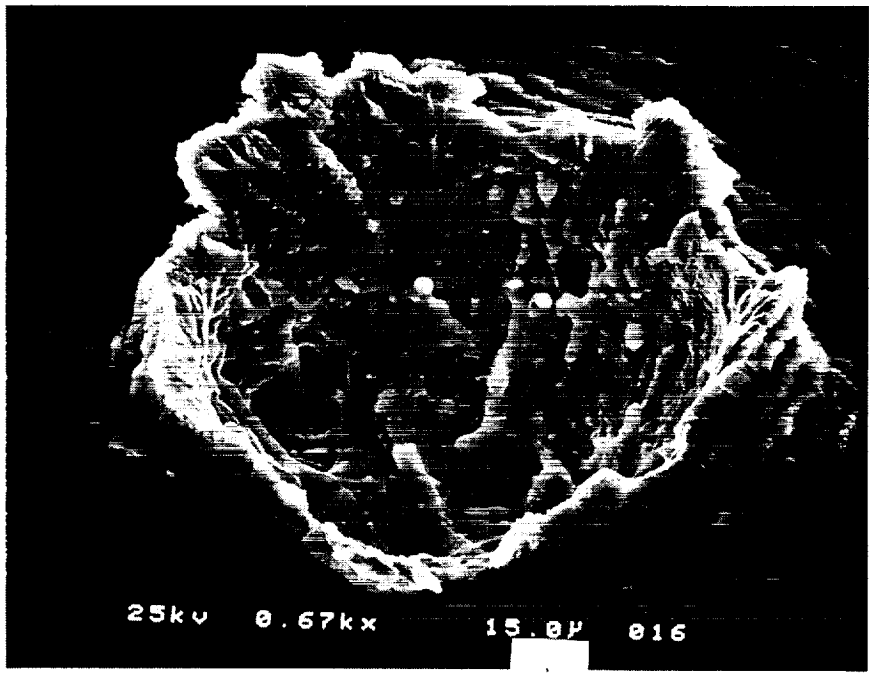

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

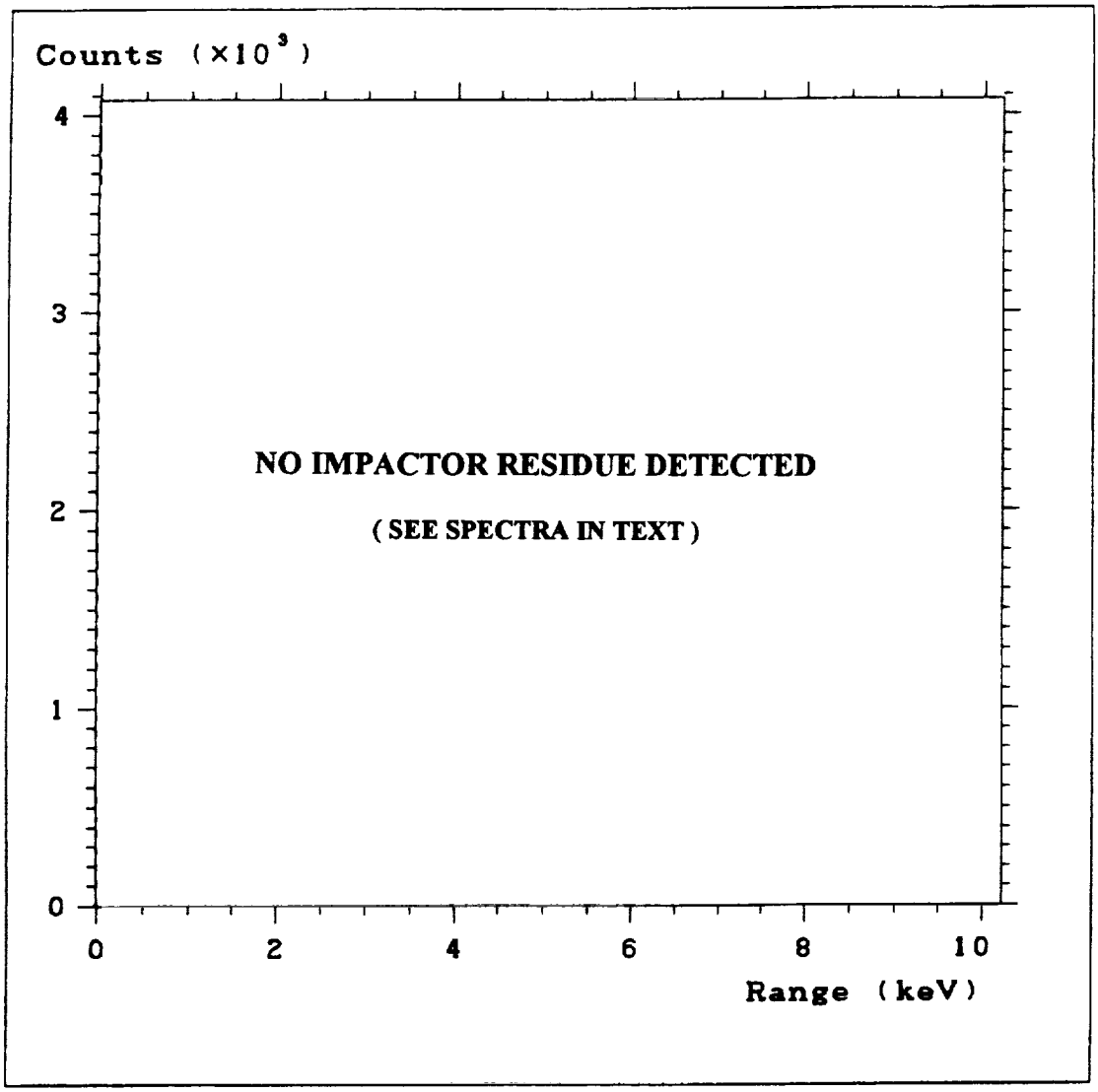

25kV 0.31kx 32.0μ 020

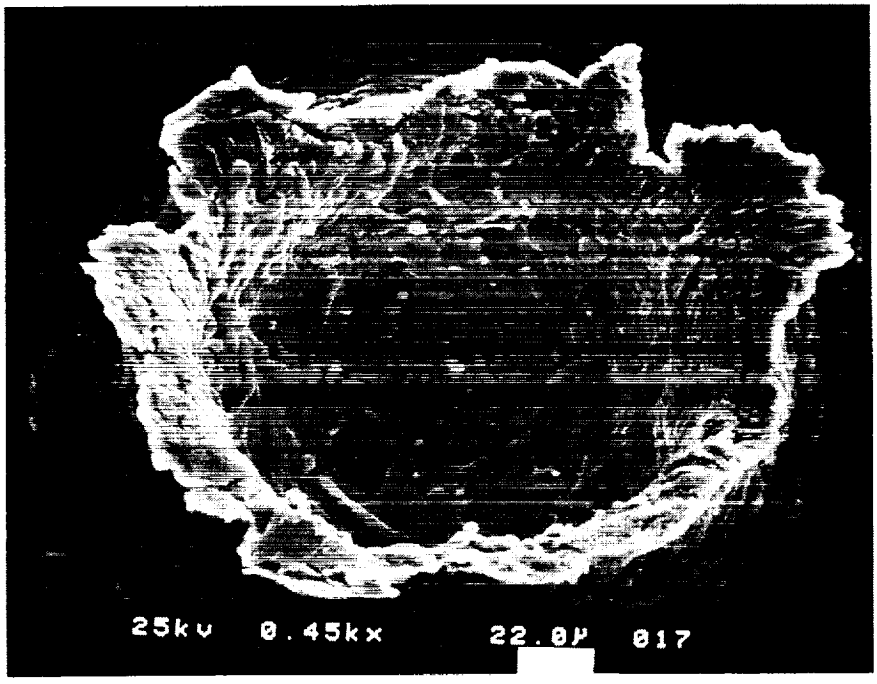

Counts (×10³)
8
7
6
5
4
3
2
1
0
Al
Si
Ca
Fe
Fe
Zn
S Cl K
K
Ca
Ti Ti
Fe
Zn
Zn
2
4
6
8
10
Range (keV)
A07-C01 002

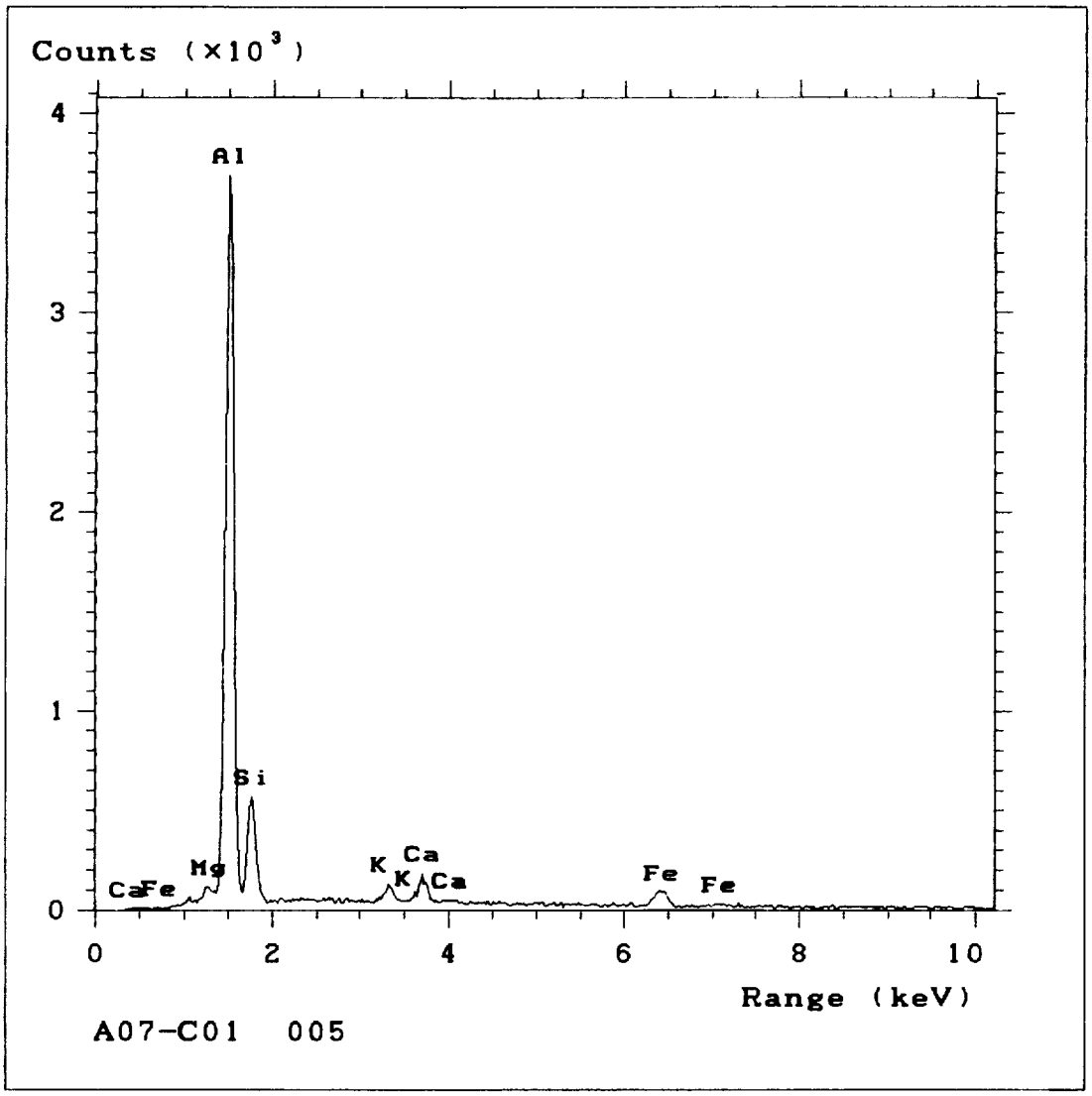

25kV 0.62kx 16.0μ 019

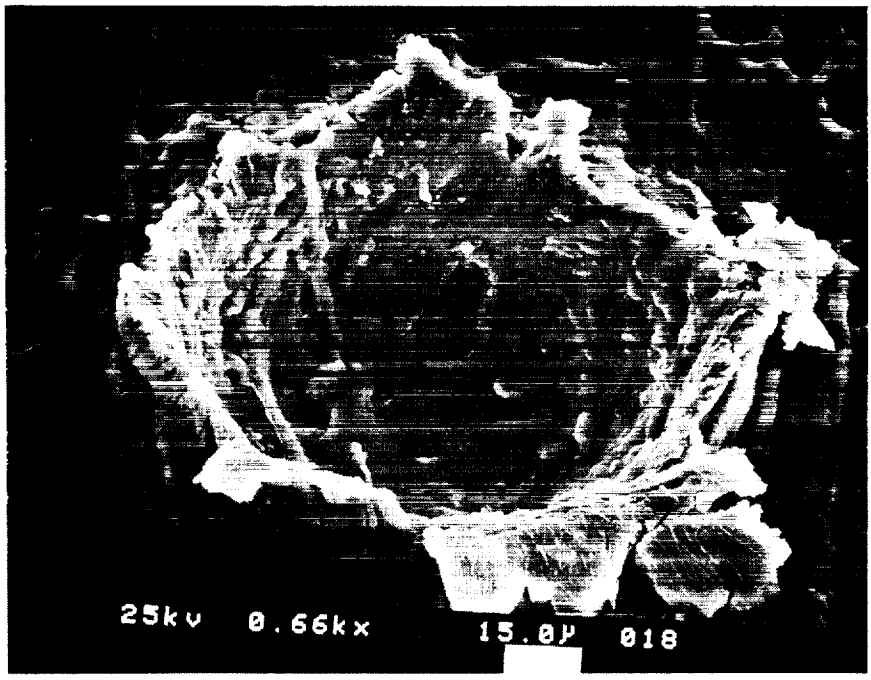

Counts (×10³)
Al
Si
S
Ca
Ca
Fe
Ni
Ni
Ni
4
3
2
1
0
2
4
6
8
10
Range (keV)
A07-C01 003


25kv 0.67kx 15.0μ 016


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

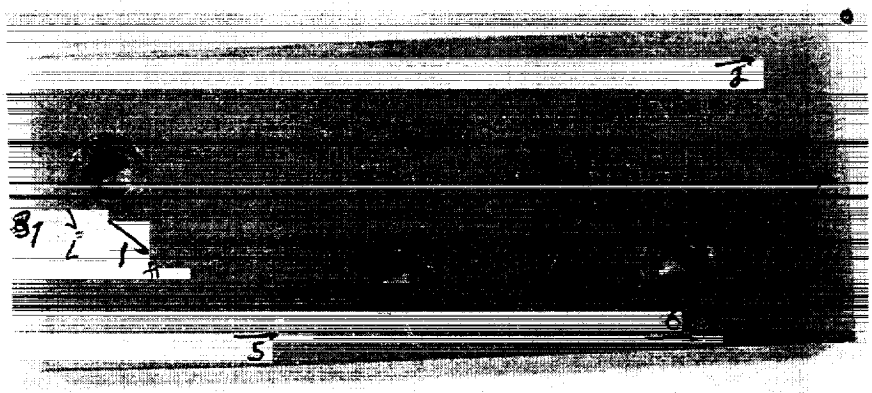

25kv 0.45kx 22.0µ 017

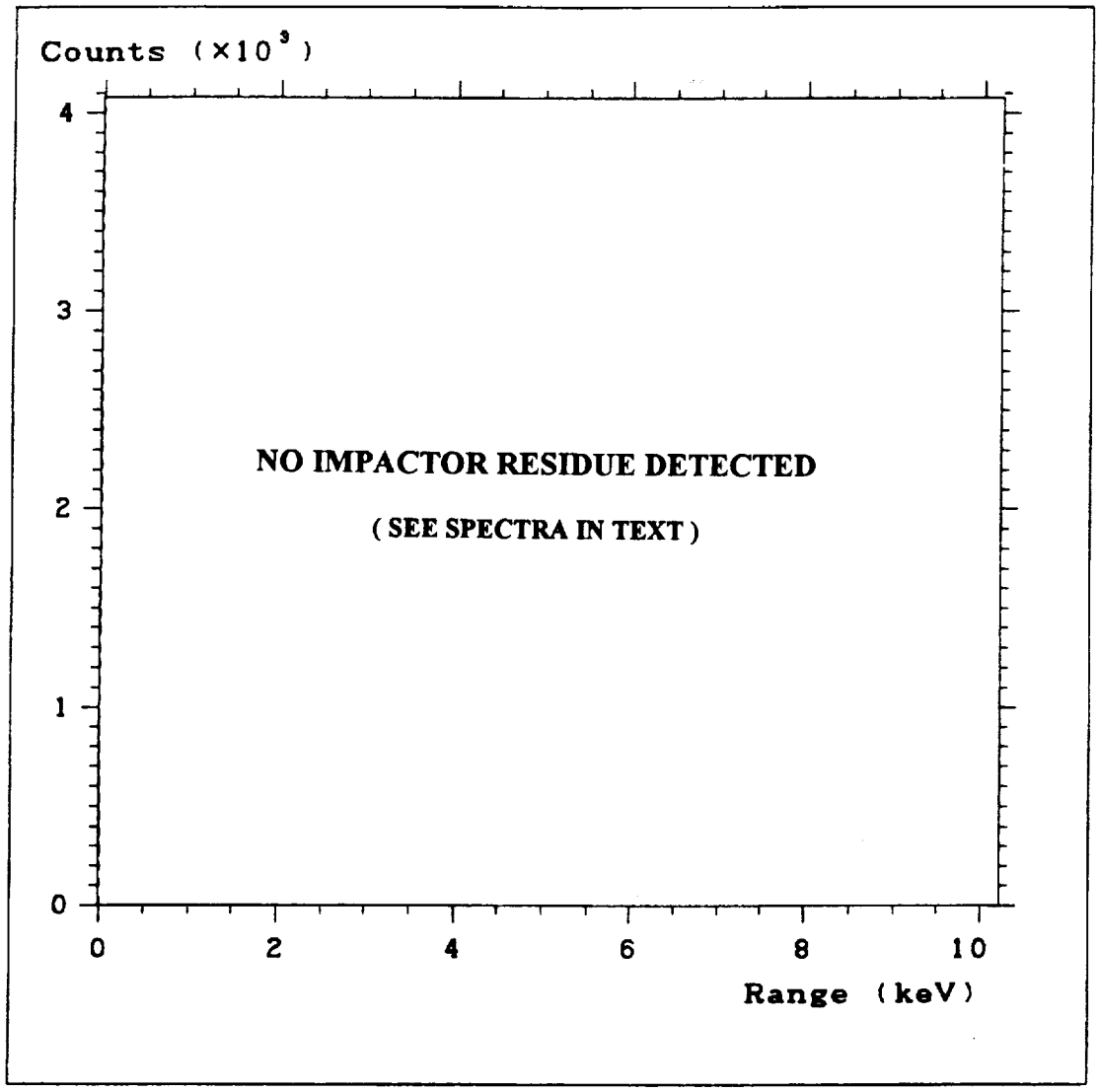

Counts (×10³)
4
3
2
1
0
Al
Si
Mg
Ca
Fe
K
K
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A07-C01 005

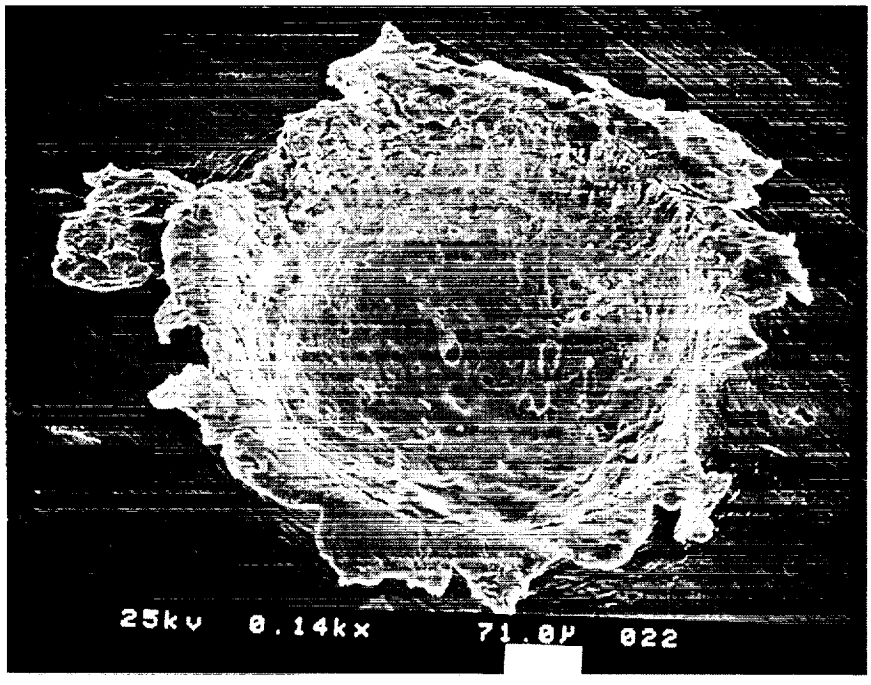

25kv 0.66kx 15.0μ 018

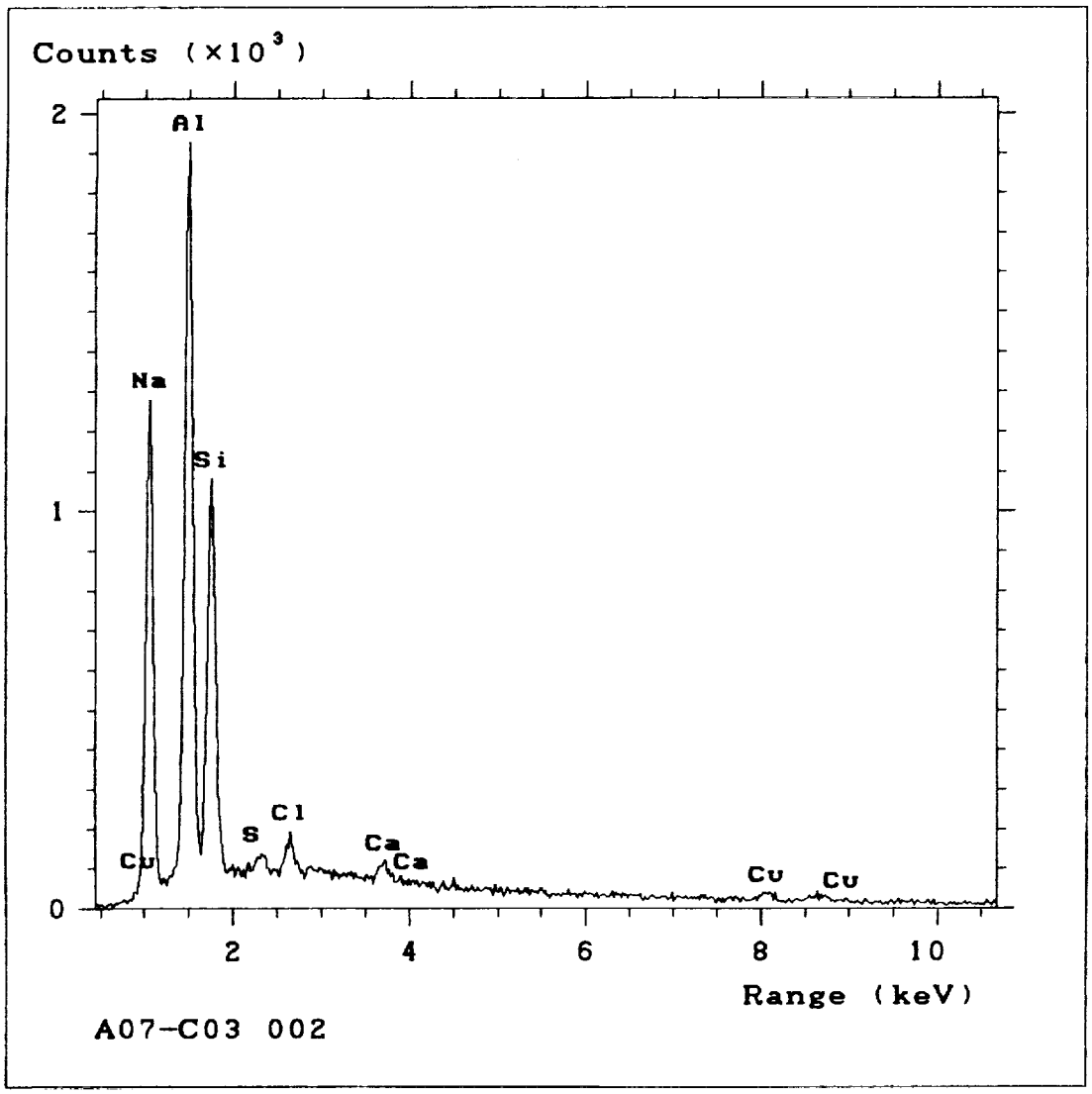
CLAMP NUMBER A07 CO3

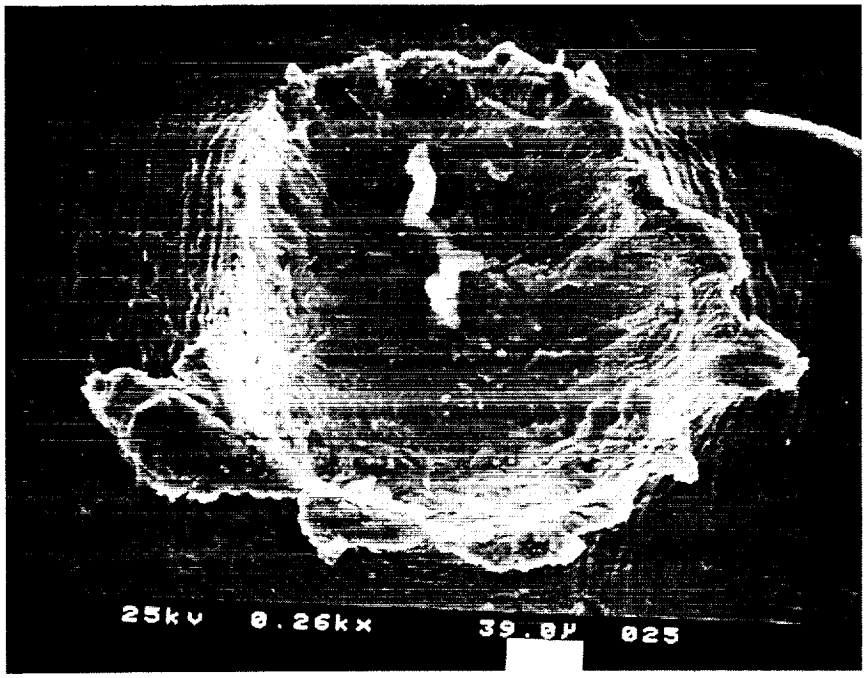
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	380	Unkown
002	260	Contamination
003	N/A	No Impact
004	40	Unkown
005	180	Paint
006	400	Unkown
007	40	Contamination

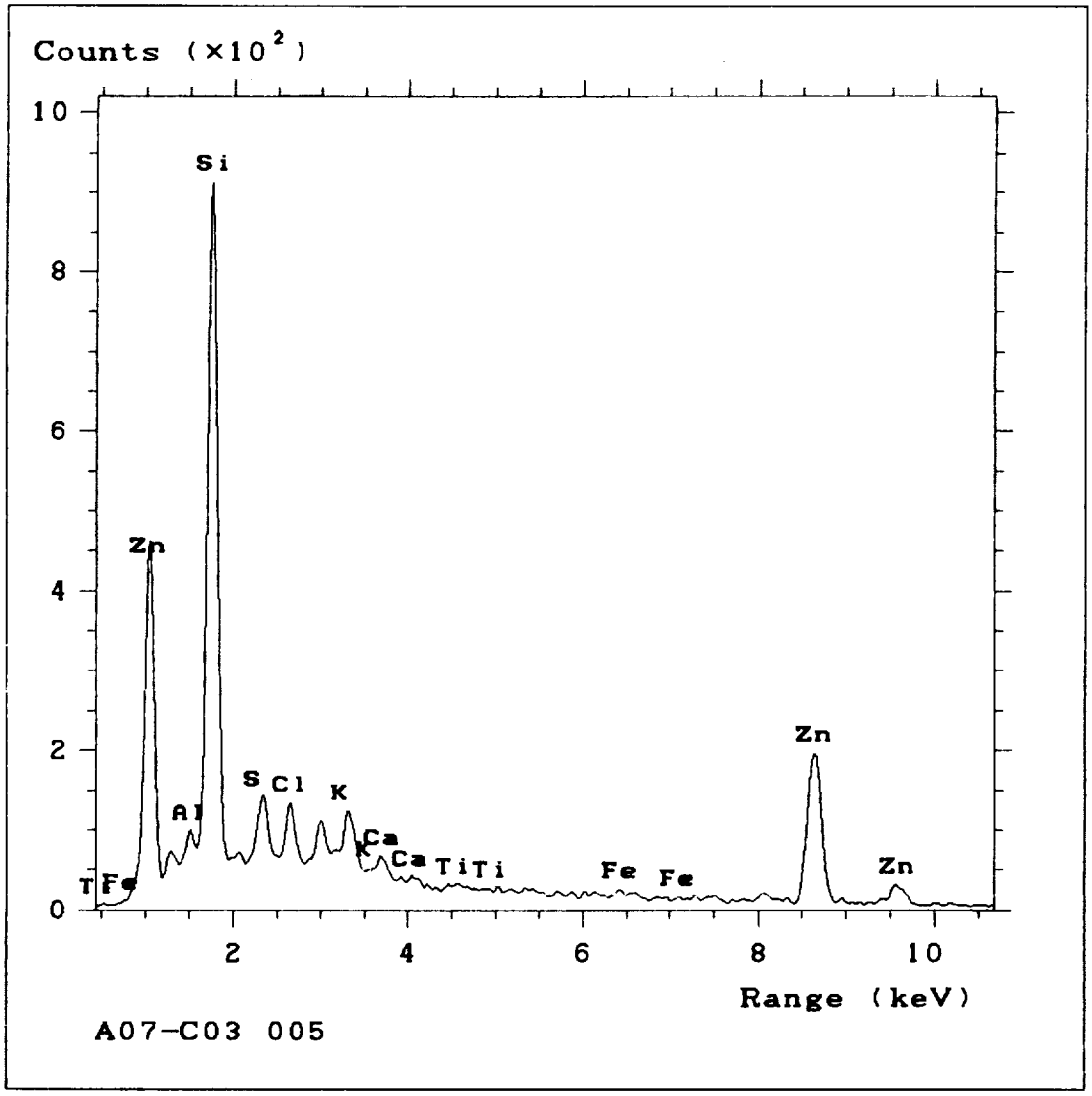


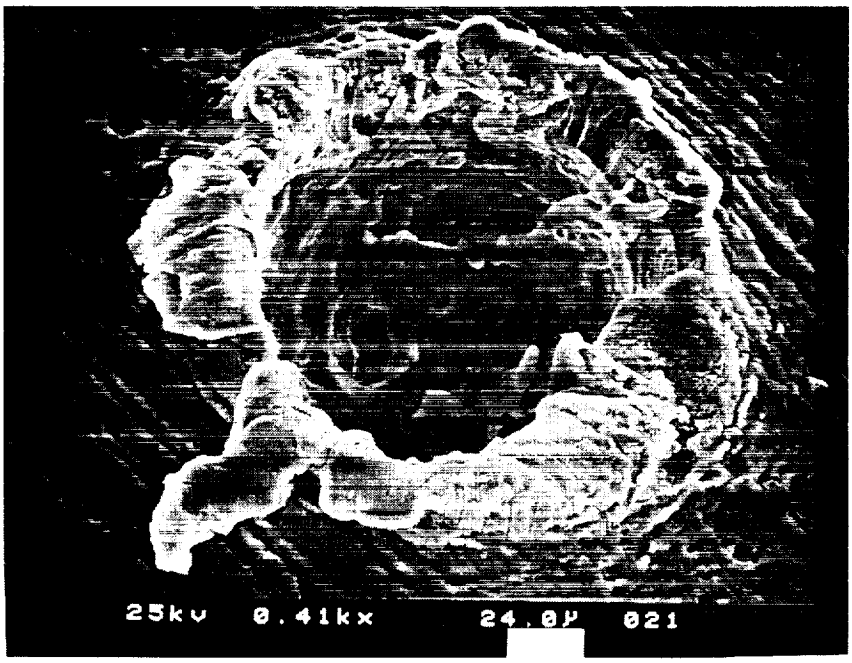

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

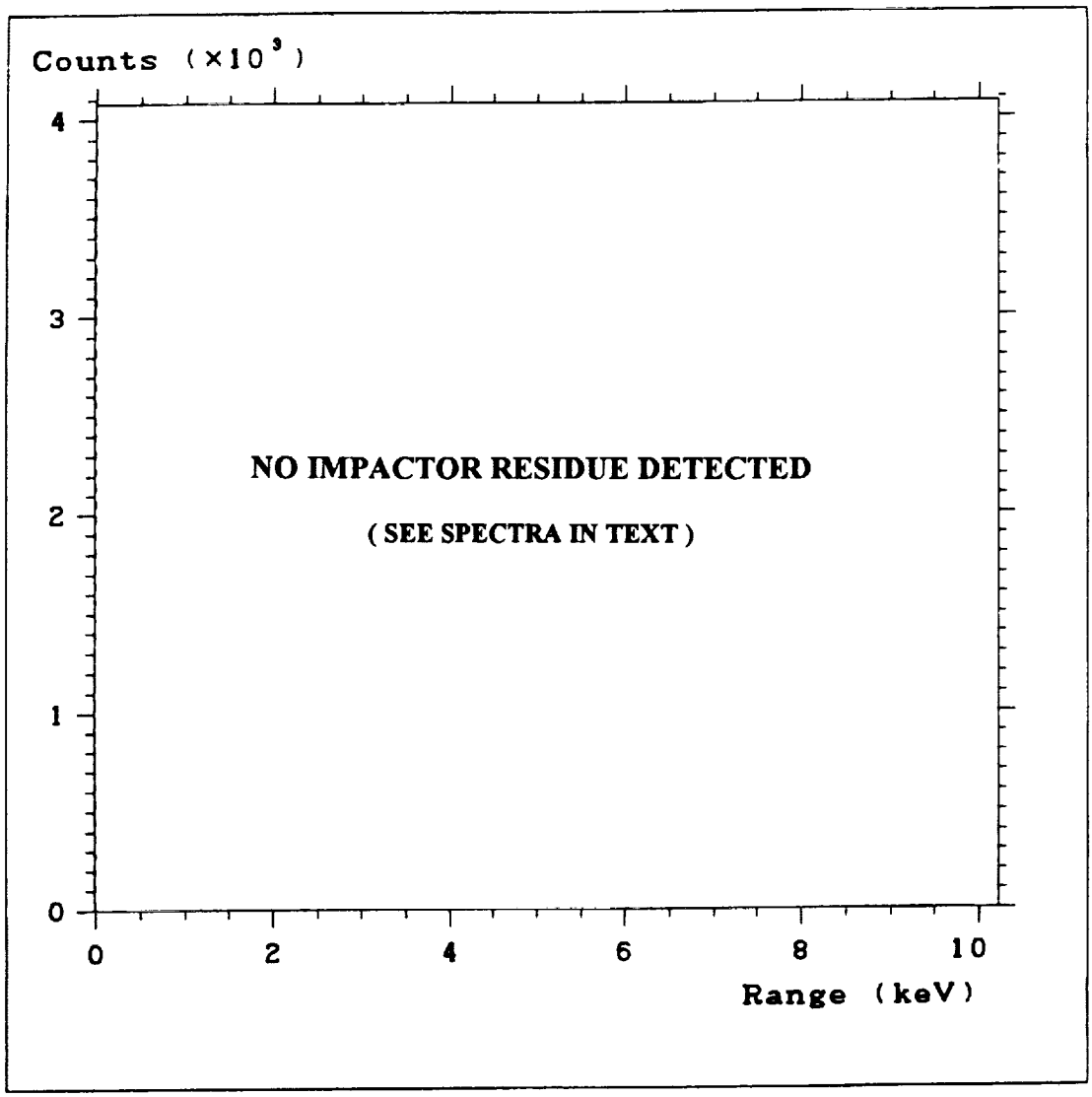

25kv 0.14kx 71.0µ 022

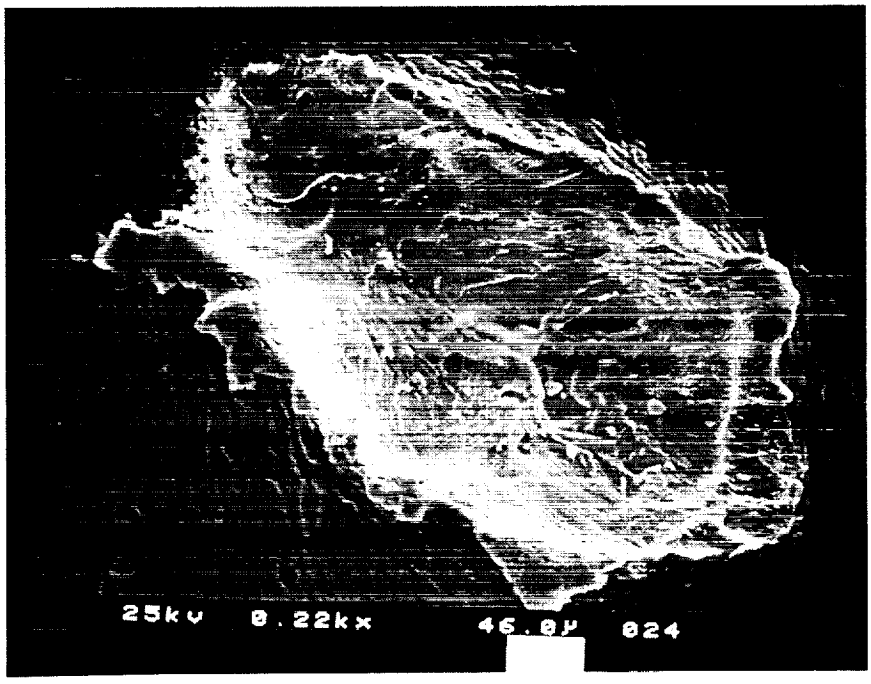

Counts (×10³)
2
1
0
Al
Na
Si
S
Cl
Ca
Ca
Cu
Cu
Cu
2
4
6
8
10
Range (keV)
A07-C03 002

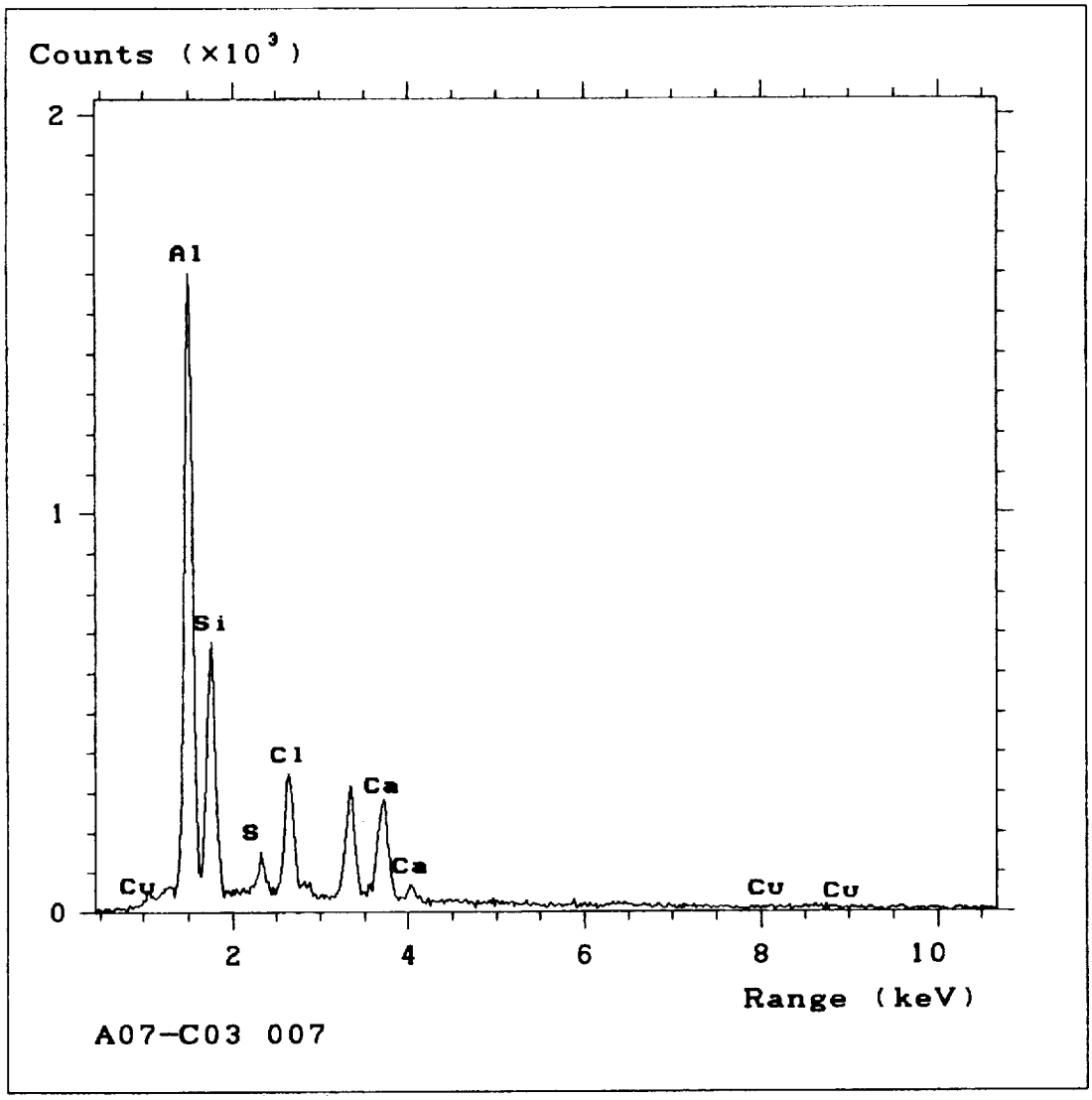

25kv 0.26kx 39.0µ 025

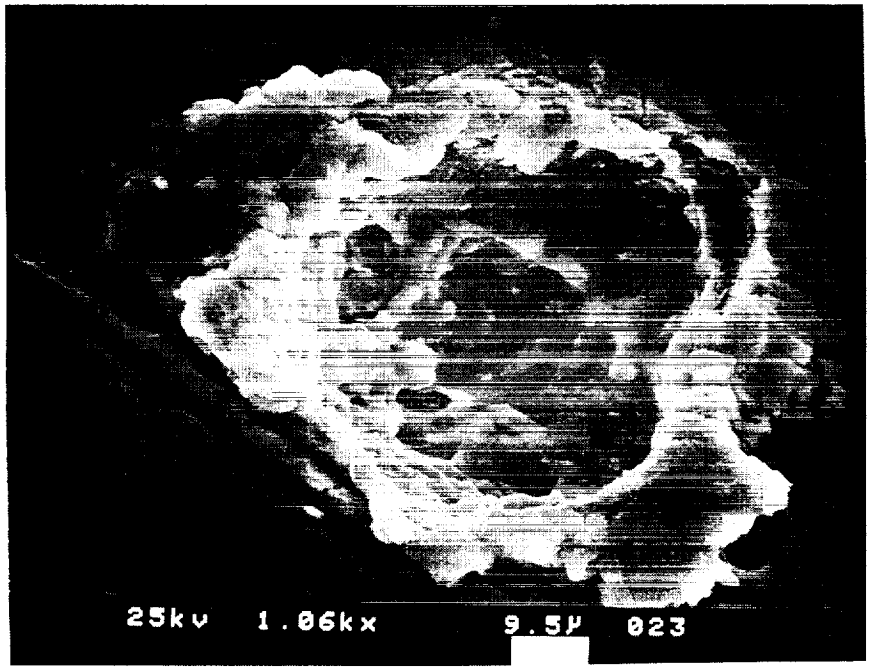

Counts (×10²)
10
8
6
4
2
0
Si
Zn
Al
S Cl K
Ca
Ca
Ti Ti
Fe Fe
Zn
Zn
T Fe
2
4
6
8
10
Range (keV)
A07-C03 005


25kv 0.41kx 24.0µ 021


Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

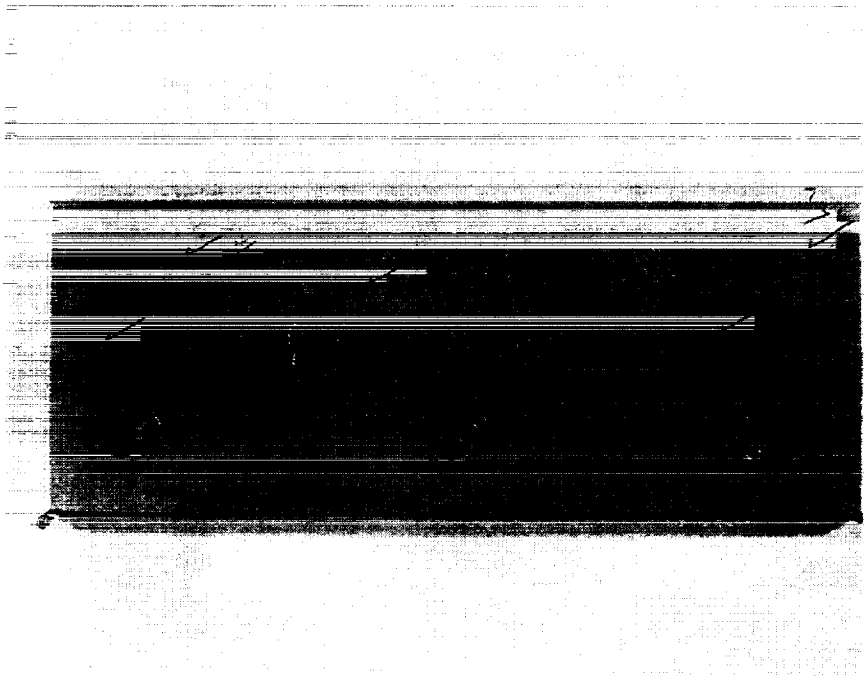

25kv 0.22kx 46.0µ 024

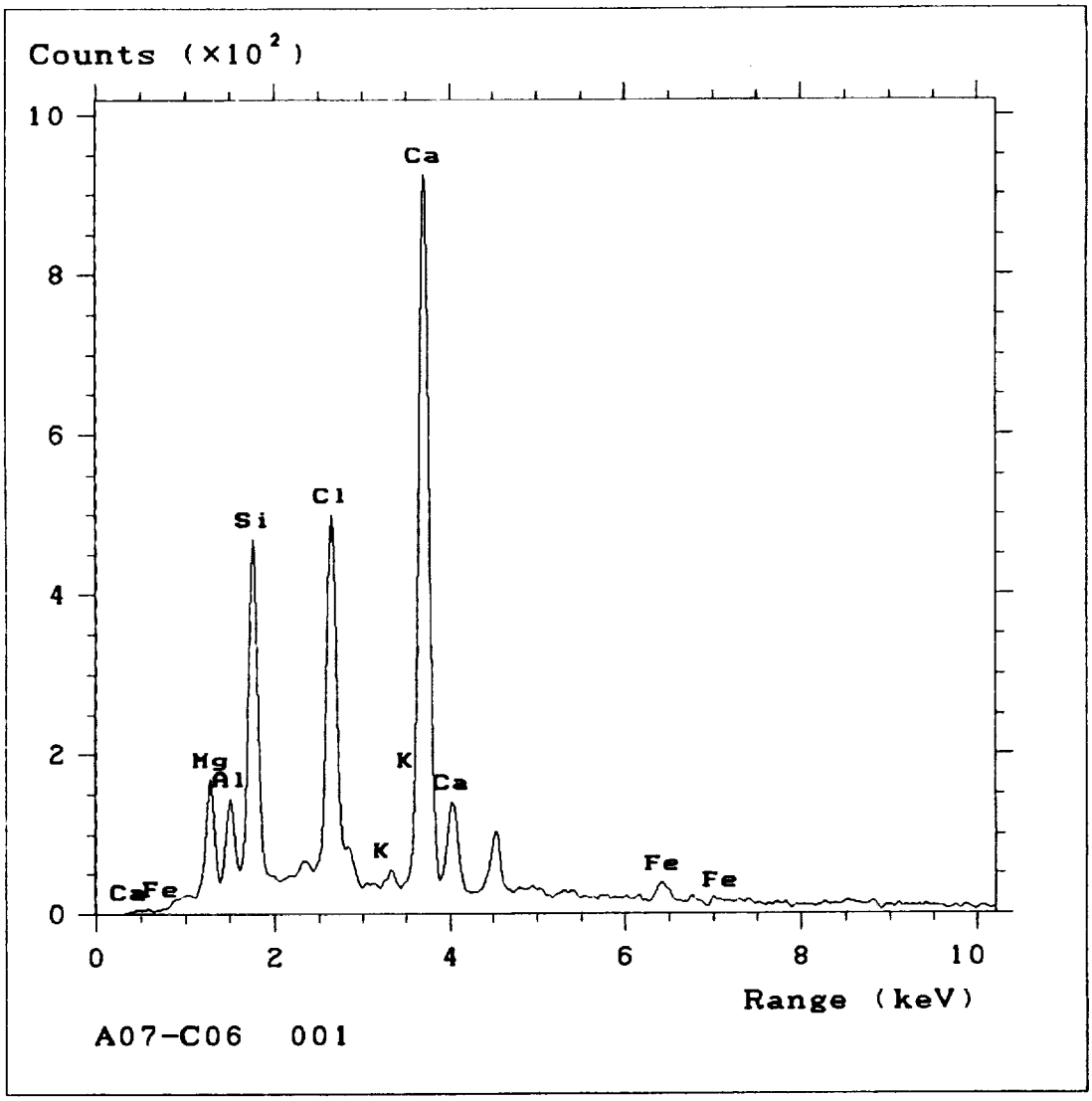

Counts (×10³)
2
1
0
Al
Si
S
Cl
Ca
Ca
Cu
Cu
Cu
2
4
6
8
10
Range (keV)
A07-C03 007

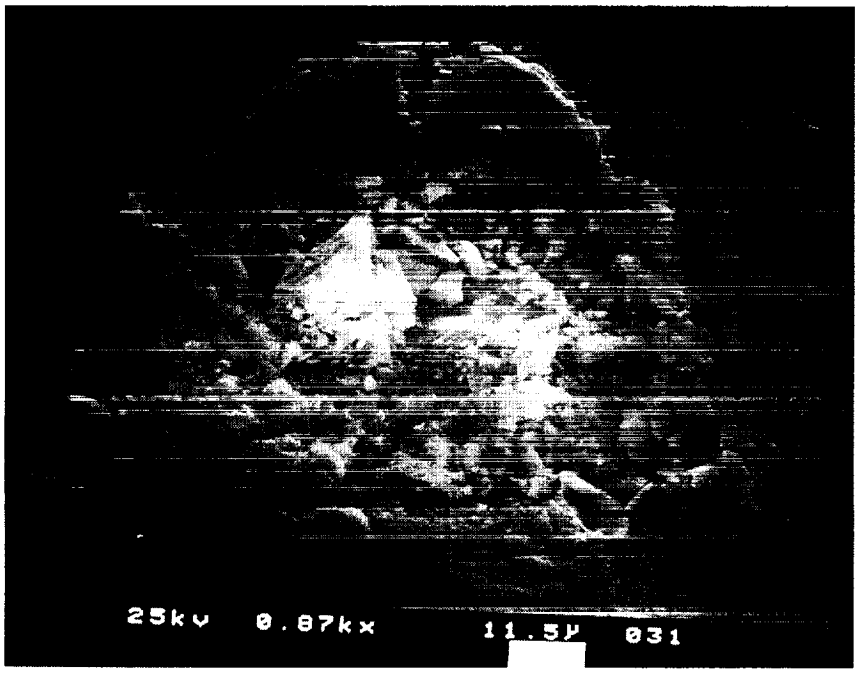

25kv 1.06kx 9.5μ 023

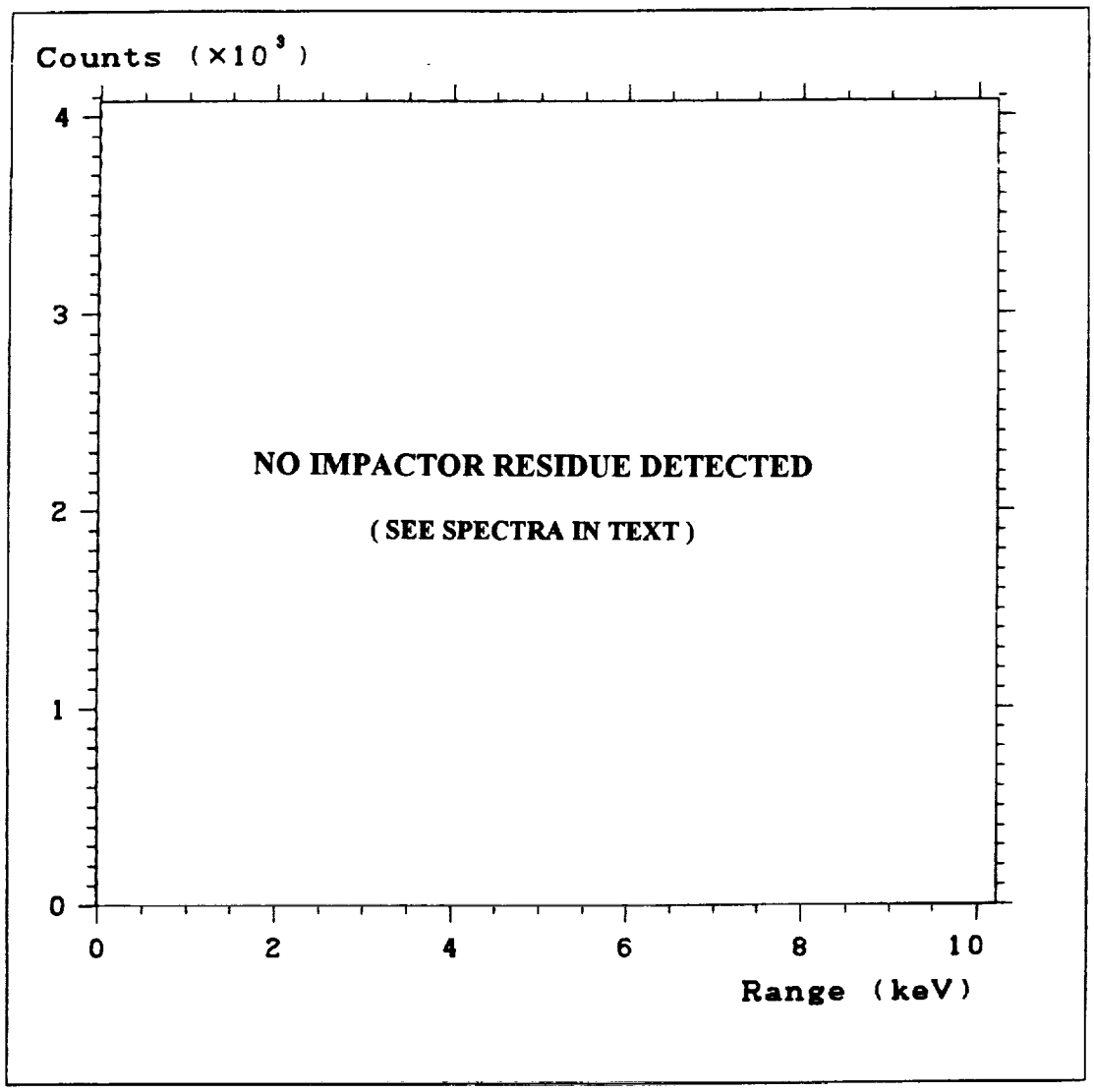
CLAMP NUMBER A07 CO6

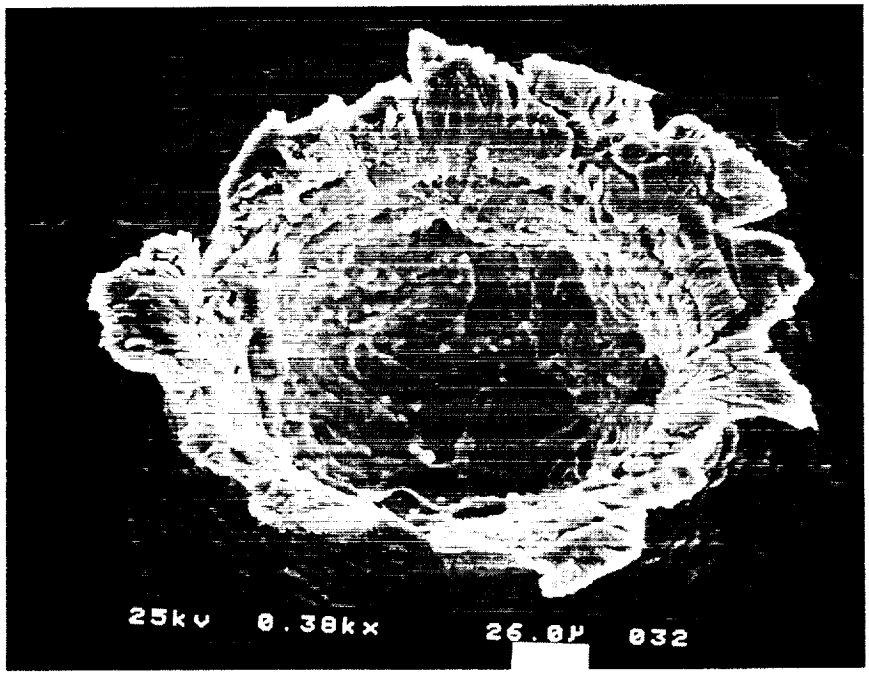
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	100	Contamination
002	220	Unkown
003	200	Si, Ca, Na, Mg, Fe
004	240	Unkown
005	100	Fe, Ni, Cr
006	150	Unkown
007	300	Trace
008	150	Unkown

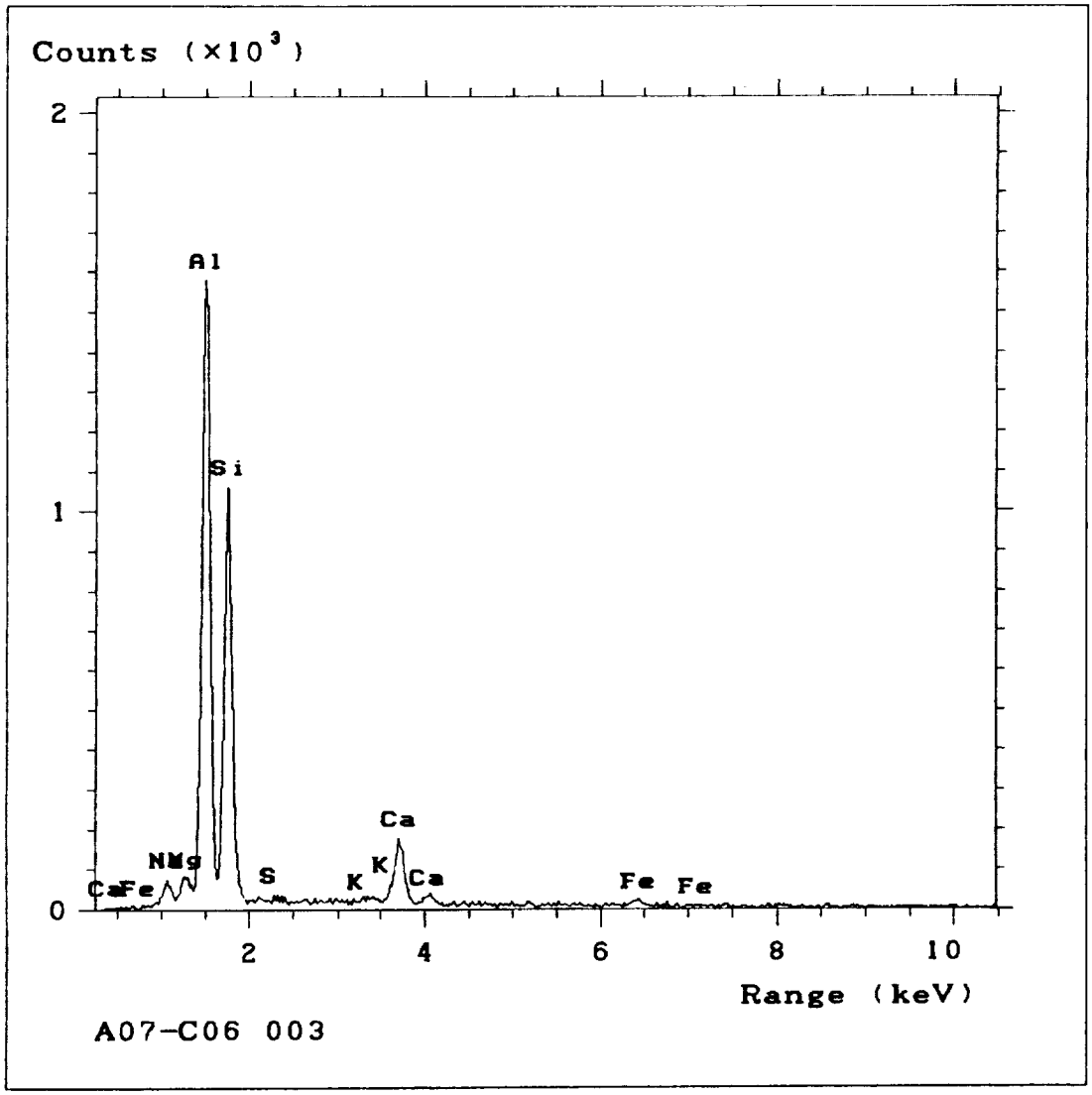


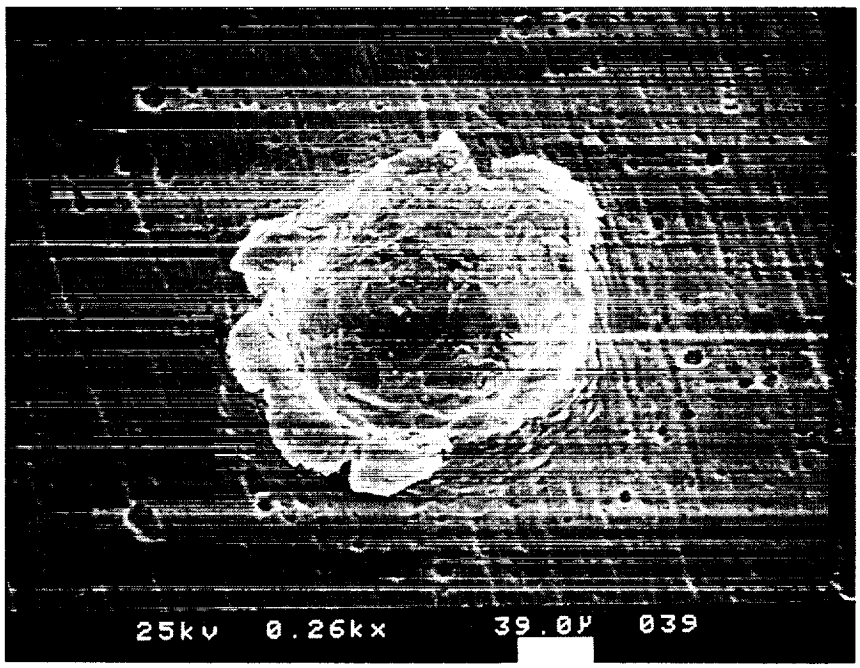

Counts (×10²)
10
8
6
4
2
0
Ca
Si
Cl
Mg
Al
K
K
Ca
Ca
Fe
Fe
Fe
0
2
4
6
8
10
Range (keV)
A07-C06 001

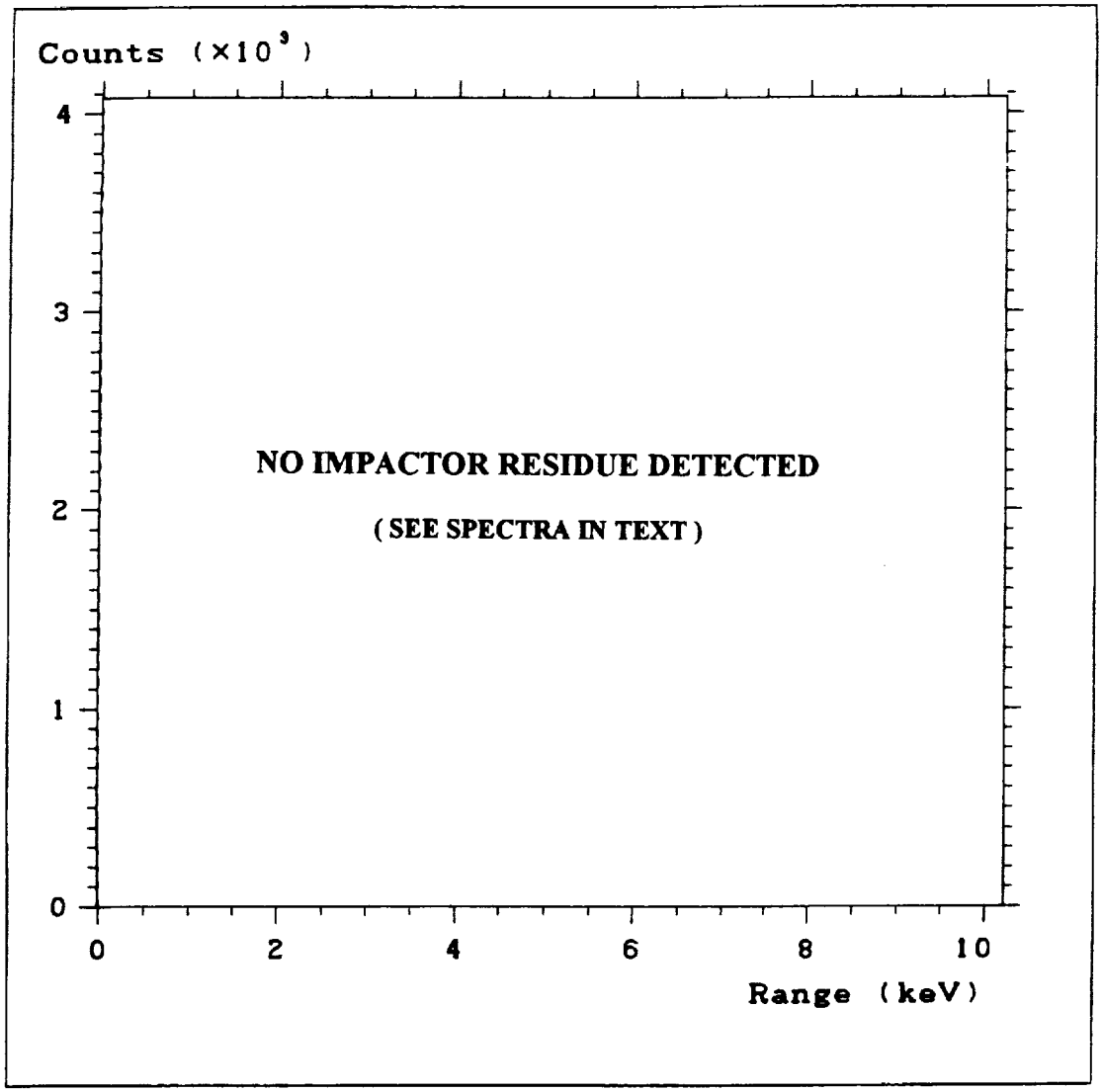

25kv 0.87kx 11.5μ 031

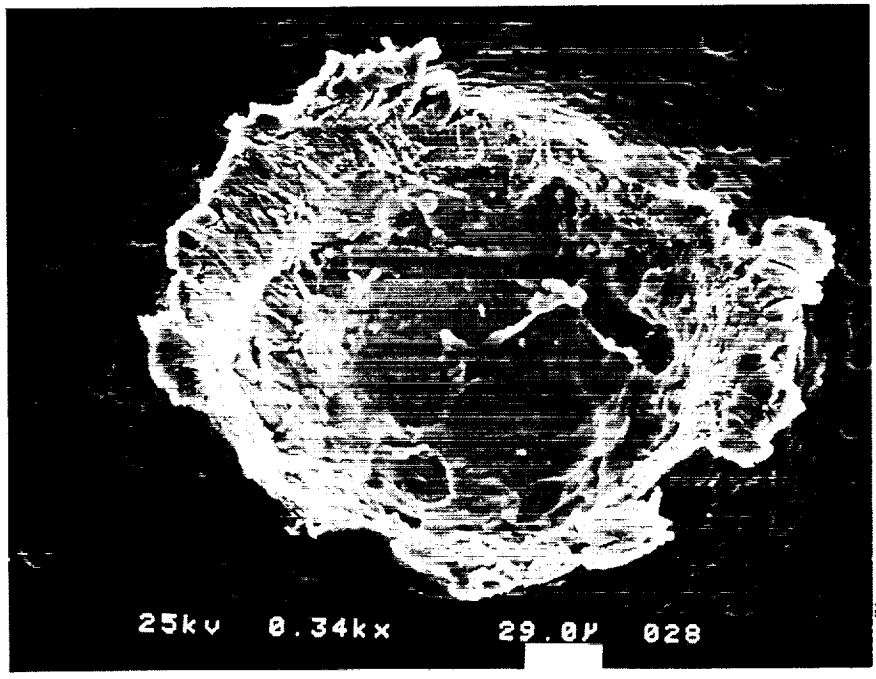

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

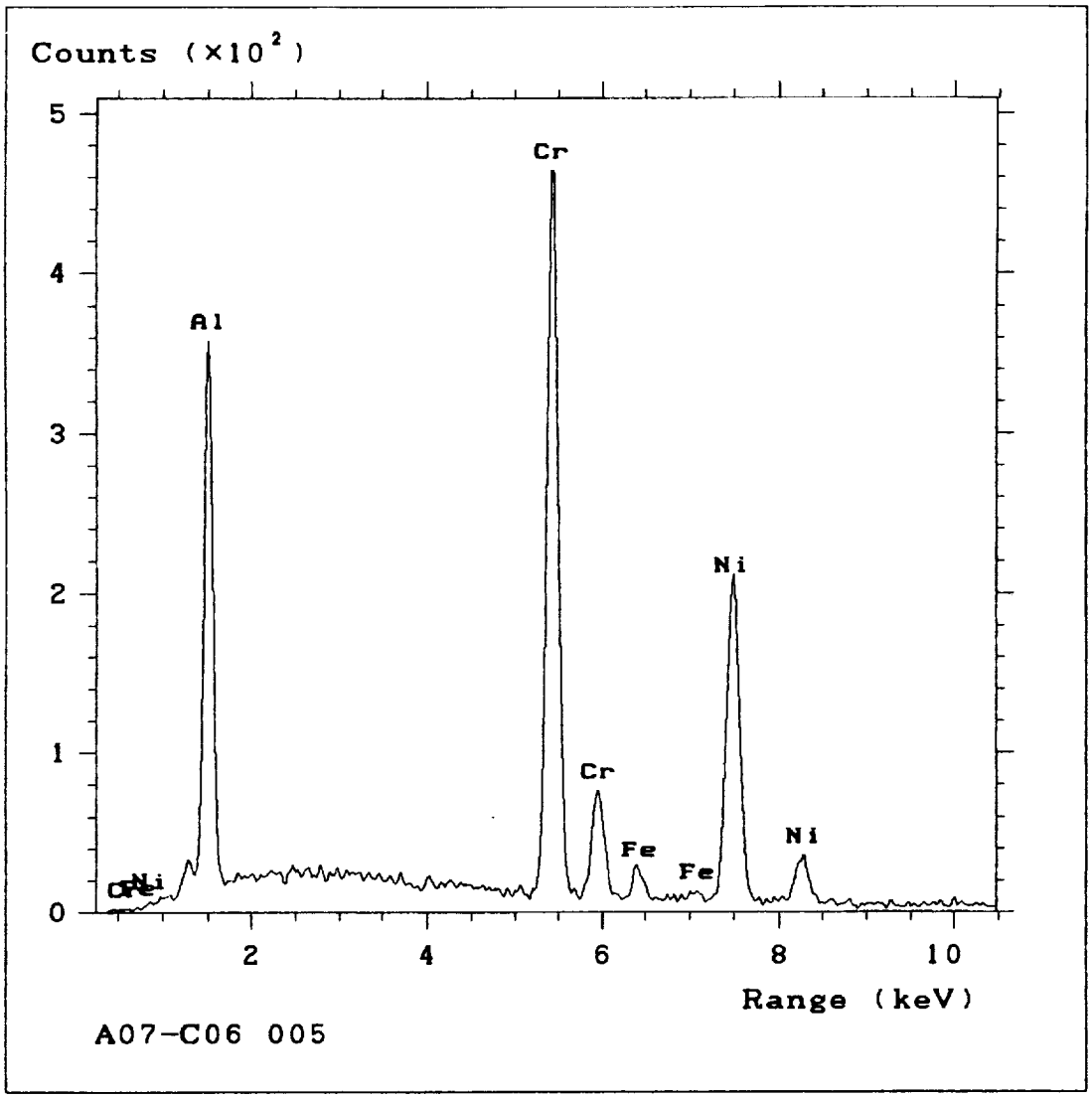

25kv 0.38kx 26.0µ 032

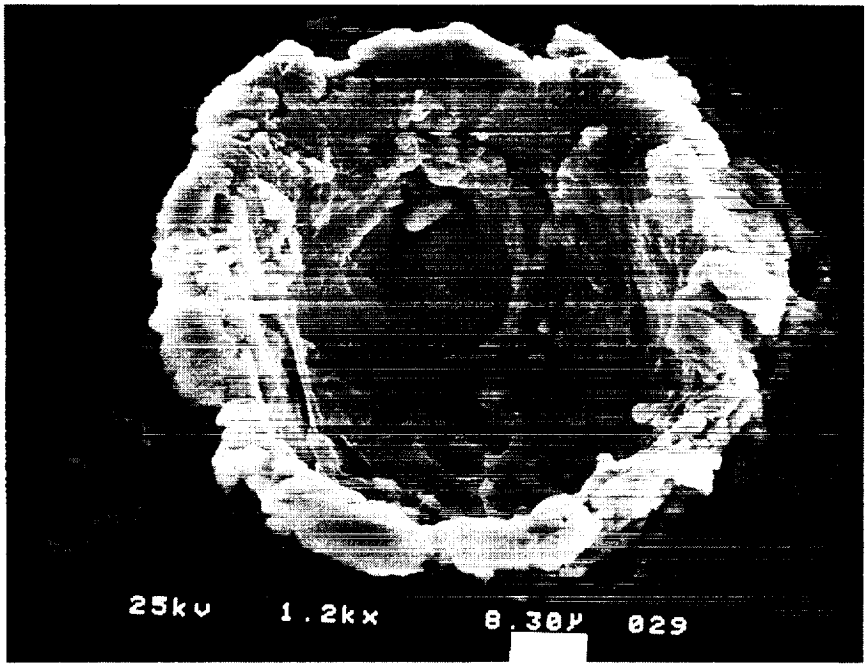

Counts (×10³)
2
1
0
Al
Si
Ca
K
K
Ca
S
Fe
Fe
Fe
Mg
2
4
6
8
10
Range (keV)
A07-C06 003

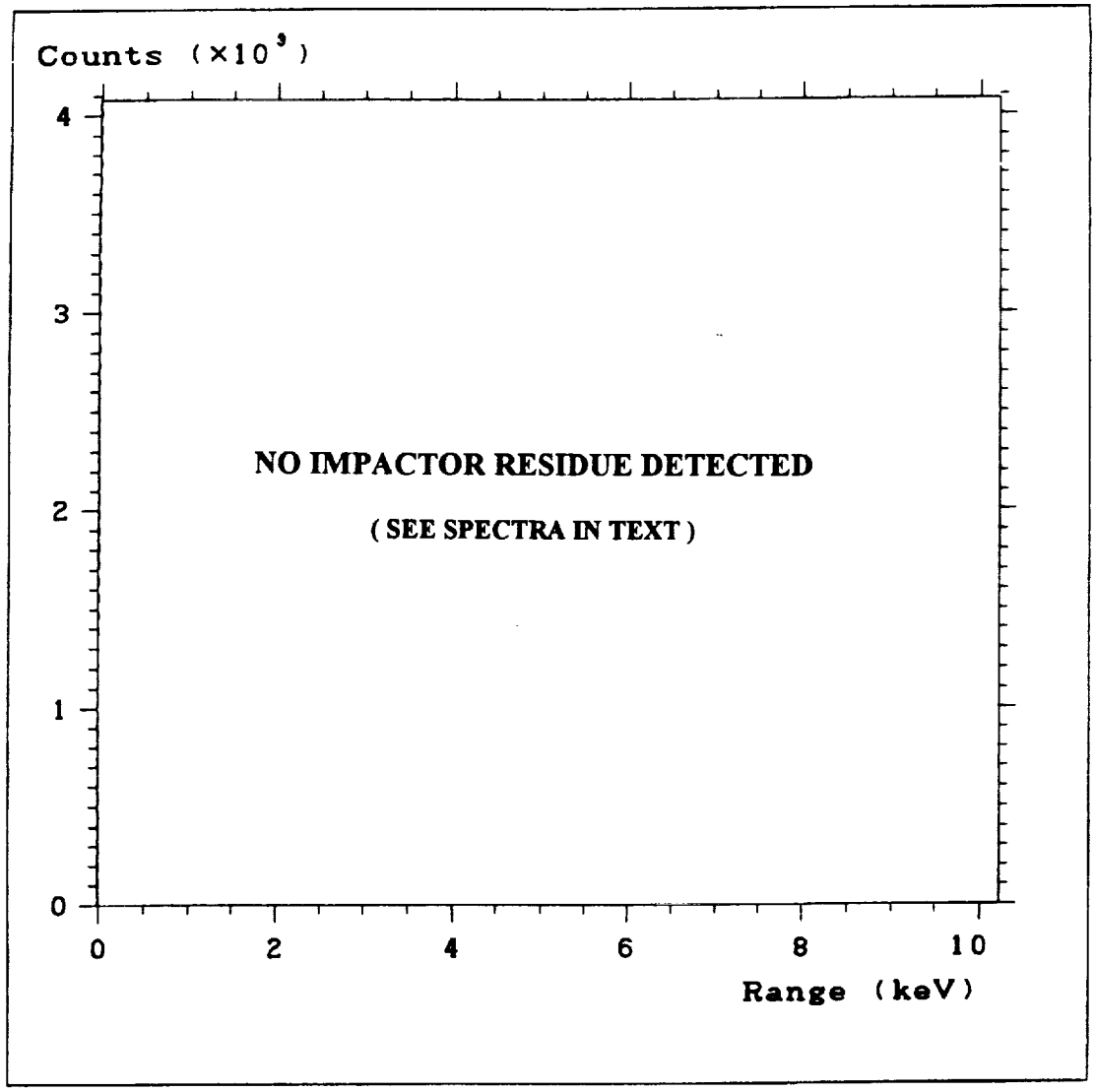

25kv 0.26kx 39.0μ 039

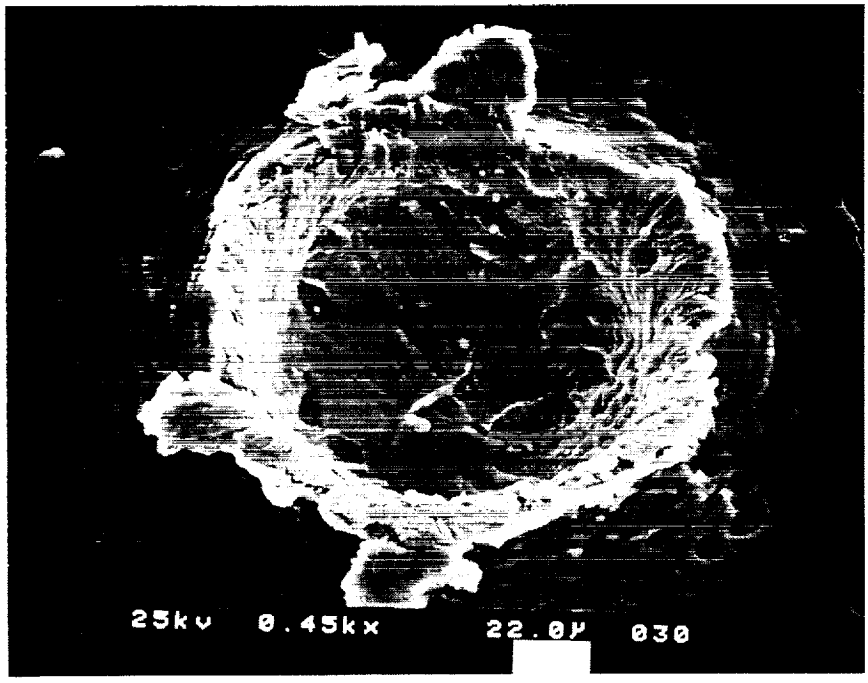

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

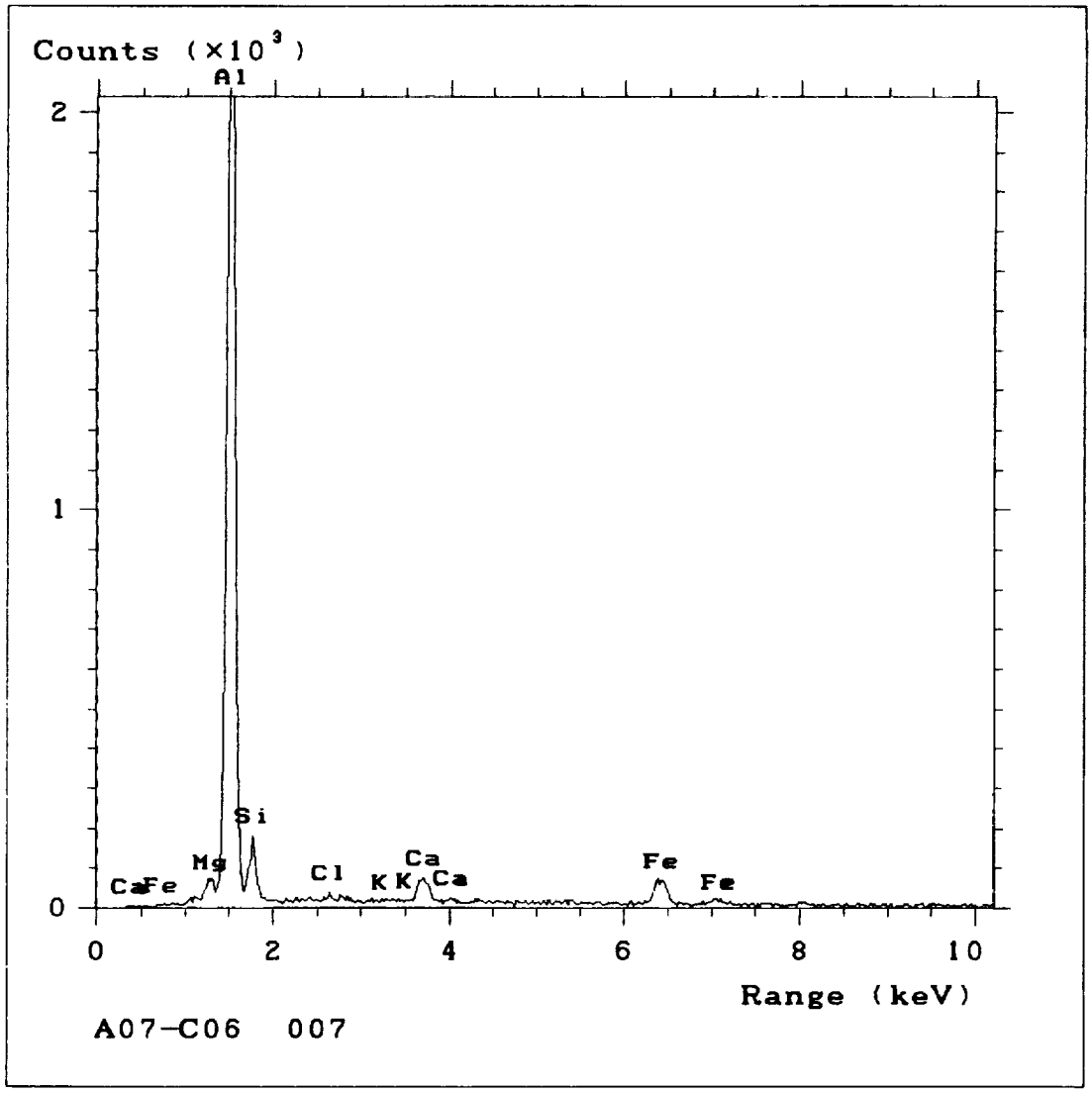

25kv 0.34kx 29.0µ 028

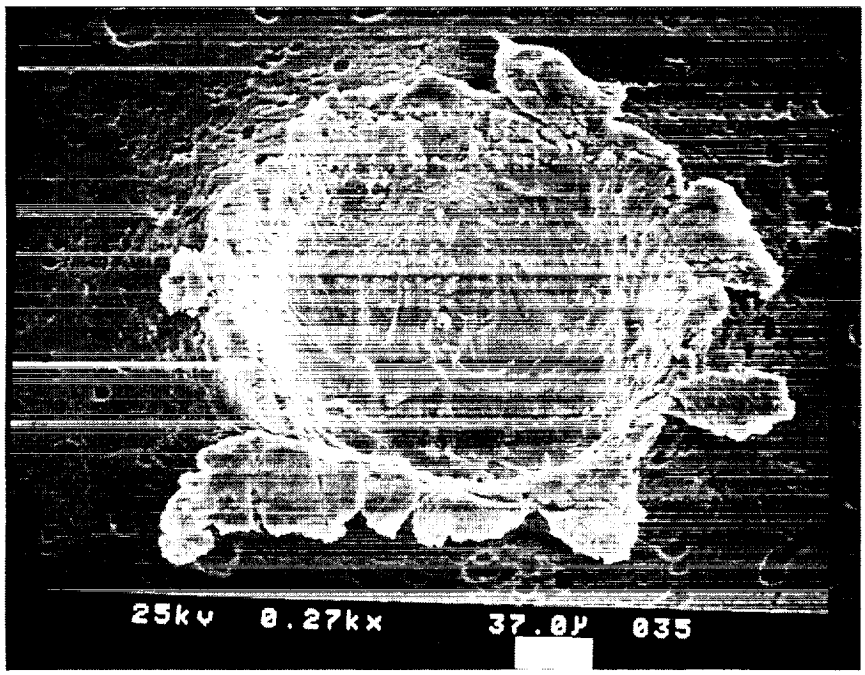

Counts (×10²)
5
4
3
2
1
0
Al
Cr
Cr
Fe
Fe
Ni
Ni
Ni
2
4
6
8
10
Range (keV)
A07-C06 005

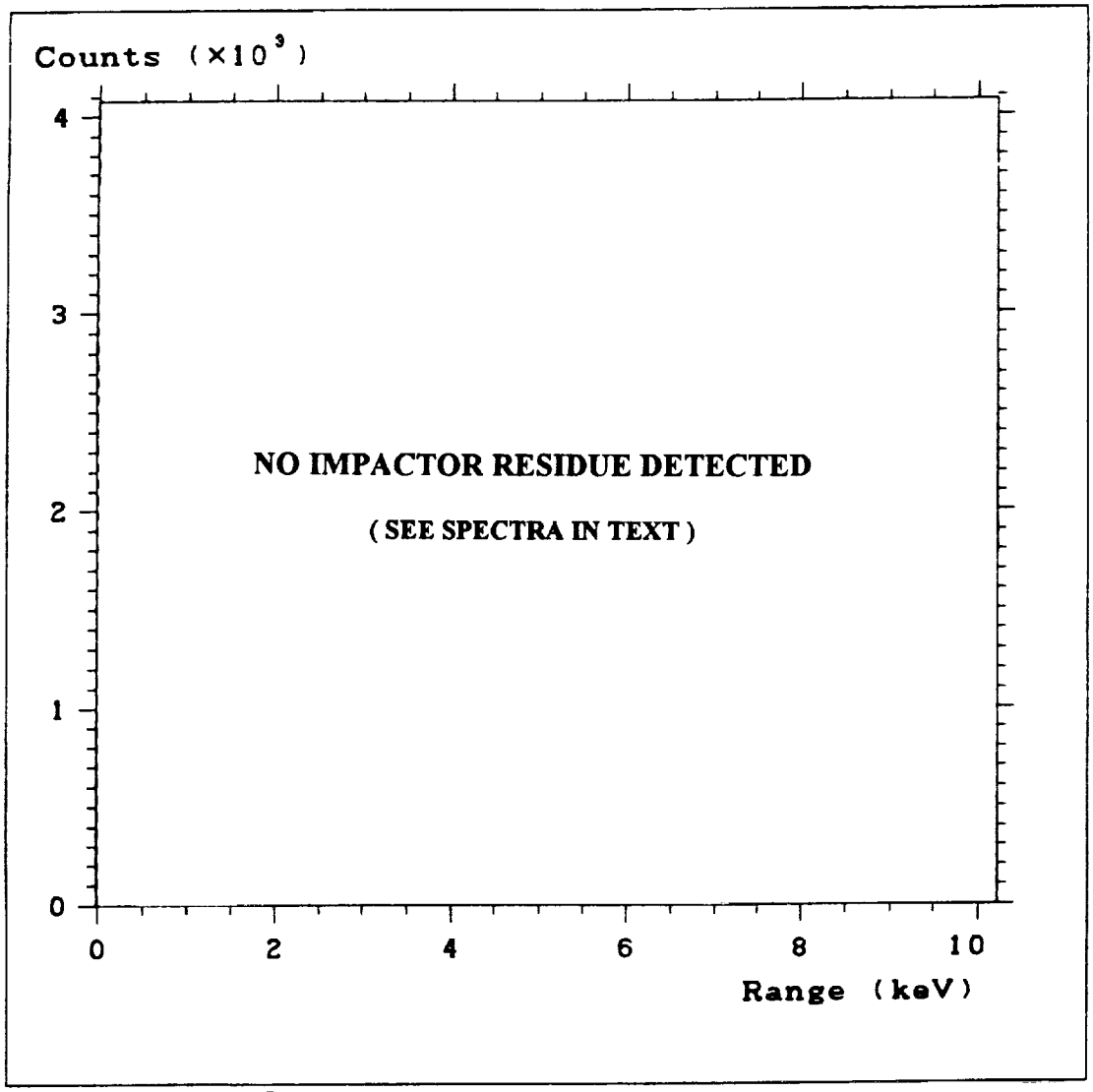

25kv 1.2kx 8.30µ 029

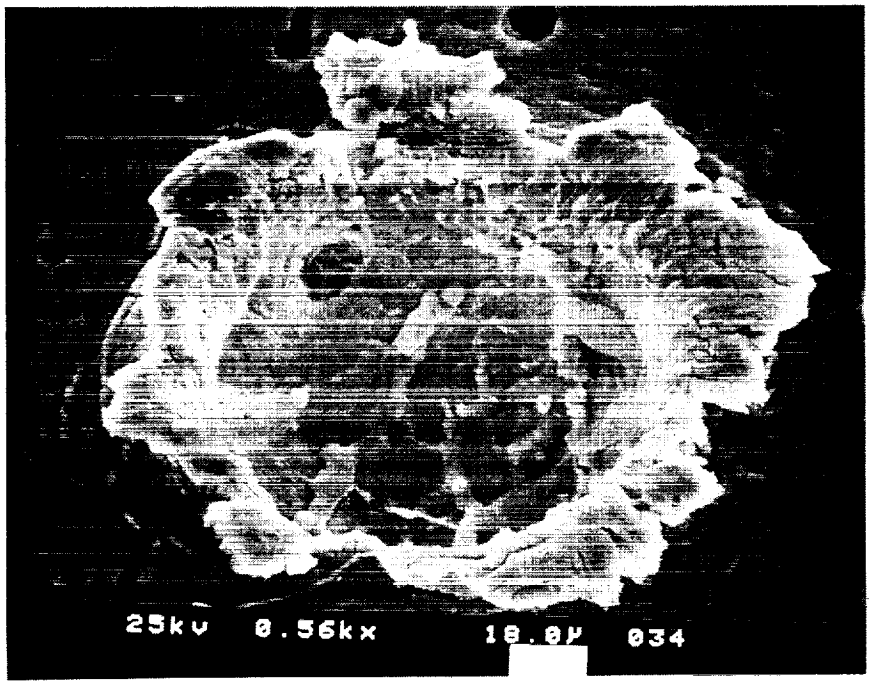

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 0.45kx 22.0µ 030


Counts (×10³)
Al
2
1
0
Si
Mg
Ca
Fe
Cl
K K
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A07-C06 007

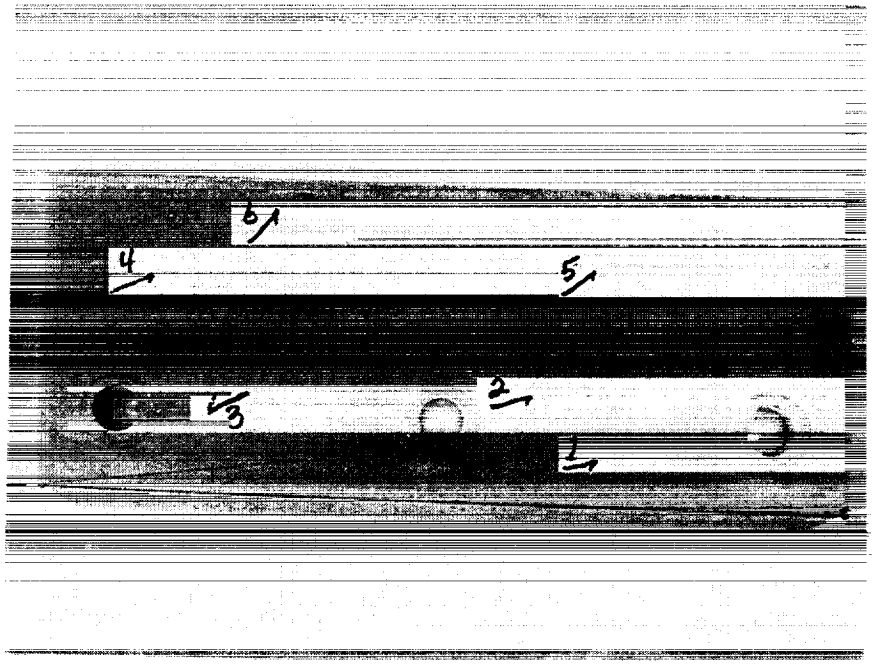

25kv 0.27kx 37.0μ 035

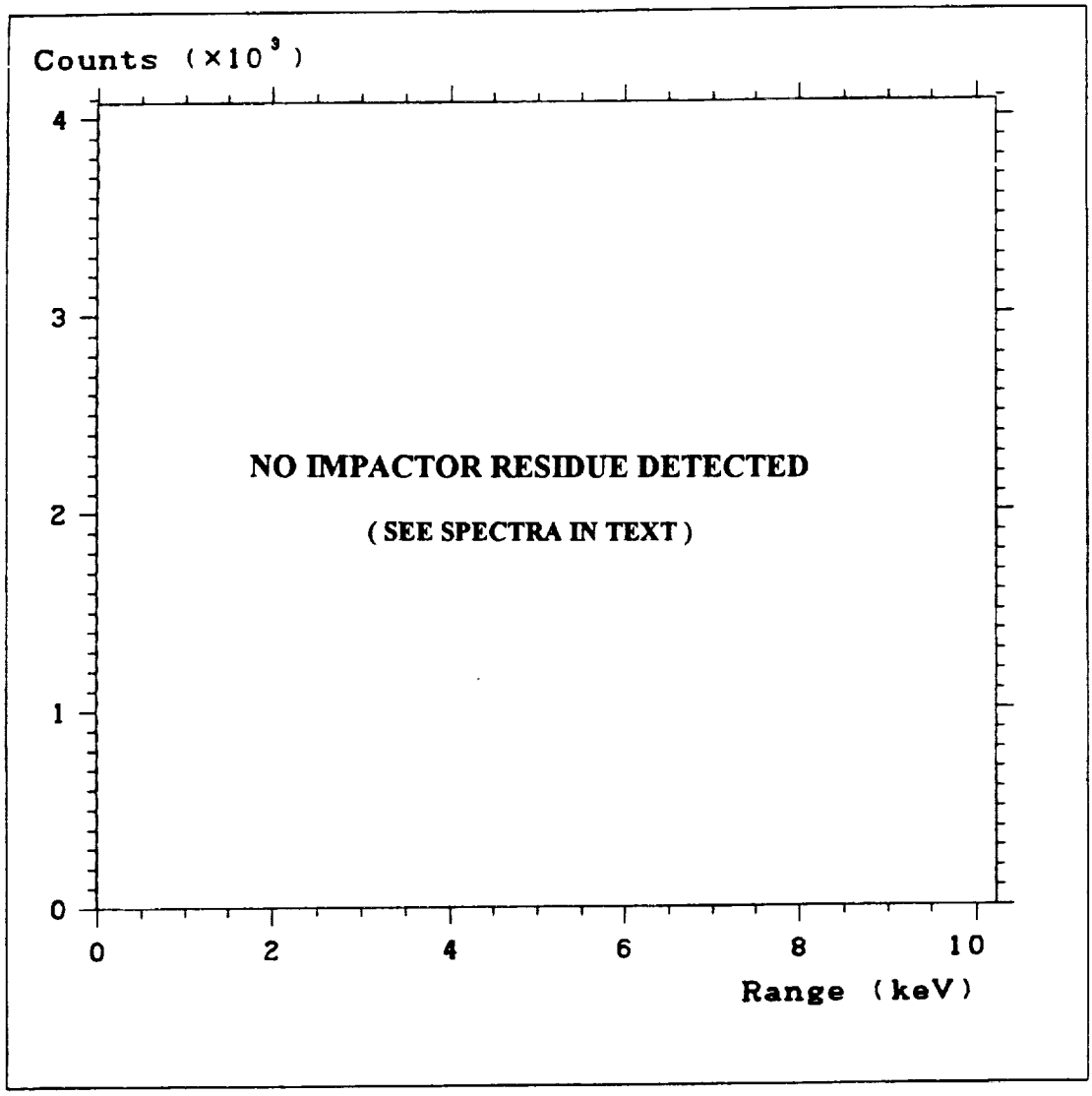

Counts (×10⁹)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

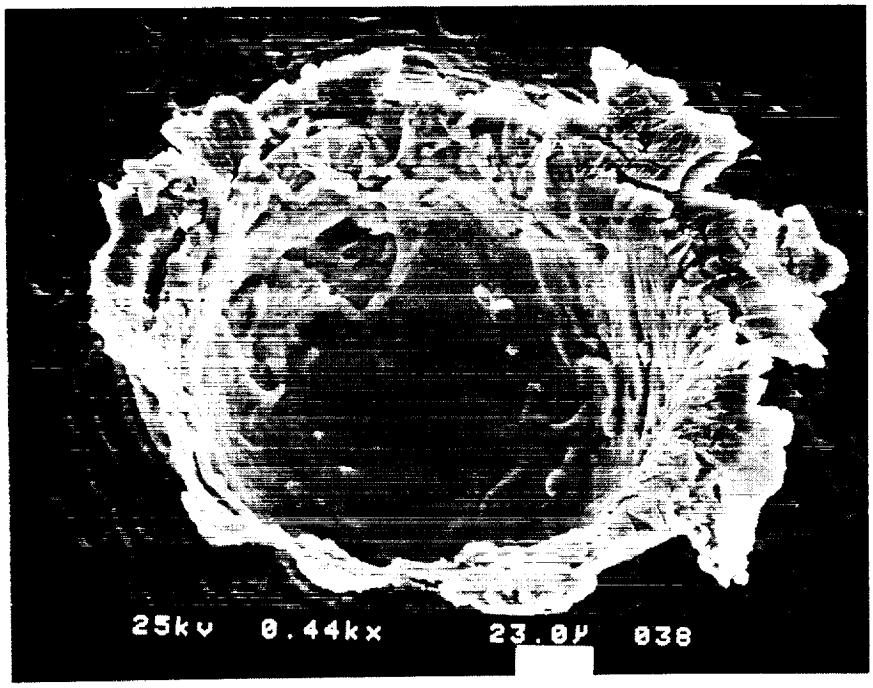

25kV 0.56kx 18.0μ 034

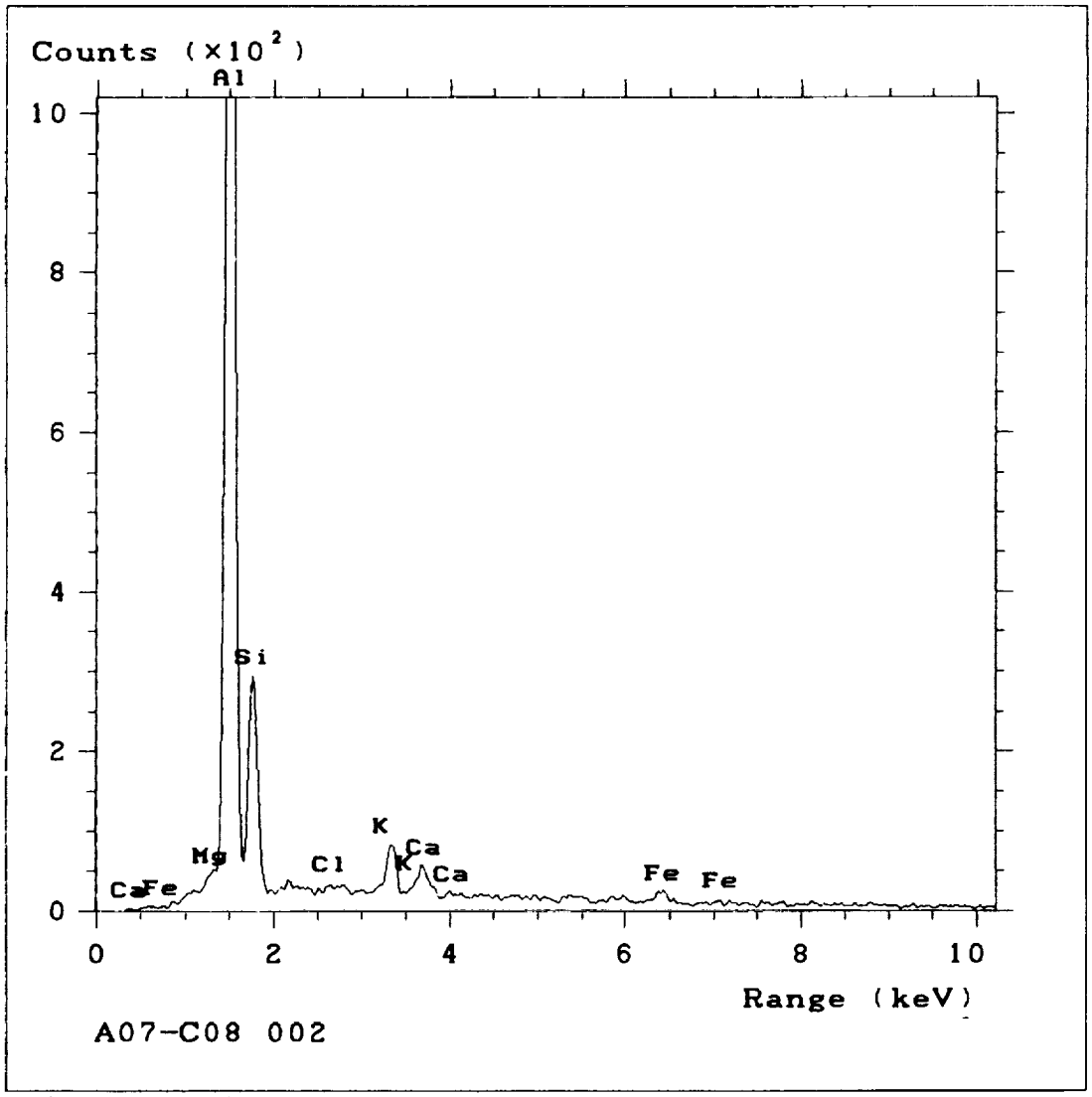
CLAMP NUMBER A07 CO8

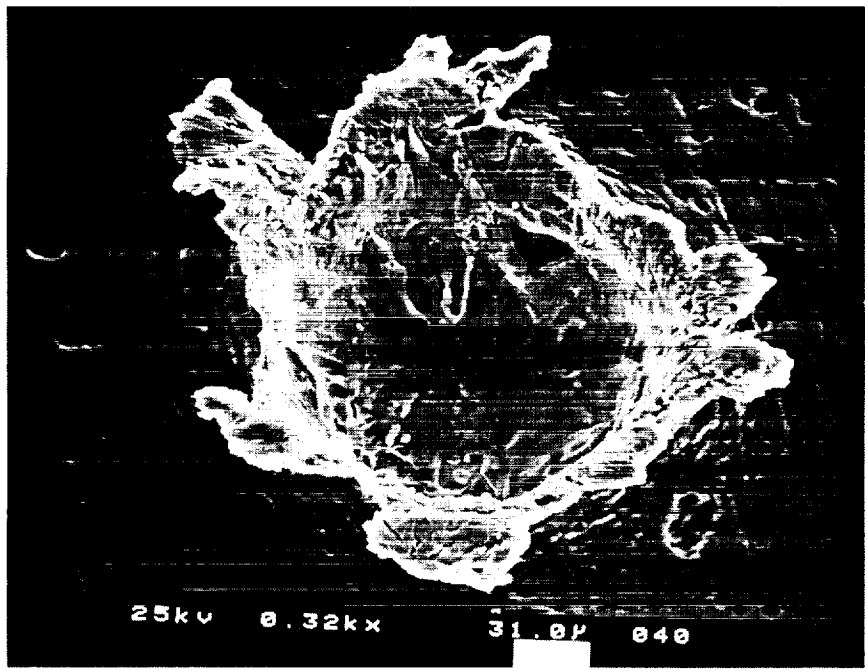
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	200	Unkown
002	220	Trace
003	210	Unkown
004	300	Unkown
005	260	Si, Ca, K, Fe, S, Mg
006	140	Si, Mg, Ca, Fe

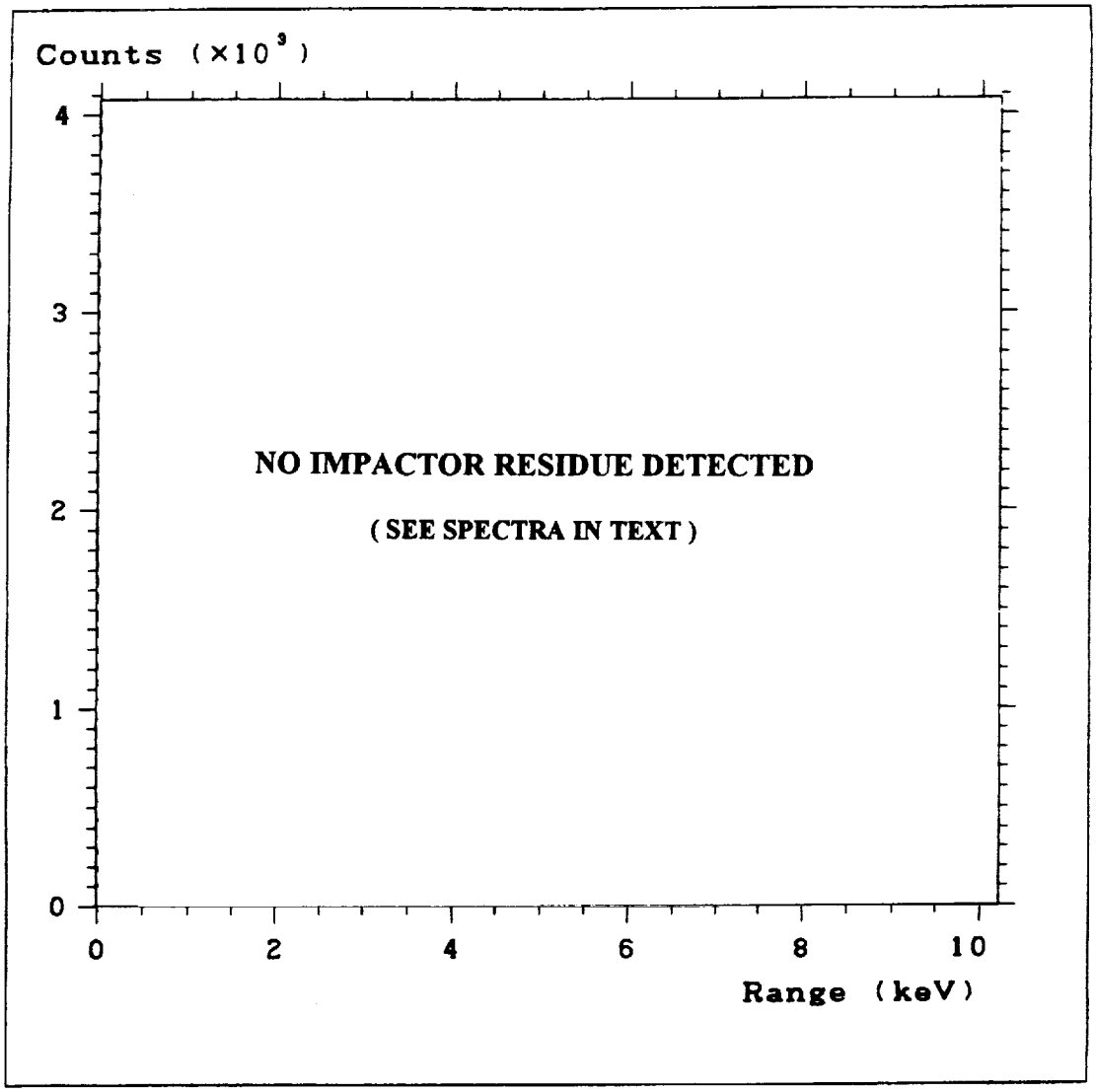


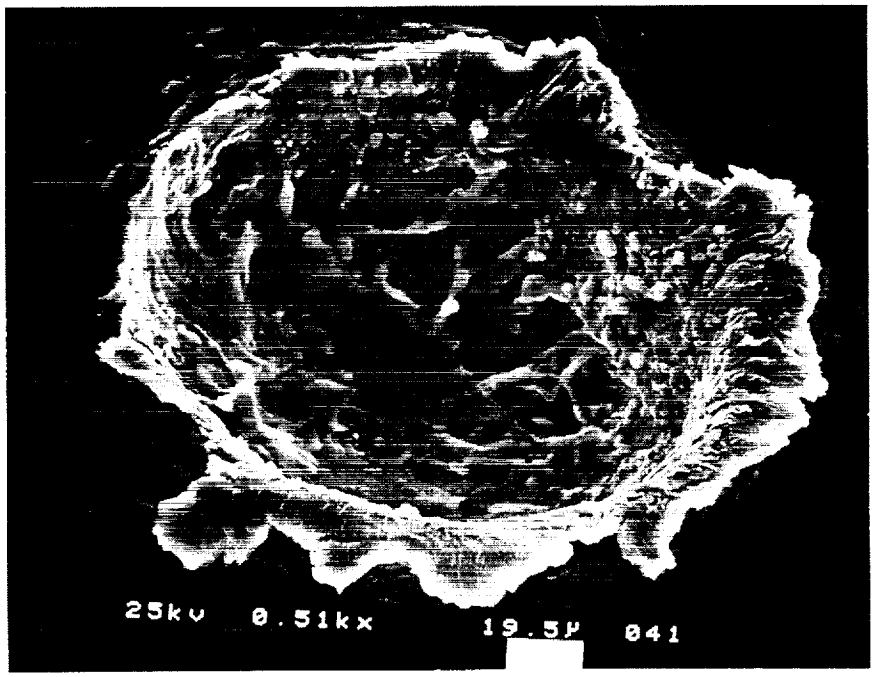

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

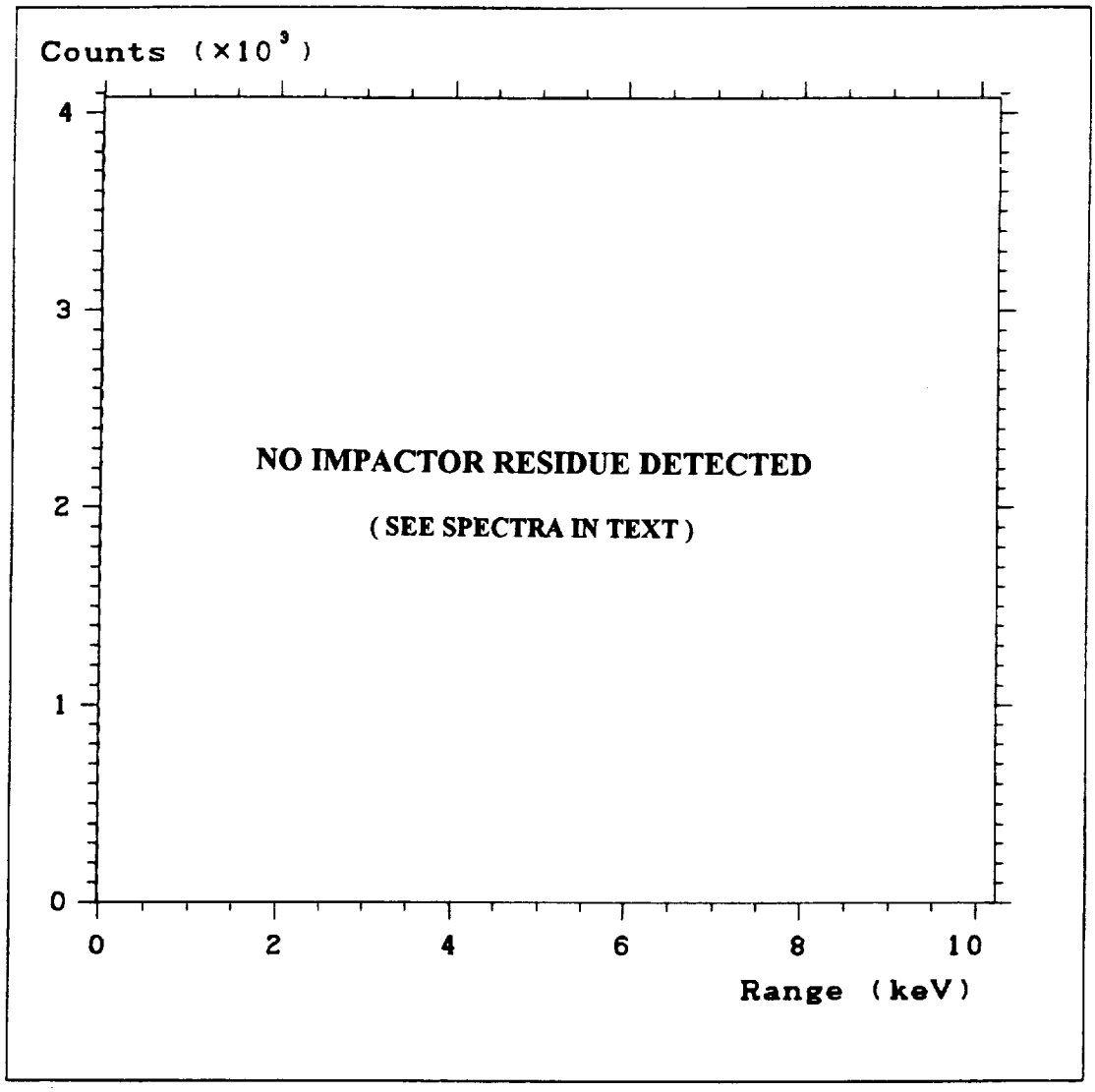

25kv 0.44kx 23.0µ 038

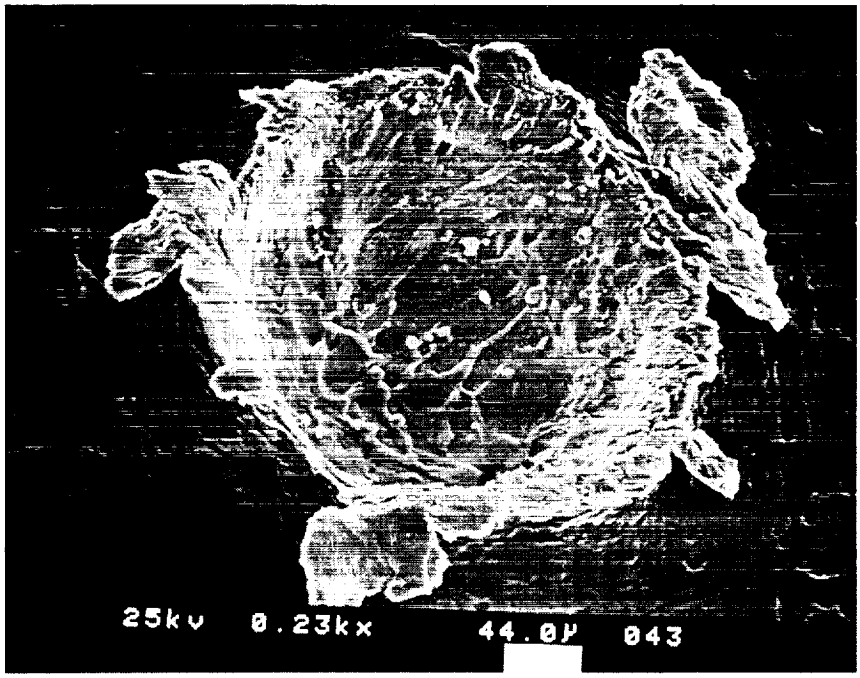

Counts (×10²)
Al
Si
Mg
Cl
K
Ca
Ca
Fe
Fe
Fe
Ca
10
8
6
4
2
0
0
2
4
6
8
10
Range (keV)
A07-C08 002

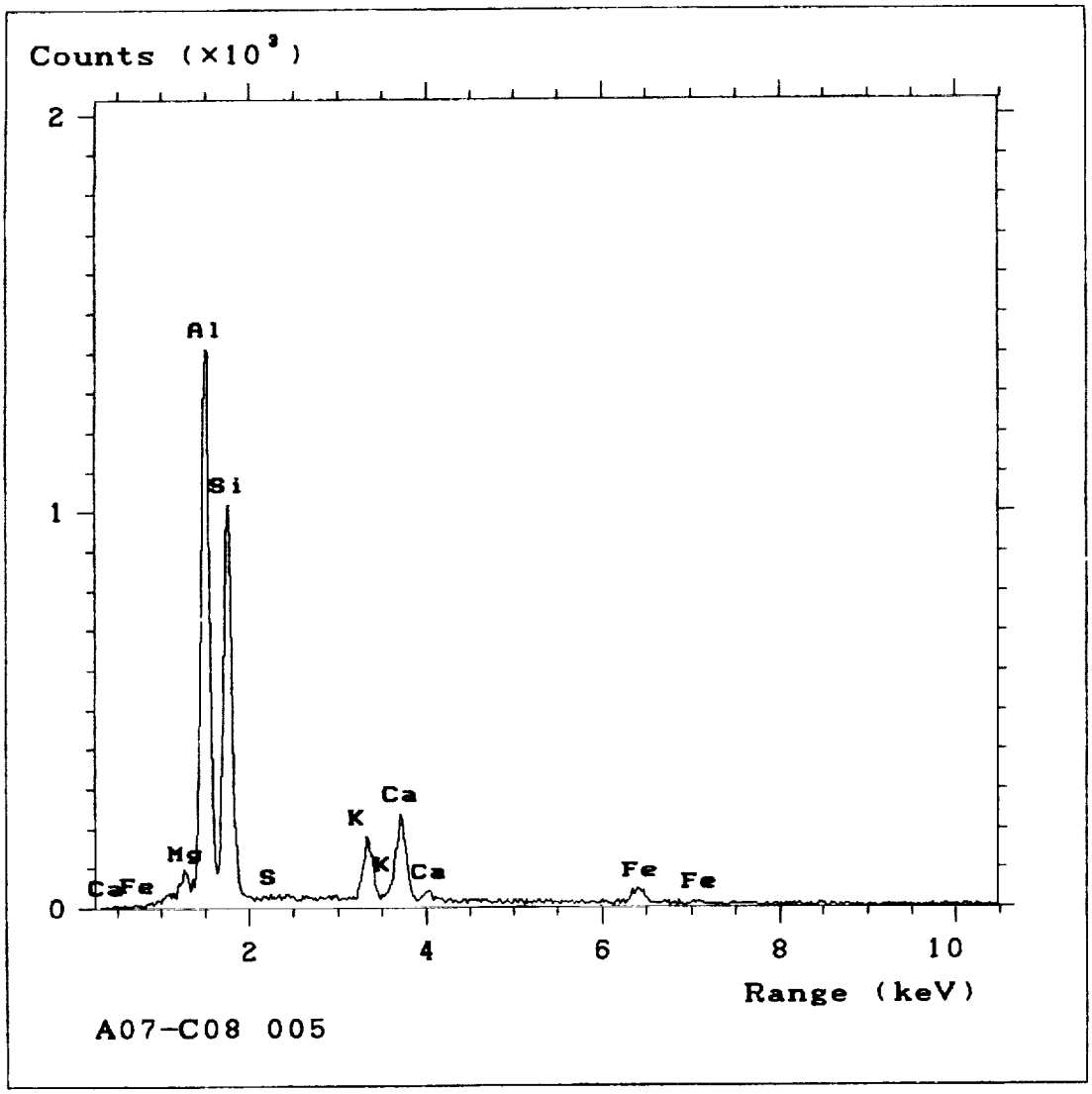

25kv 0.32kx 31.0μ 040

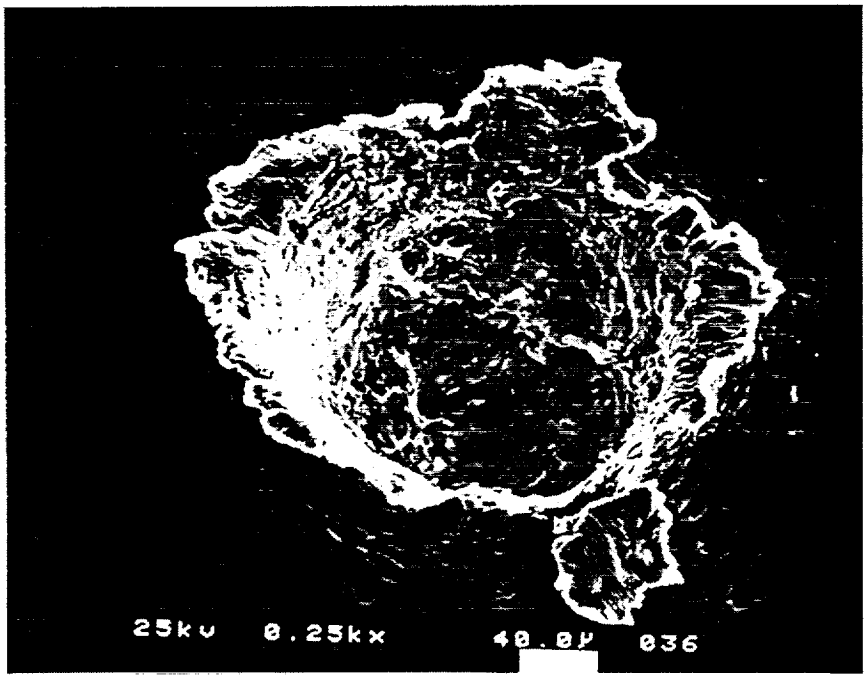

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

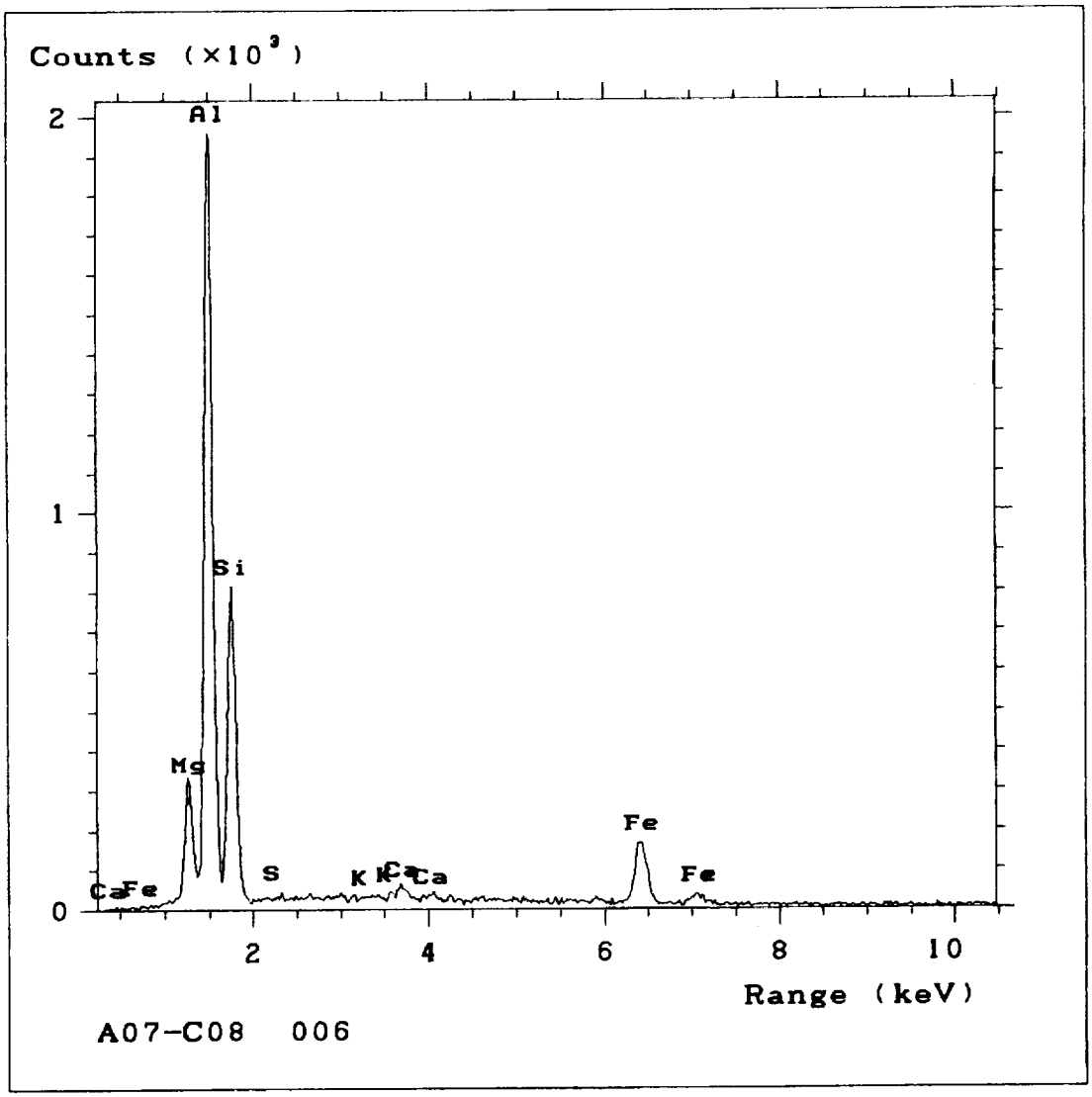

25kv 0.51kx 19.5μ 041

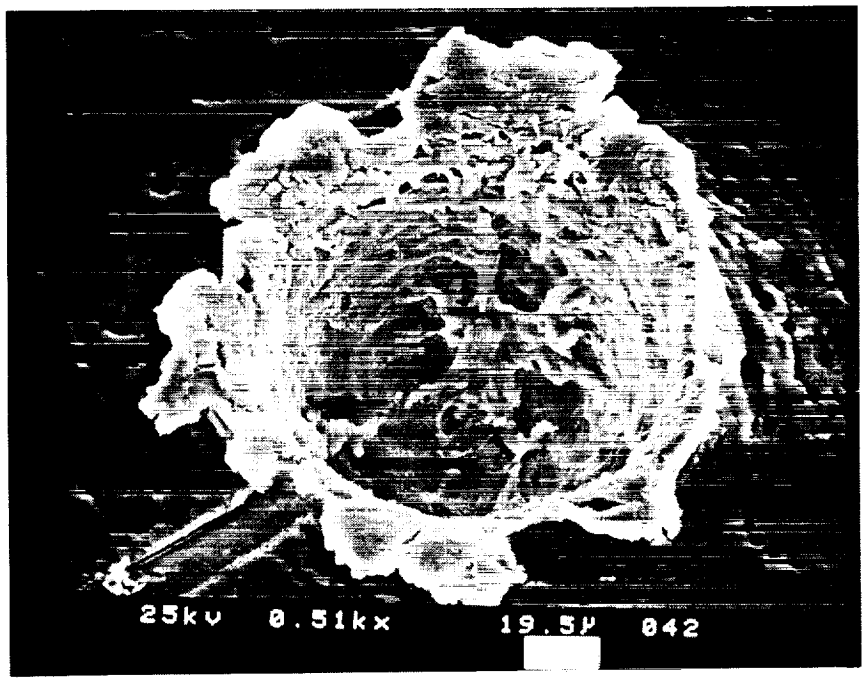

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 0.23kx 44.0µ 043


Counts (×10³)
2
1
0
Al
Si
Mg
Ca
K
Ca
K
Ca
S
Fe
Fe
Ca
Fe
2
4
6
8
10
Range (keV)
A07-C08 005

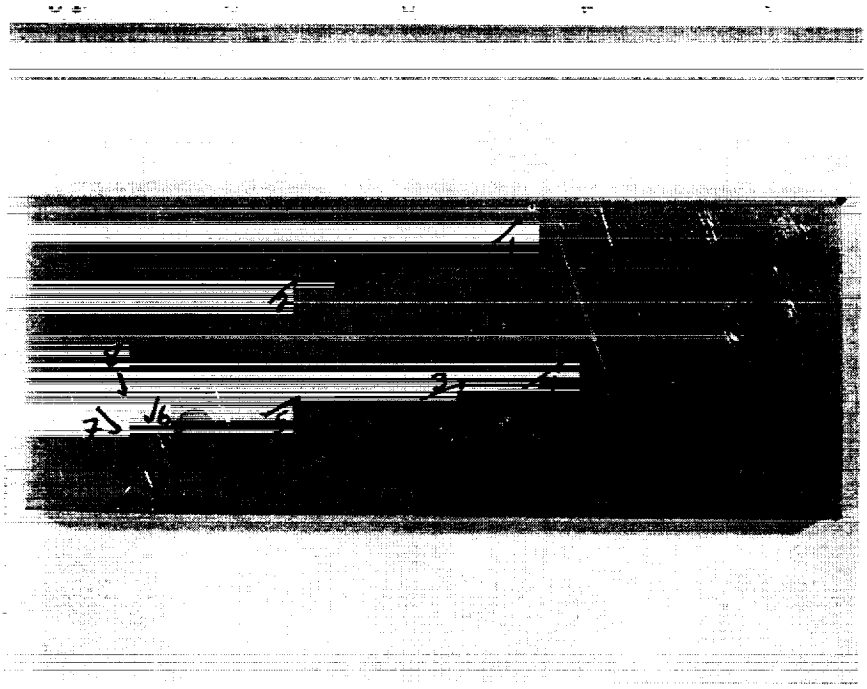

25kv 0.25kx 40.0µ 036

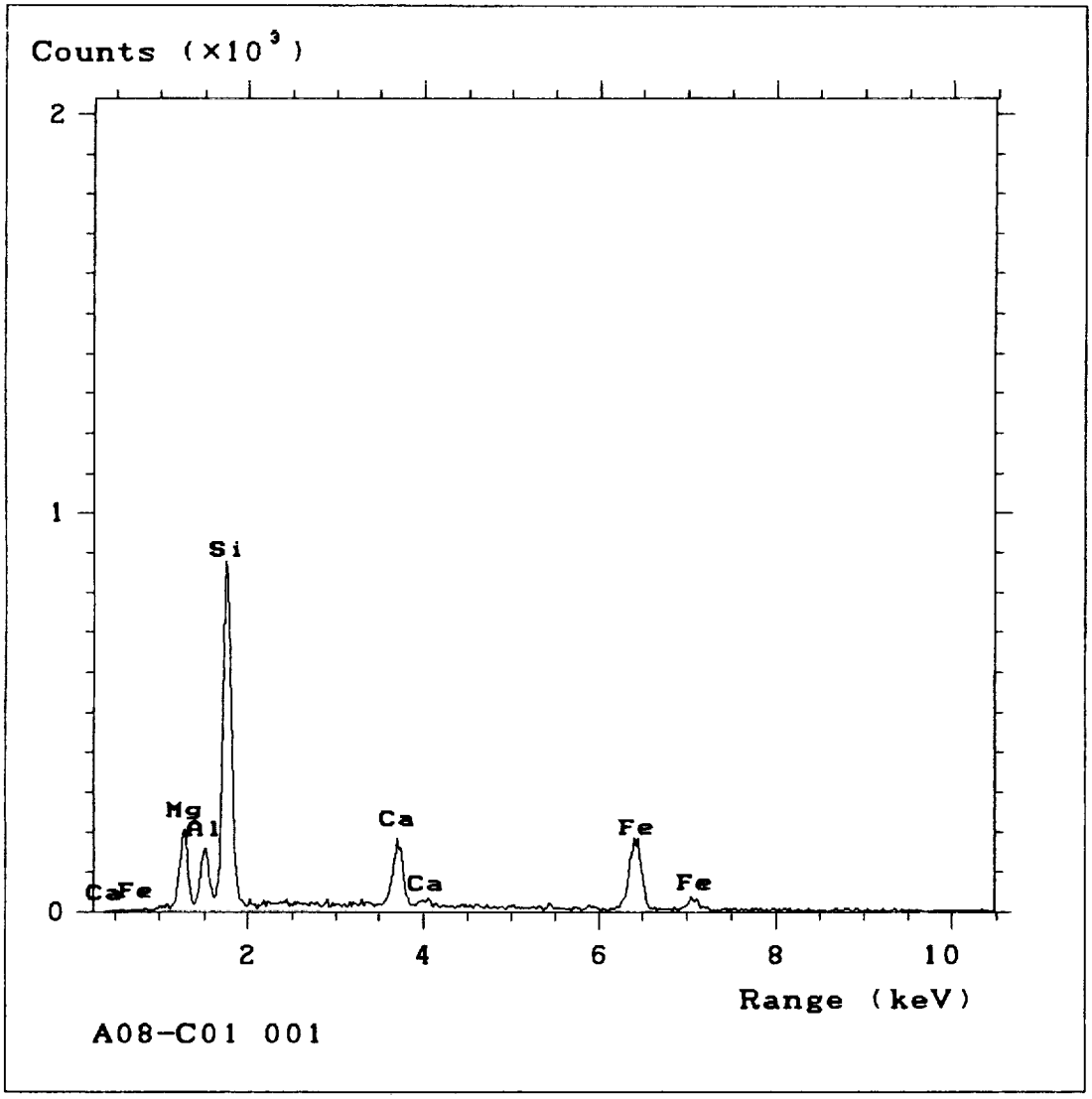

Counts (×10³)
2
1
0
Al
Si
Mg
Ca
Fe
S
K
Ca
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A07-C08 006

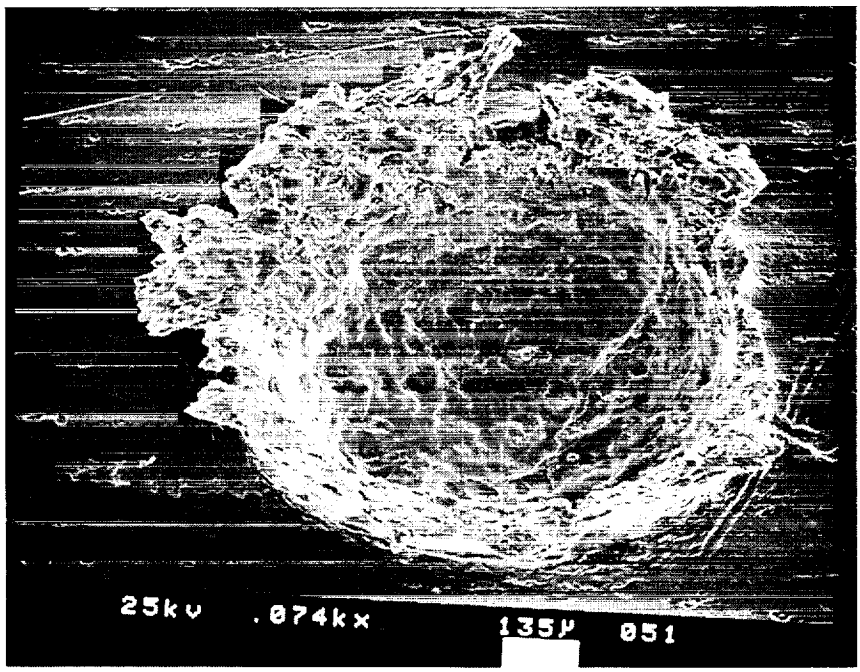

25kv 0.51kx 19.5µ 042

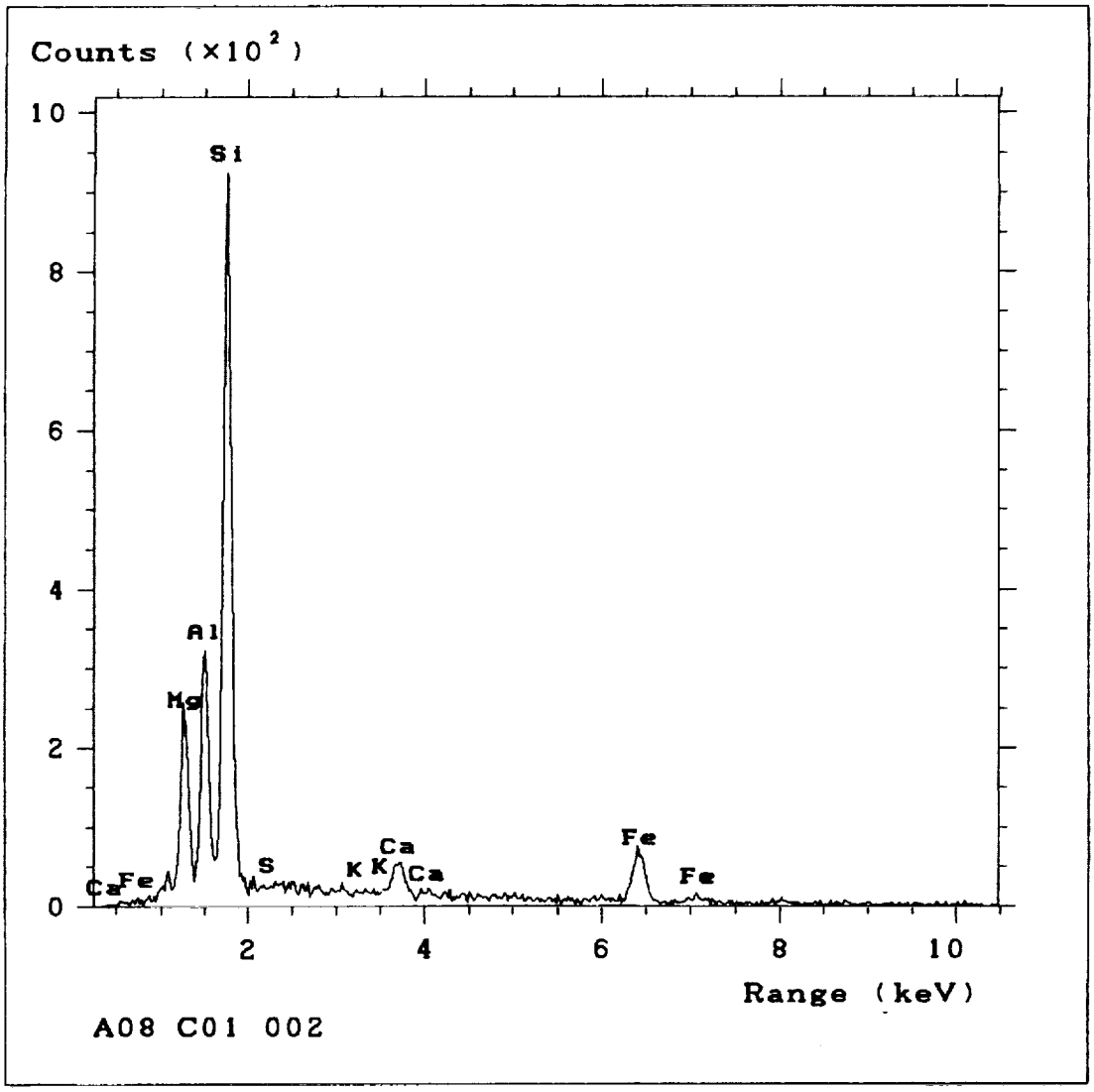
CLAMP NUMBER A08 CO1

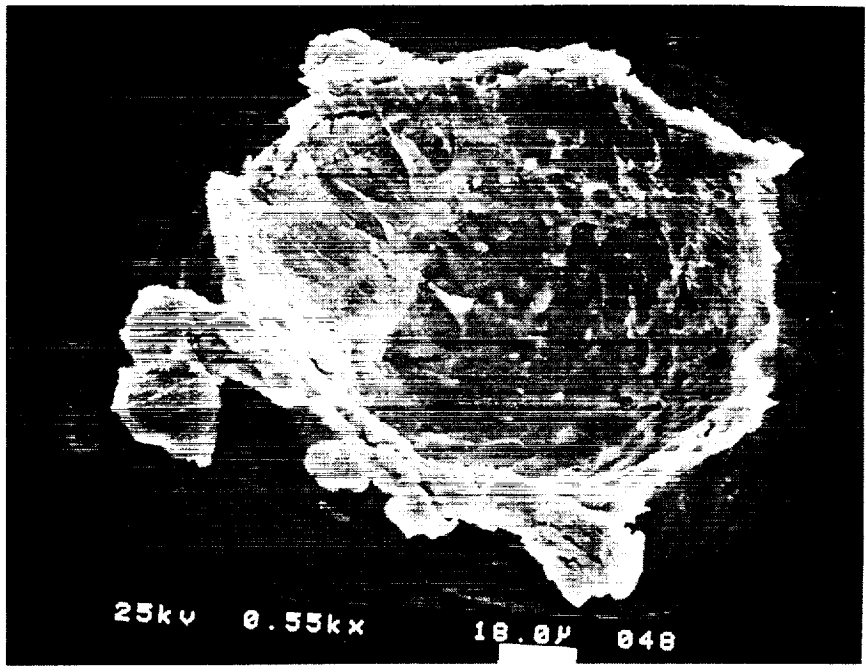
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	900	Si, Mg, Ca, Fe
002	130	Mg, Si, Ca, Fe
003	250	Trace
004	140	Unknown
005	200	Si, Mg, K
006	80	Si, Mg, Fe, Ca
007	100	Unkown
008	110	Unkown

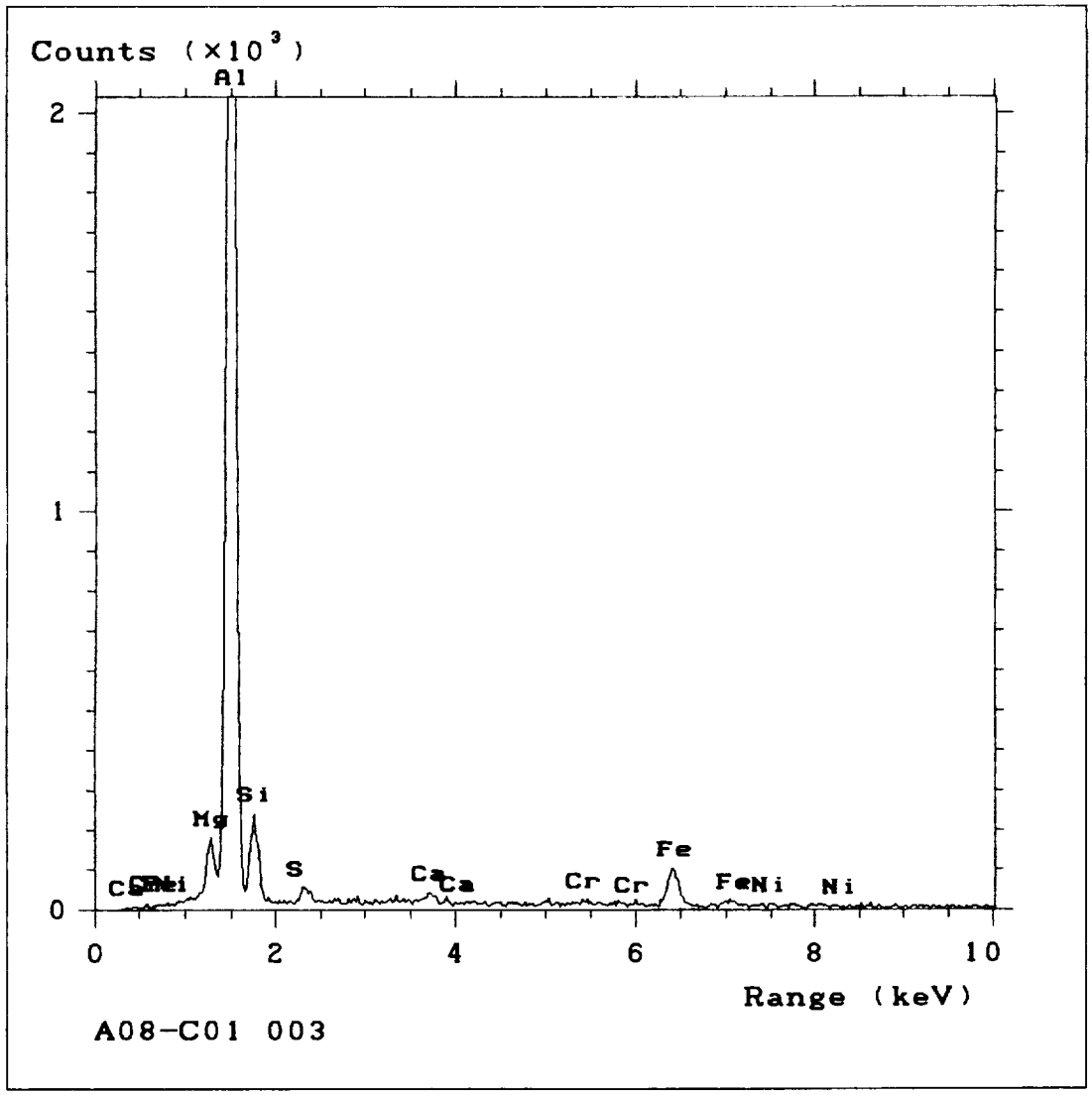


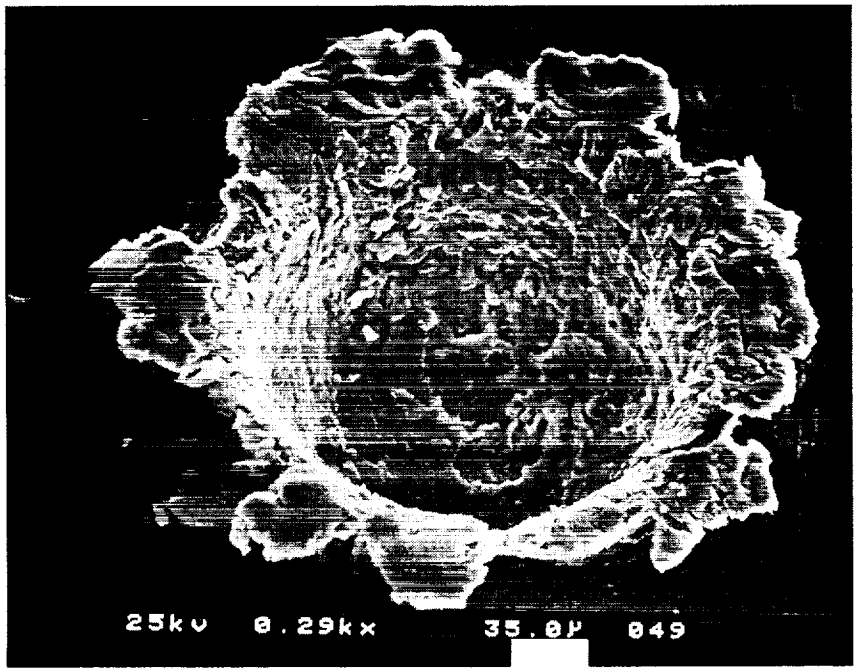

Counts (×10³)
2
1
0
Si
Mg
Al
Ca
Fe
Ca
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A08-C01 001

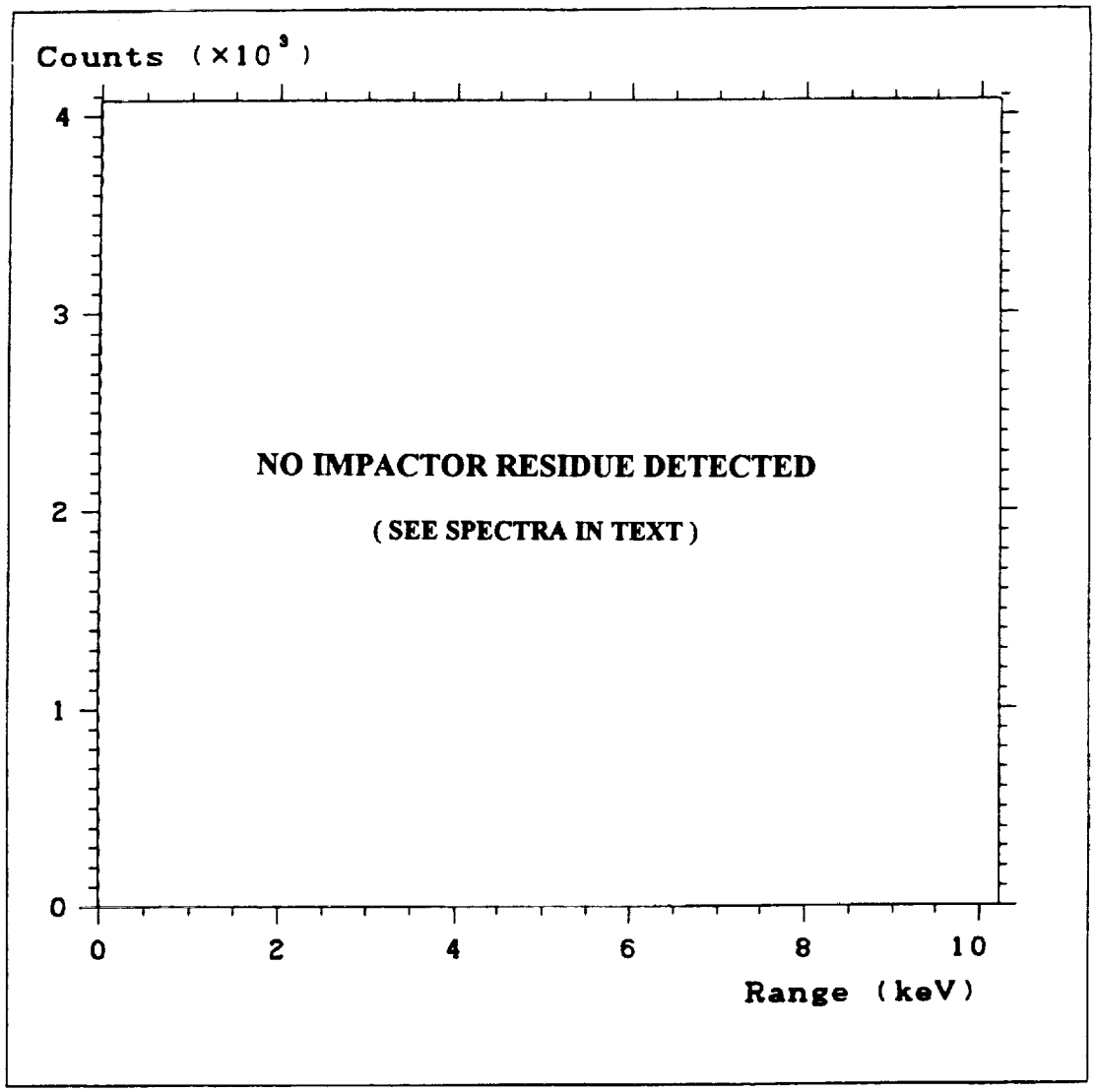

25kv .074kx 135µ 051

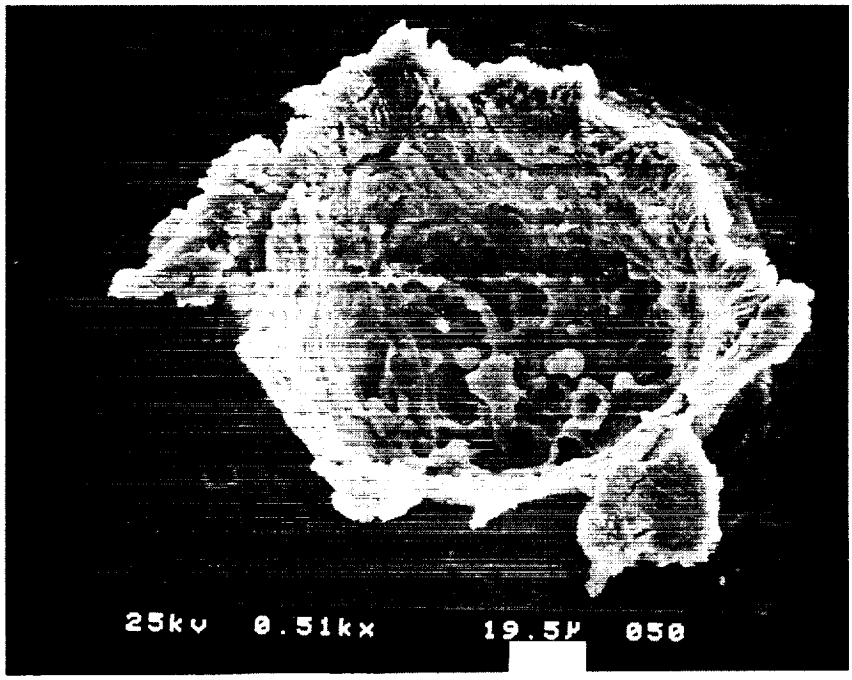

Counts (×10²)
10
8
6
4
2
0
Si
Al
Mg
Ca
Fe
S
K K
Ca
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A08 C01 002

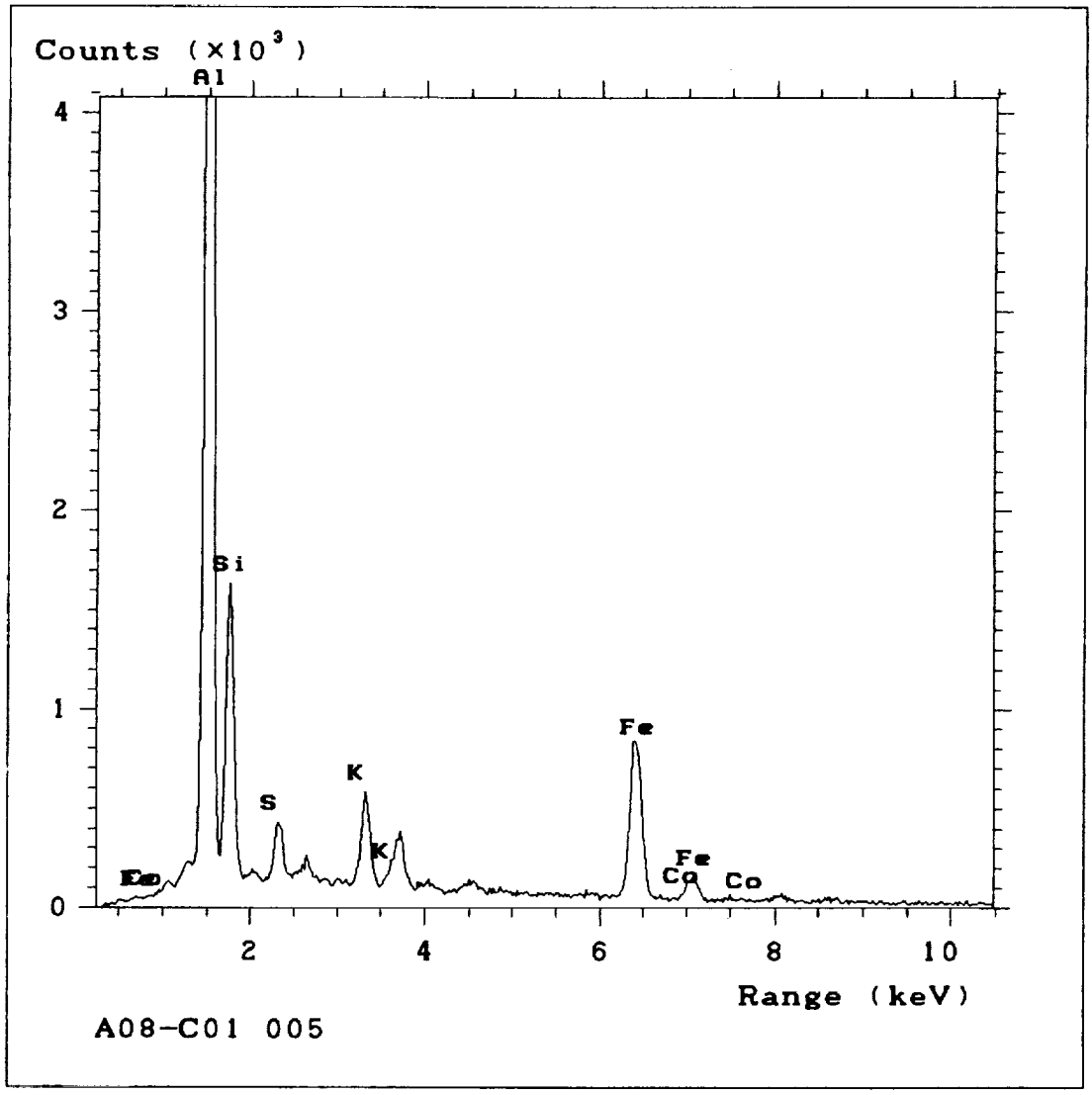

25kv 0.55kx 18.0μ 048

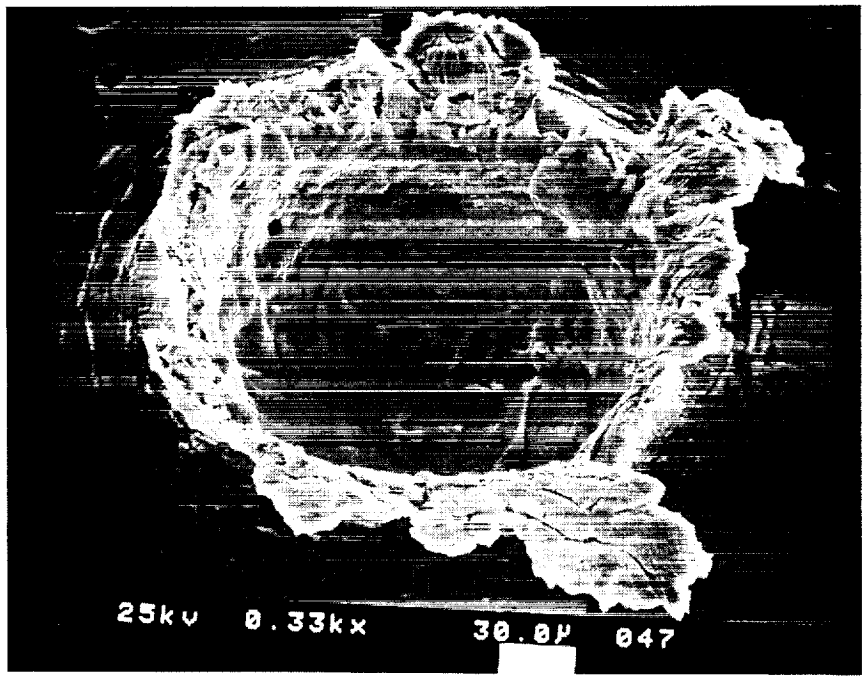

Counts (×10³)
Al
Mg
Si
S
Ca
Ca
Cr
Cr
Fe
Ni
Ni
2
1
0
0
2
4
6
8
10
Range (keV)
A08-C01 003

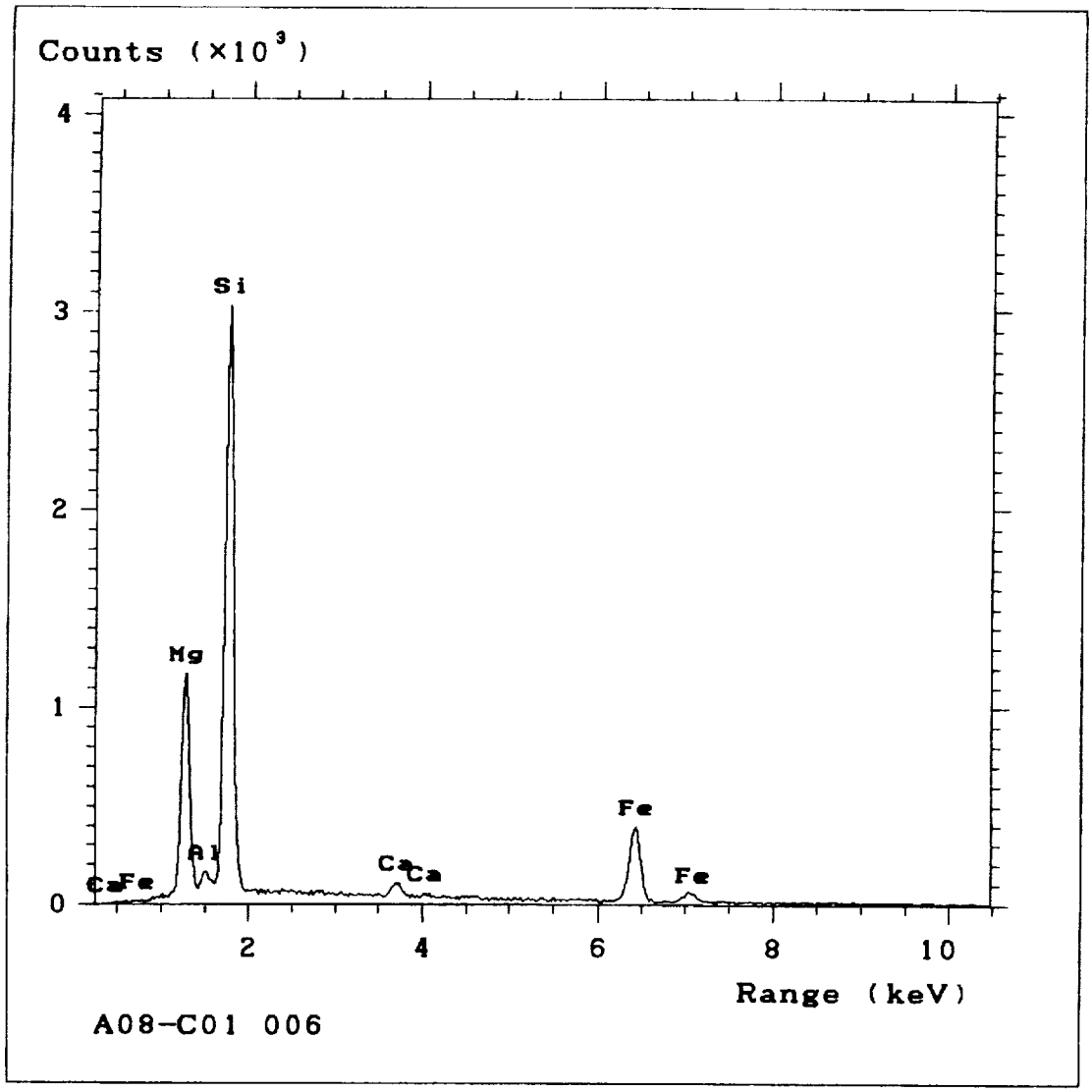

25kv 0.29kx 35.0µ 049

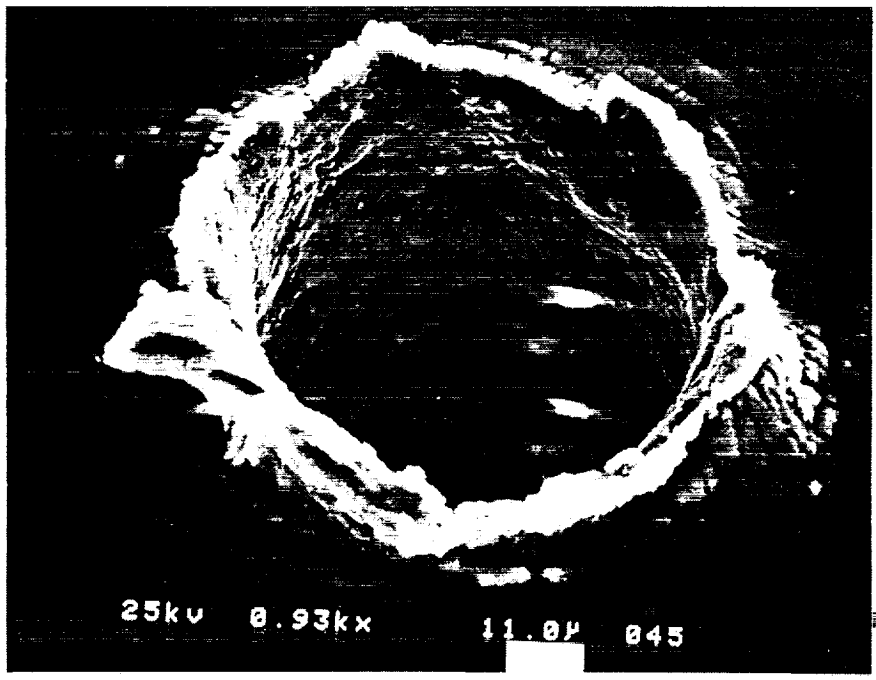

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

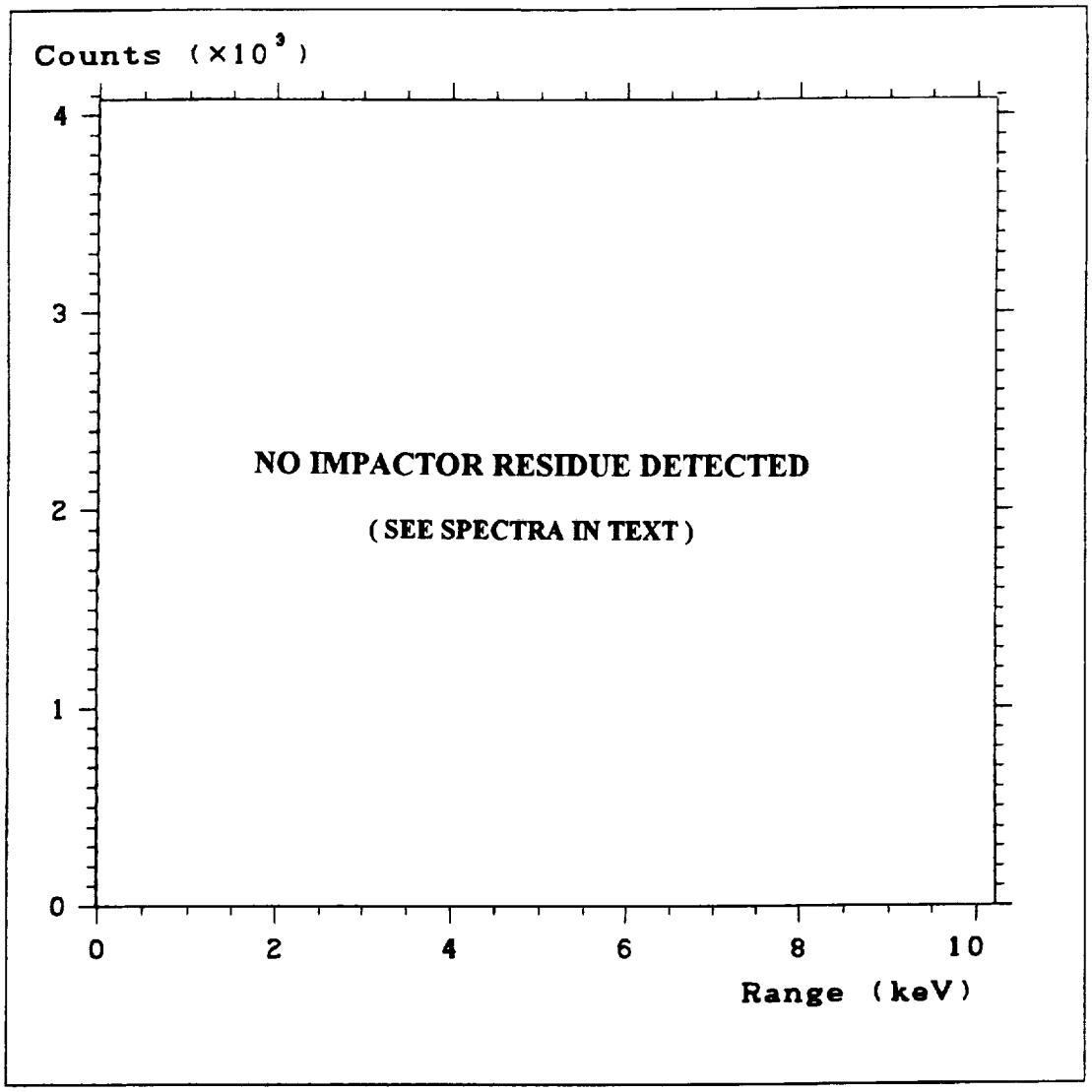

25kv 0.51kx 19.5µ 050

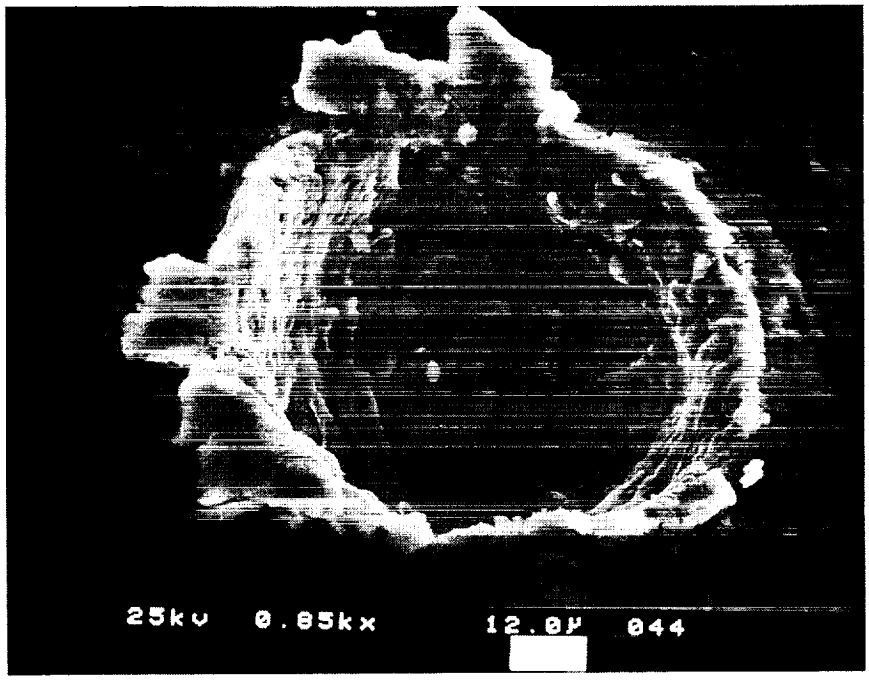

Counts (x10³)
Al
Si
S
K
K
Fe
Fe
Co
Co
Ba
4
3
2
1
0
2
4
6
8
10
Range (keV)
A08-C01 005

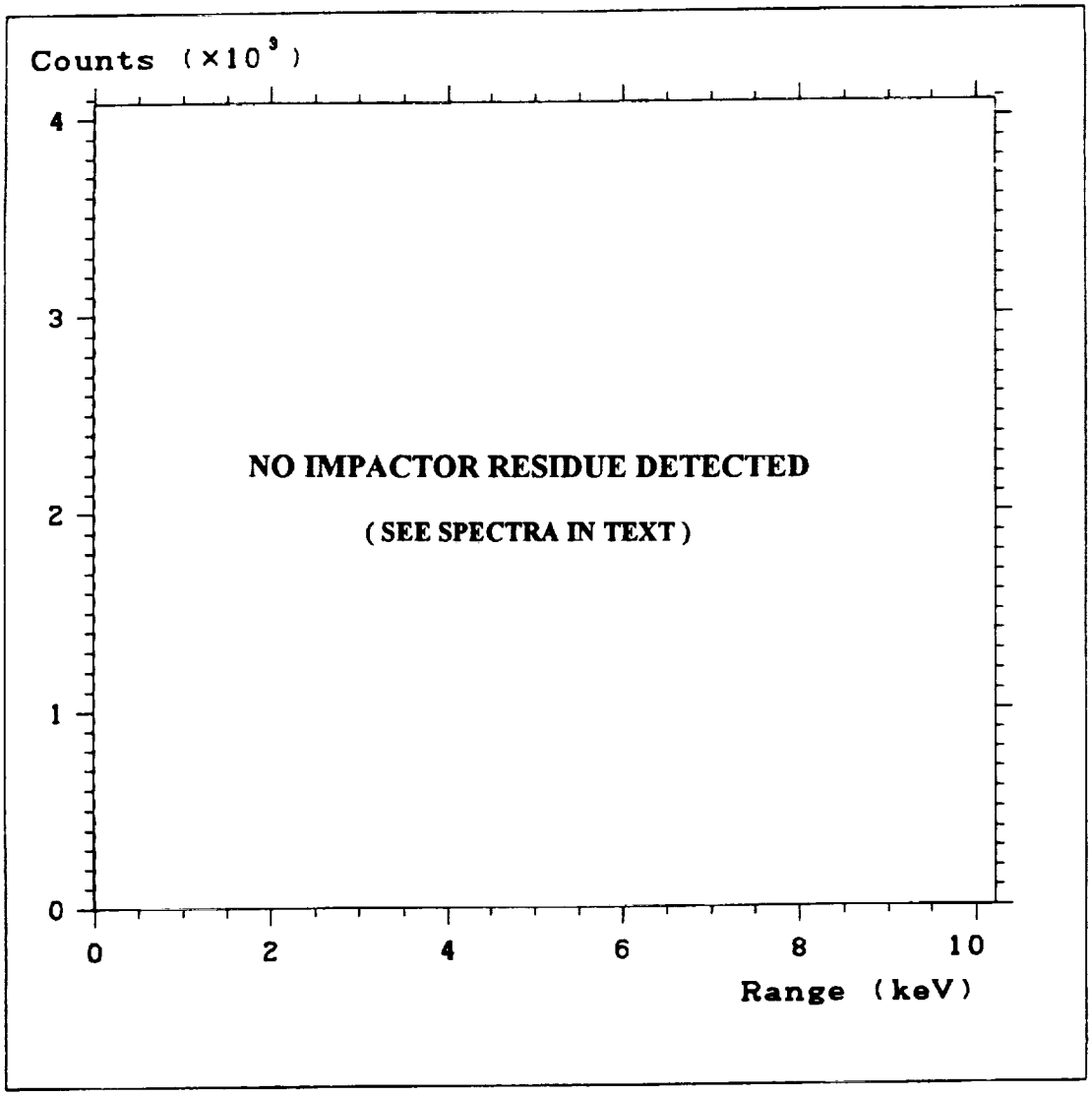

25kv 0.33kx 30.0μ 047

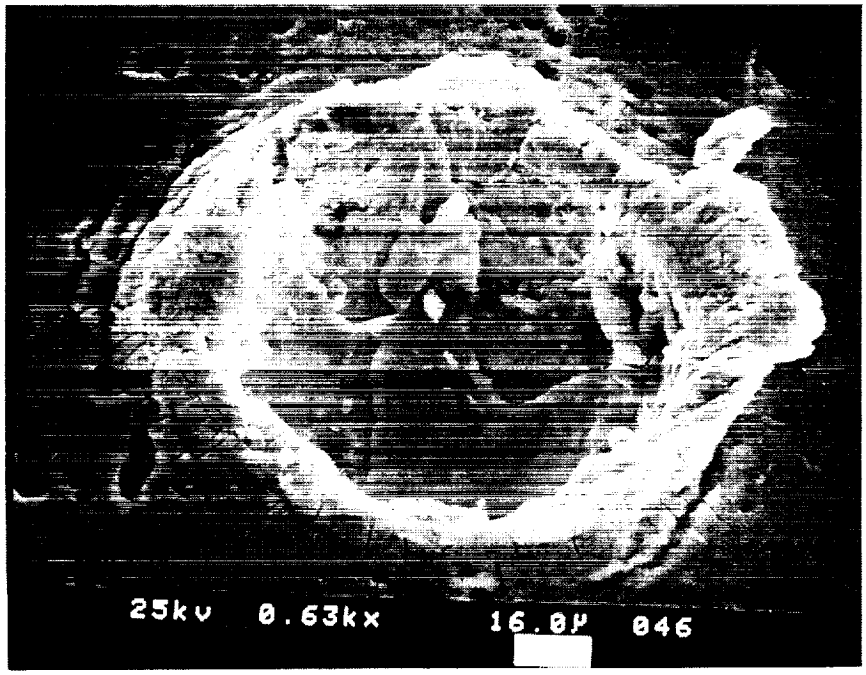

Counts (×10³)
4
3
2
1
0
Si
Mg
Al
Ca
Ca
Fe
Fe
Fe
2
4
6
8
10
Range (keV)
A08-C01 006


25kv 0.93kx 11.0μ 045


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

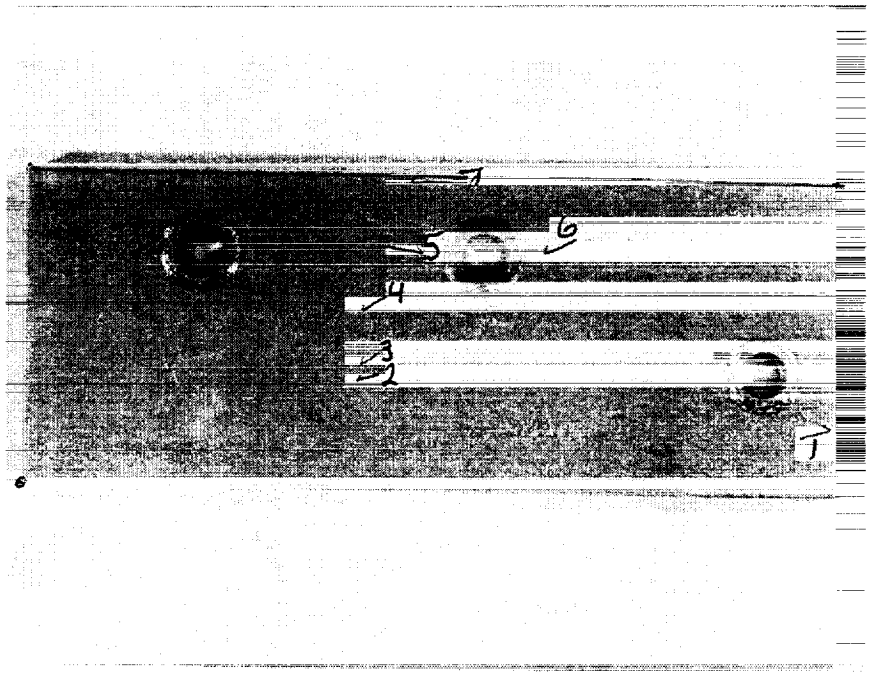

25kv 0.85kx 12.0µ 044

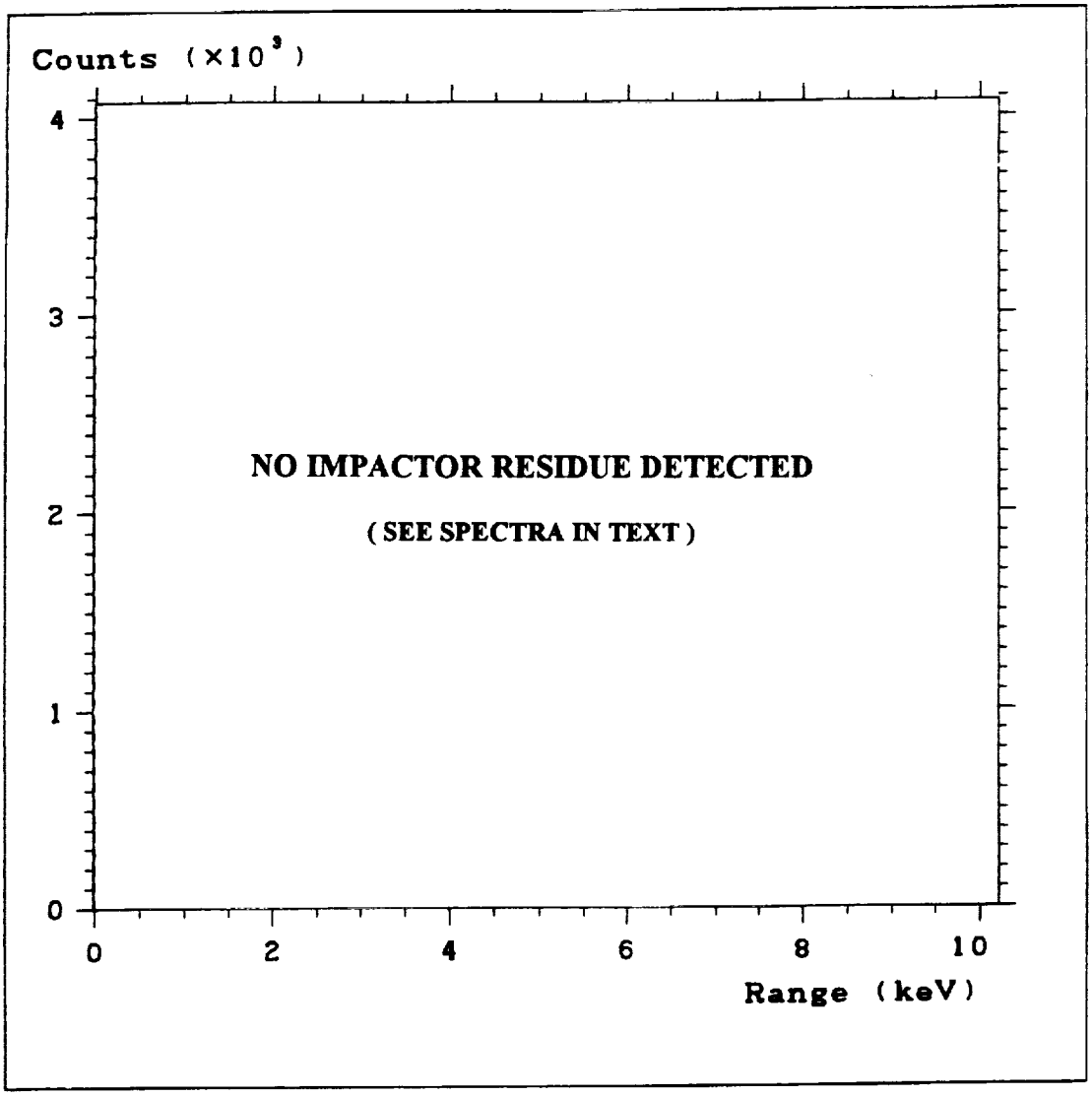

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

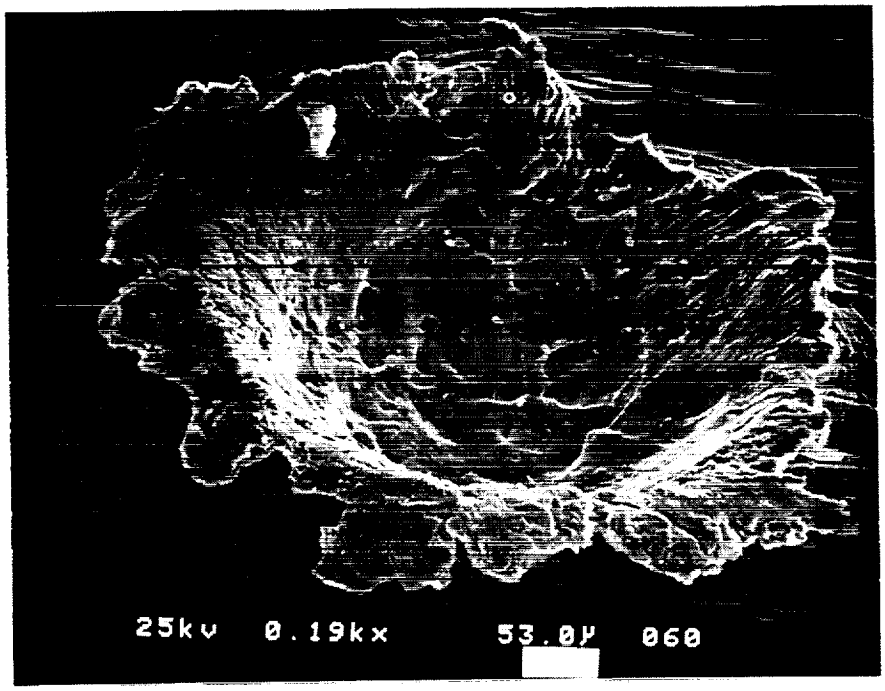

25kv 0.63kx 16.0µ 046

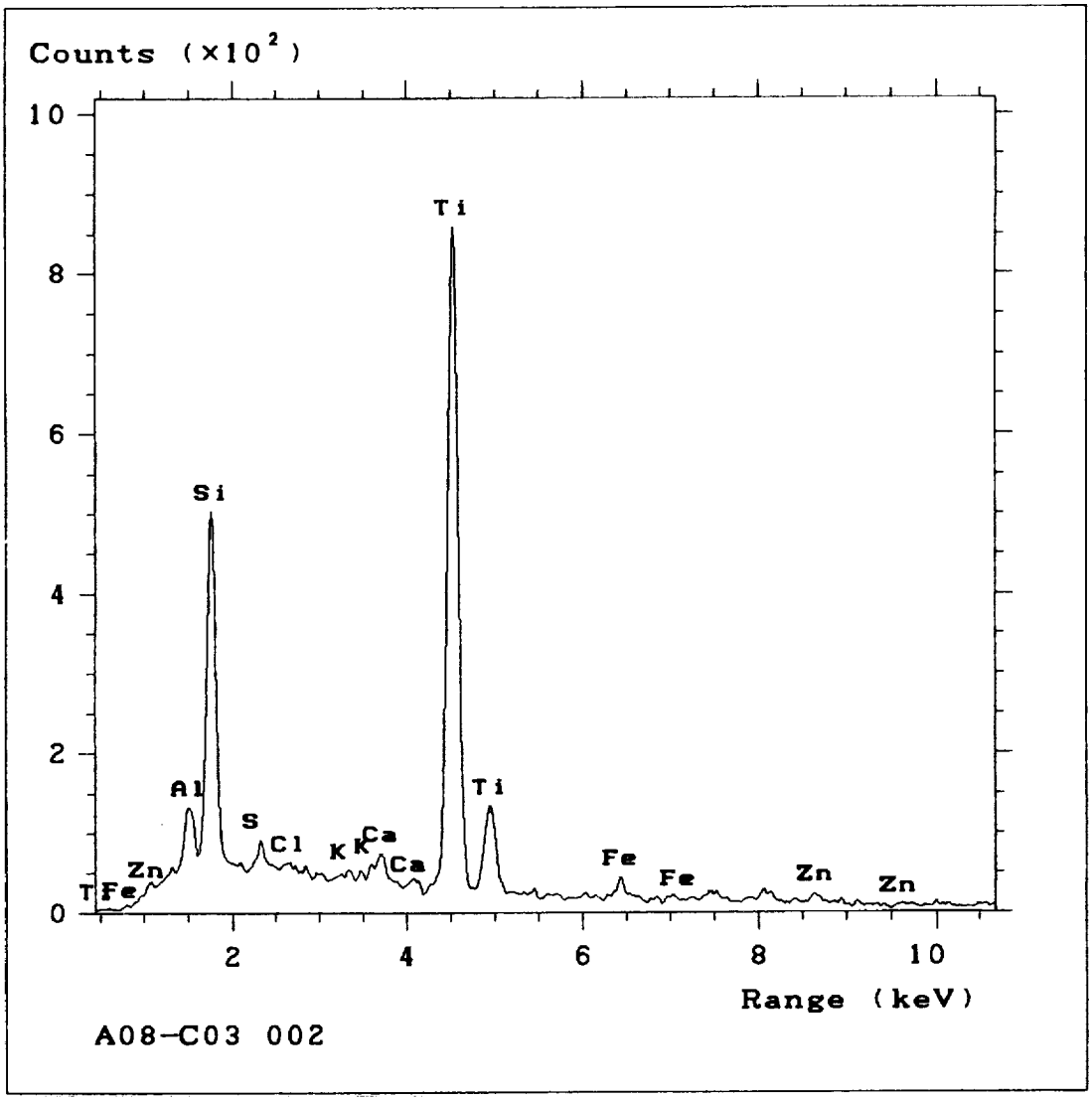
CLAMP NUMBER A08 CO3

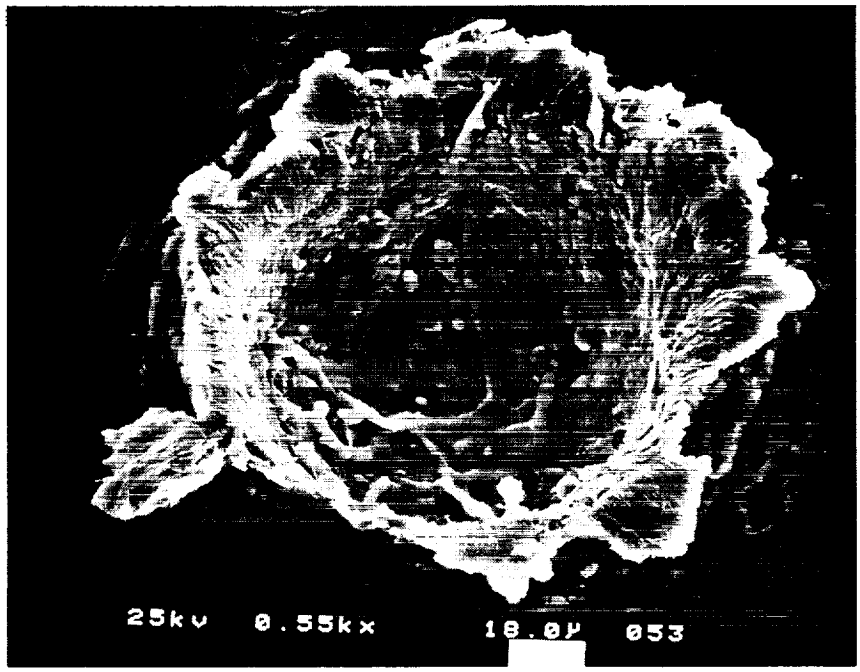
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	400	Unkown
002	140	Paint
003	80	Unkown
004	200	Unkown
005	160	Unkown
006	150	Unkown
007	380	Unkown

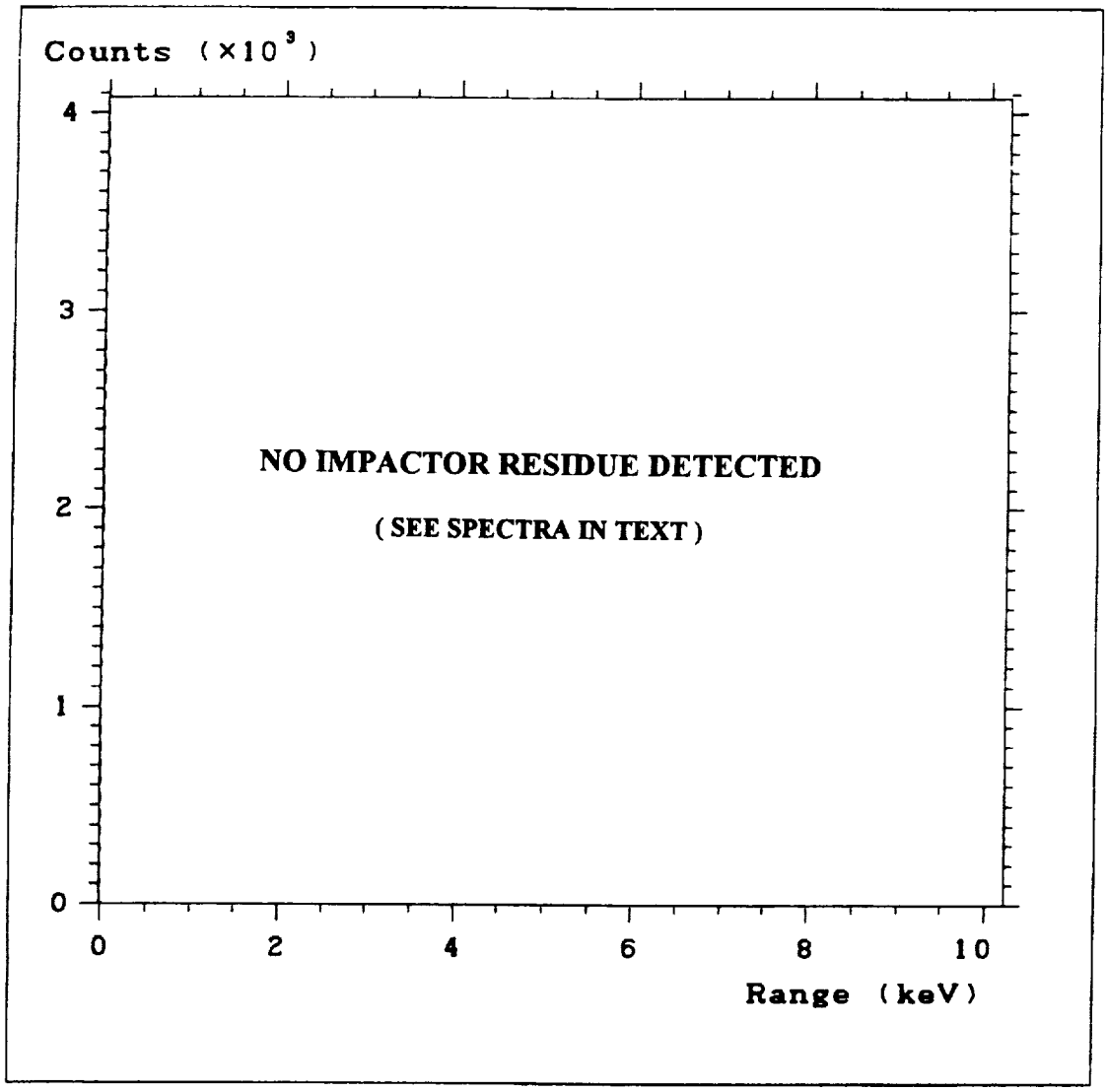


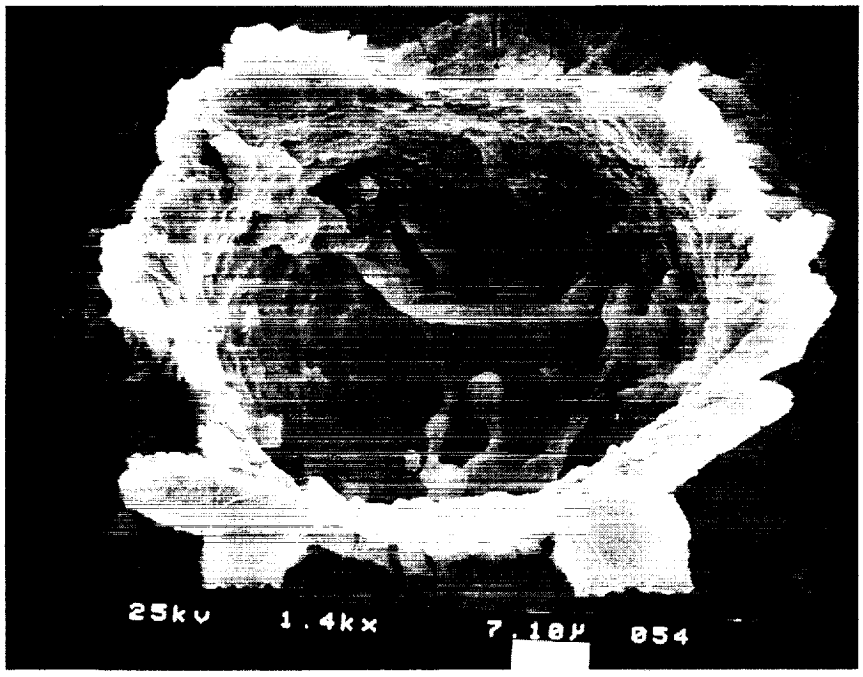

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

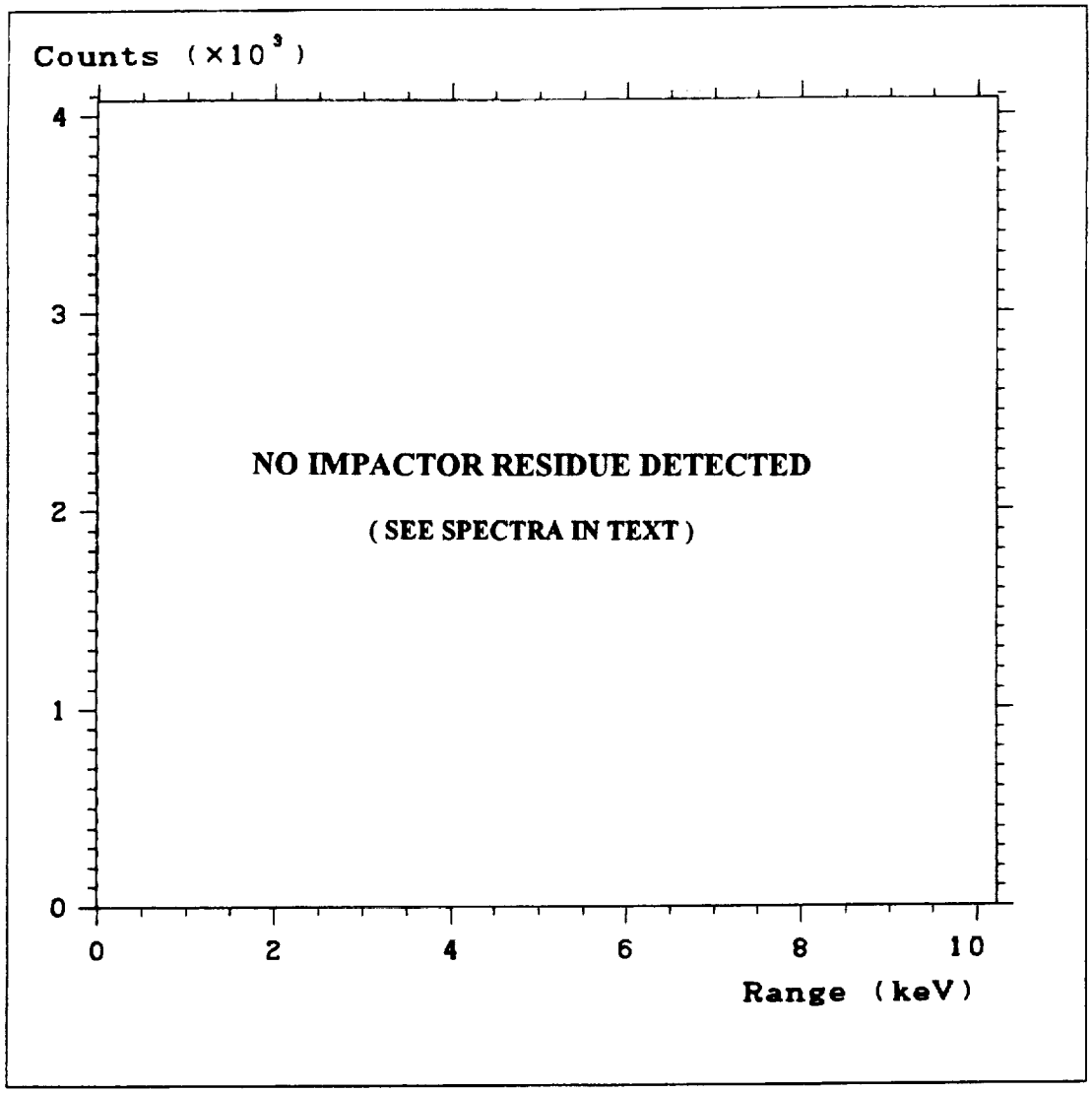

25kv 0.19kx 53.0µ 060

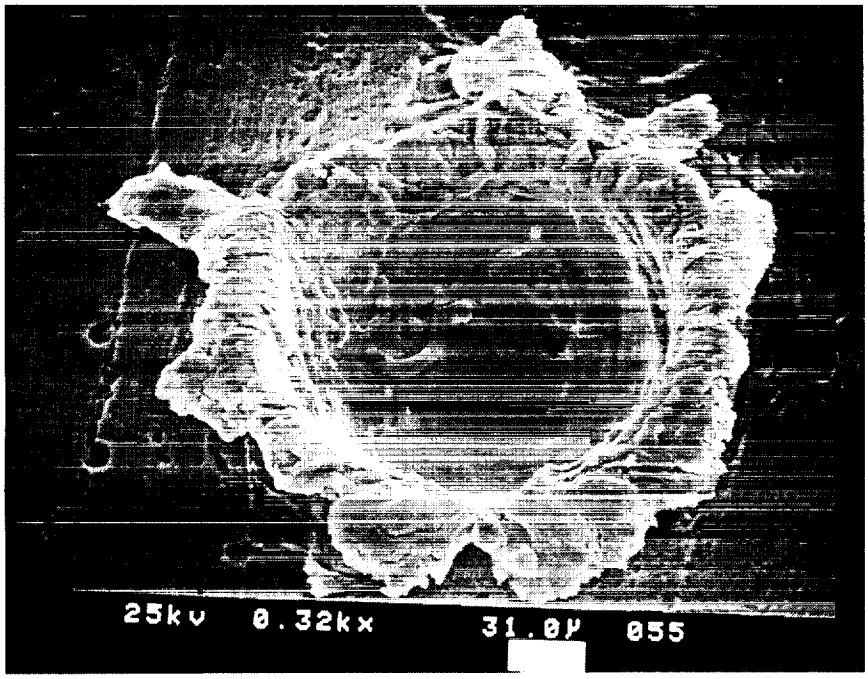

Counts (×10²)
10
8
6
4
2
0
Ti
Si
Al
S
Cl
K
K
Ca
Ca
Ti
Fe
Zn
T
Fe
Zn
Fe
Zn
Zn
2
4
6
8
10
Range (keV)
A08-C03 002

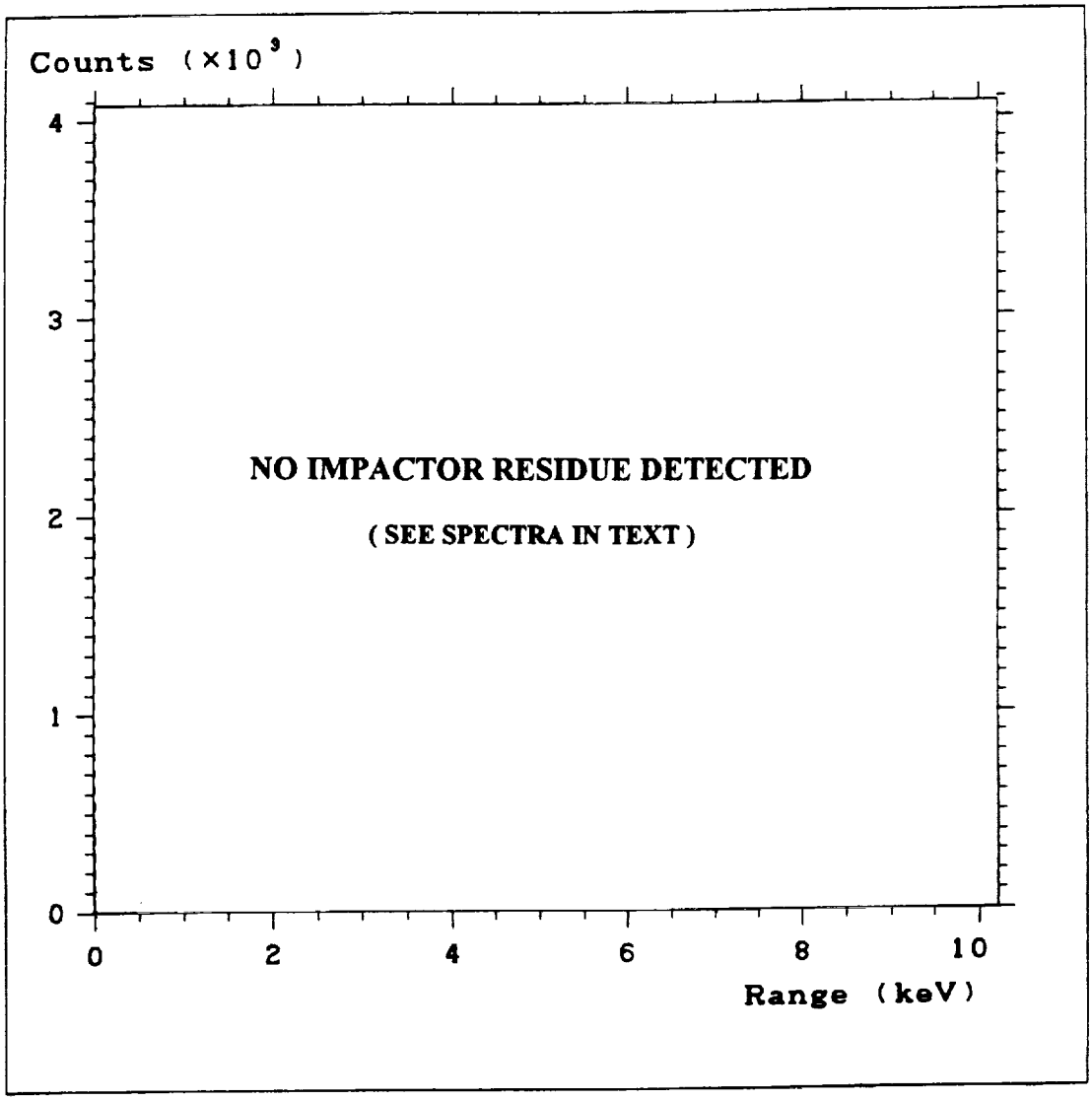

25kv 0.55kx 18.0µ 053

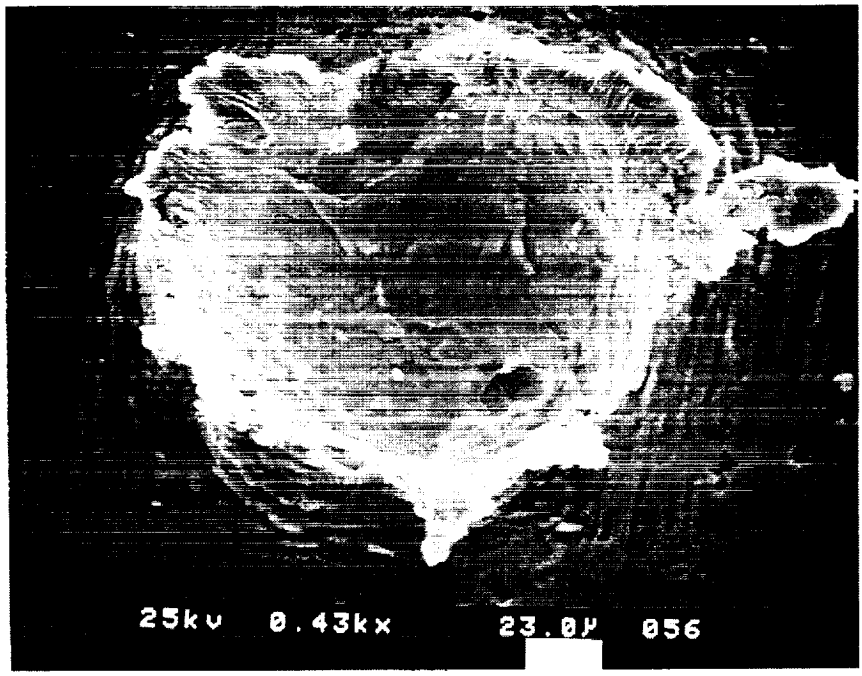

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

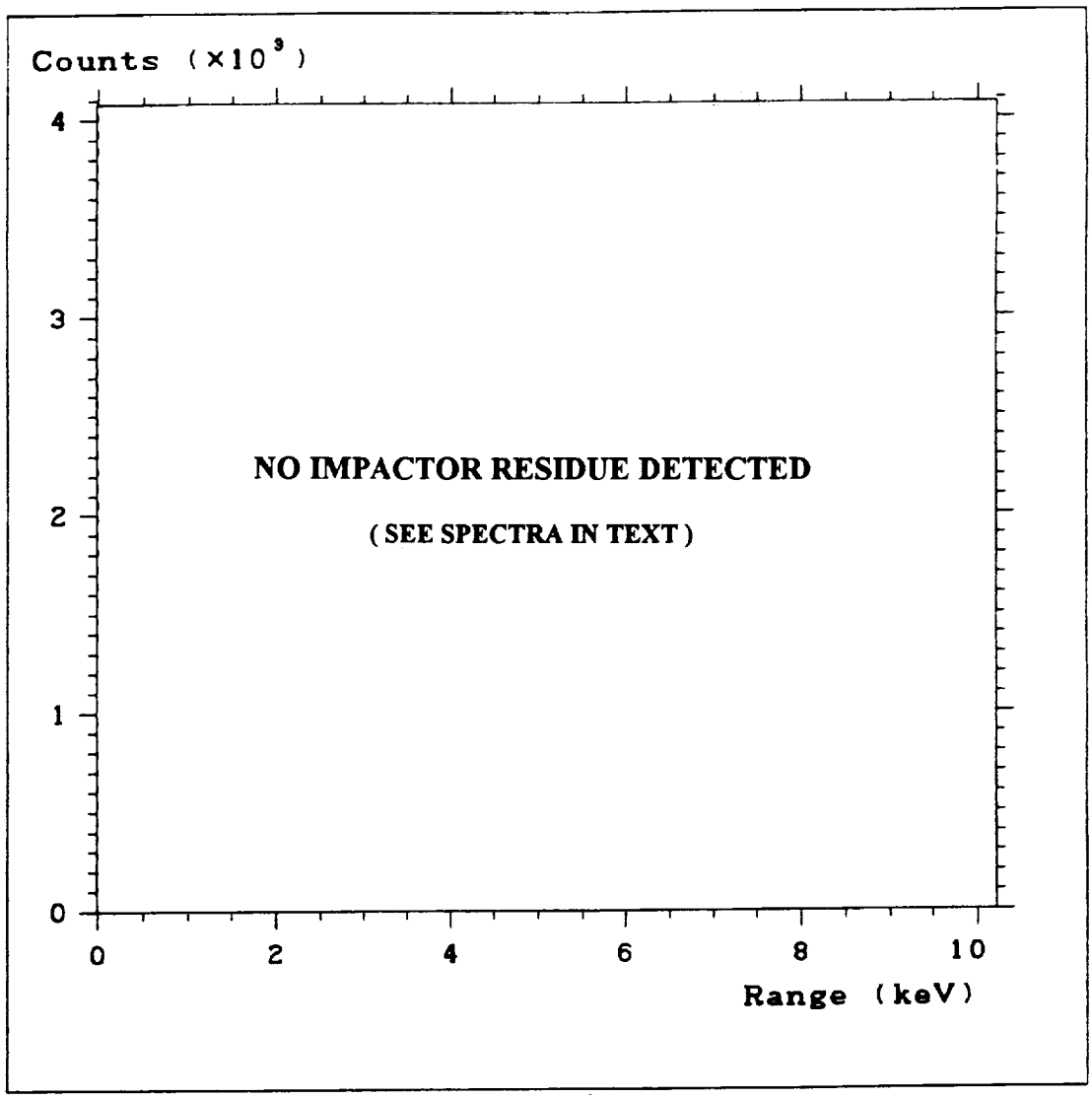

25kv 1.4kx 7.10µ 054

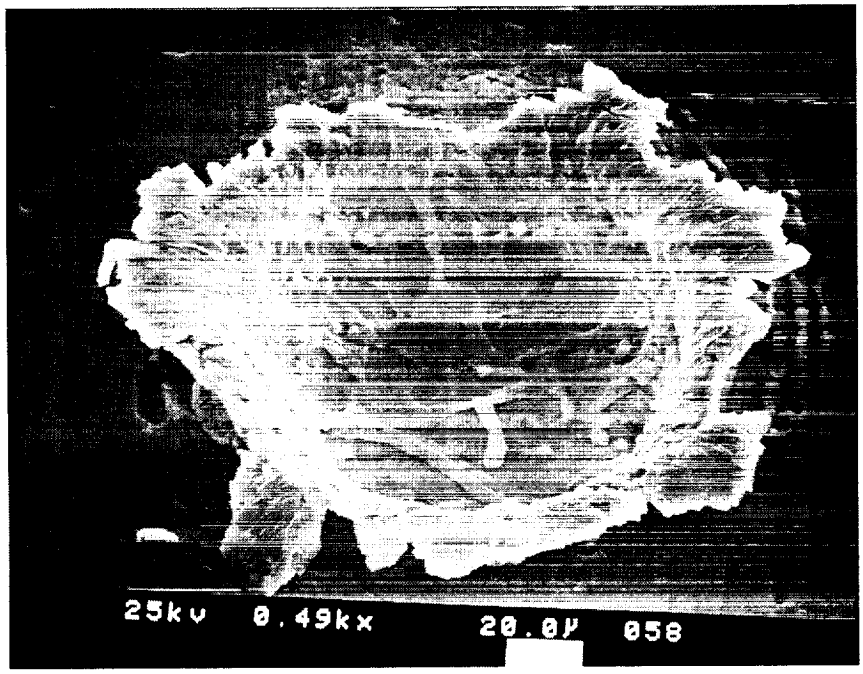

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

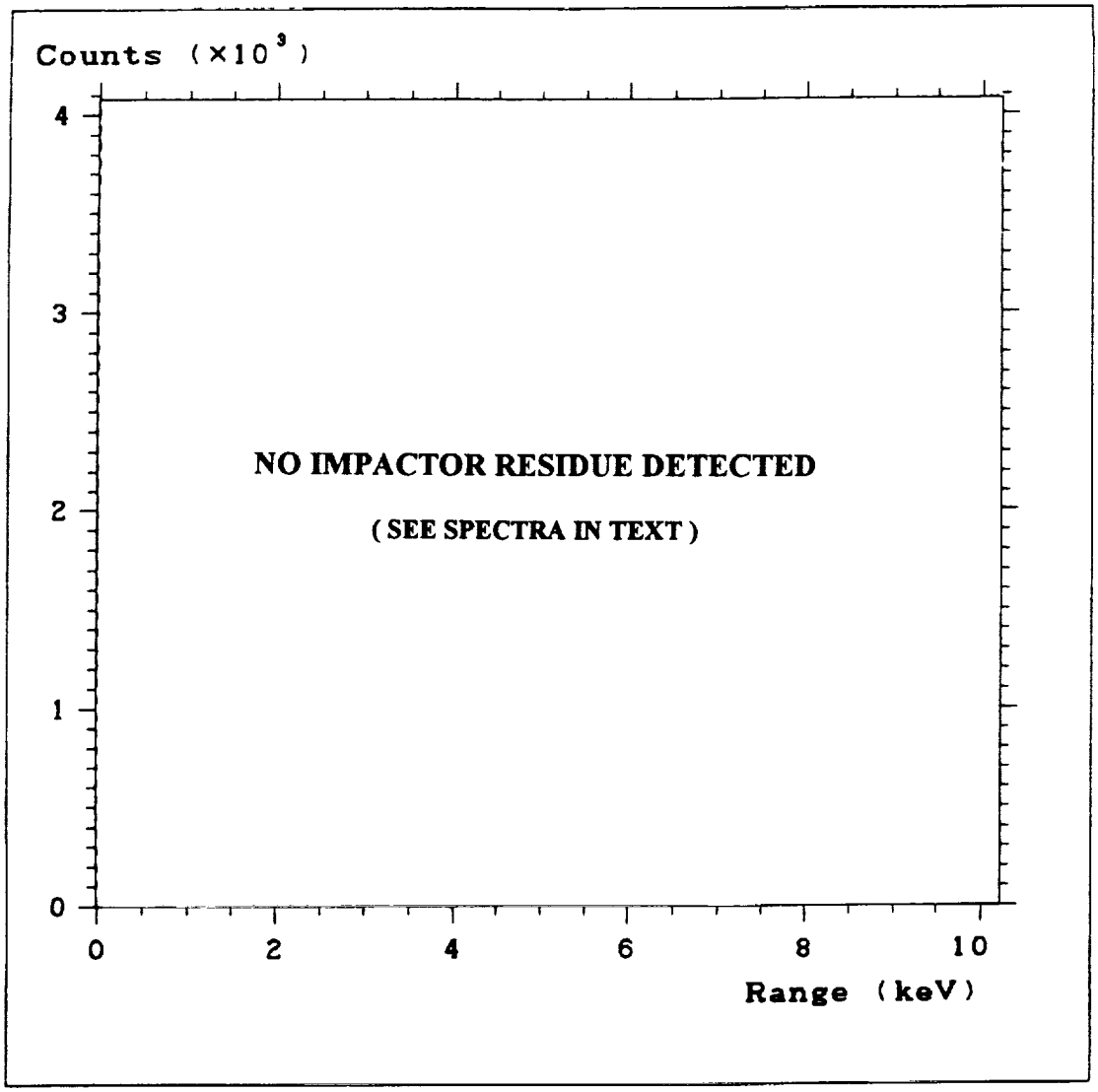

25kv 0.32kx 31.0µ 055

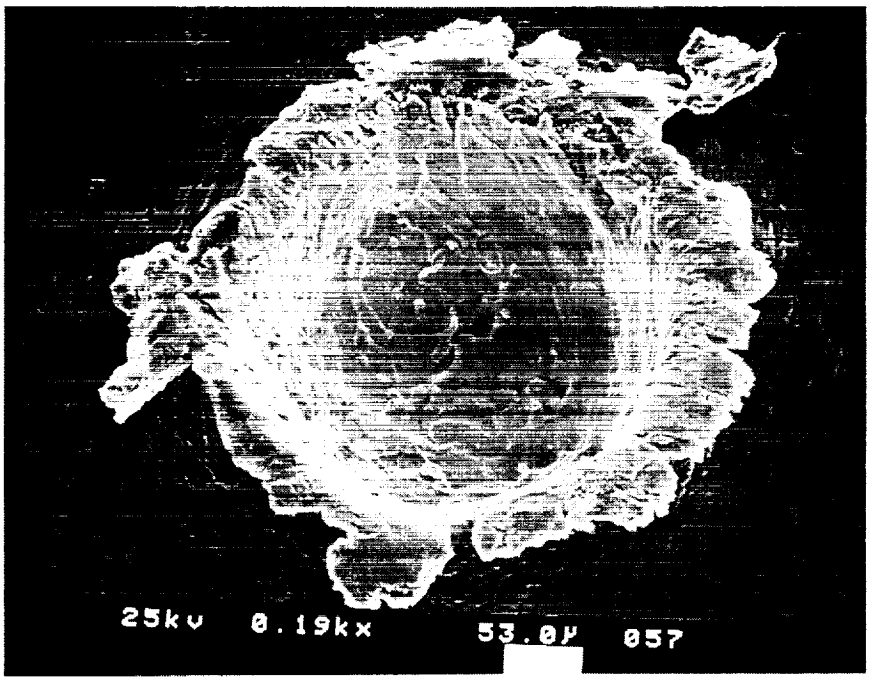

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)


25kv 0.43kx 23.0µ 056


Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

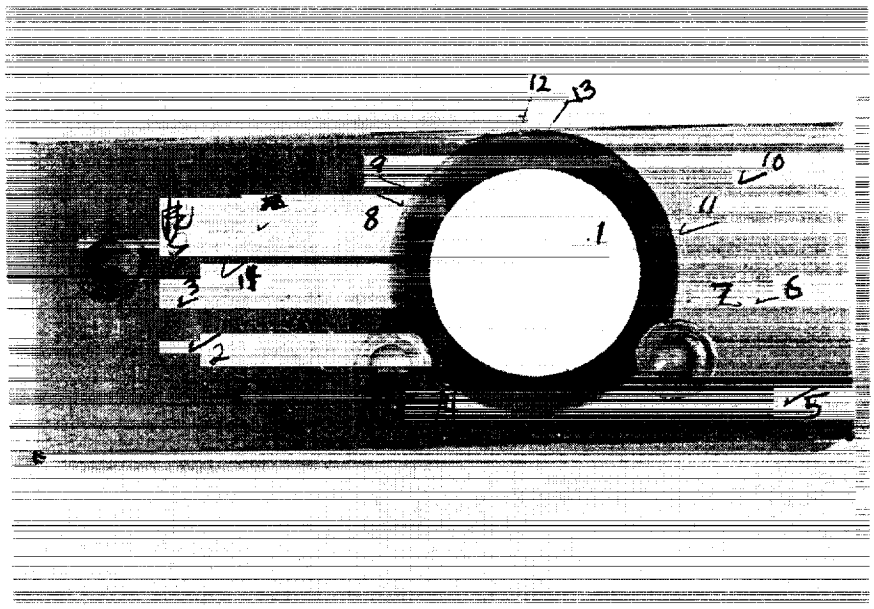

25kv 0.49kx 20.0µ 058

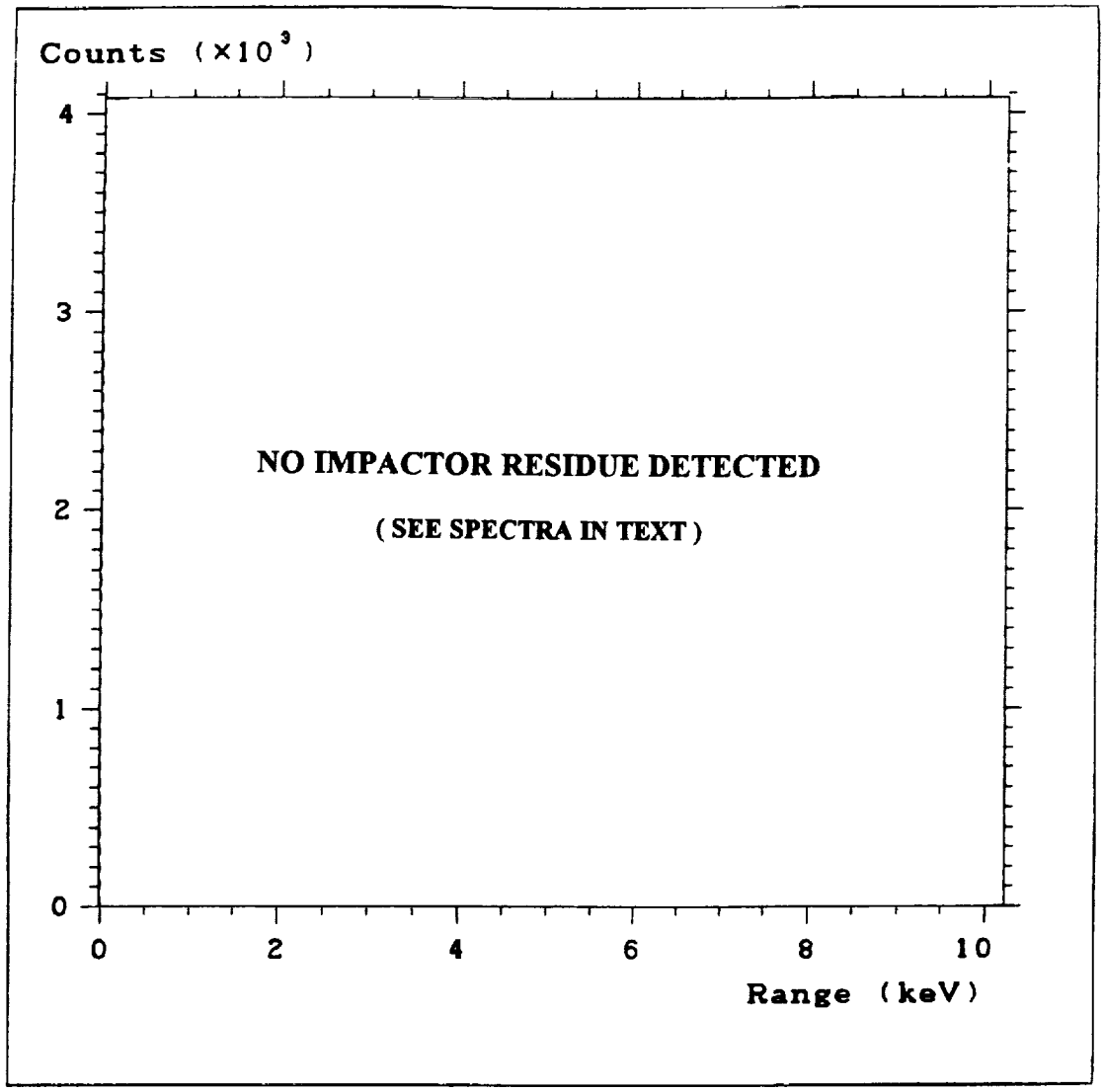

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

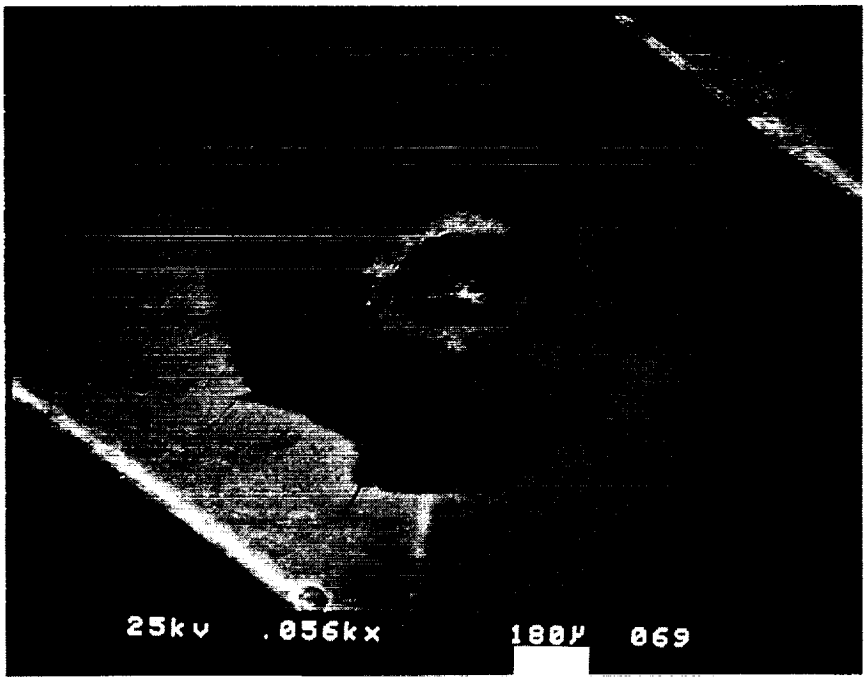

25kv 0.19kx 53.0µ 057

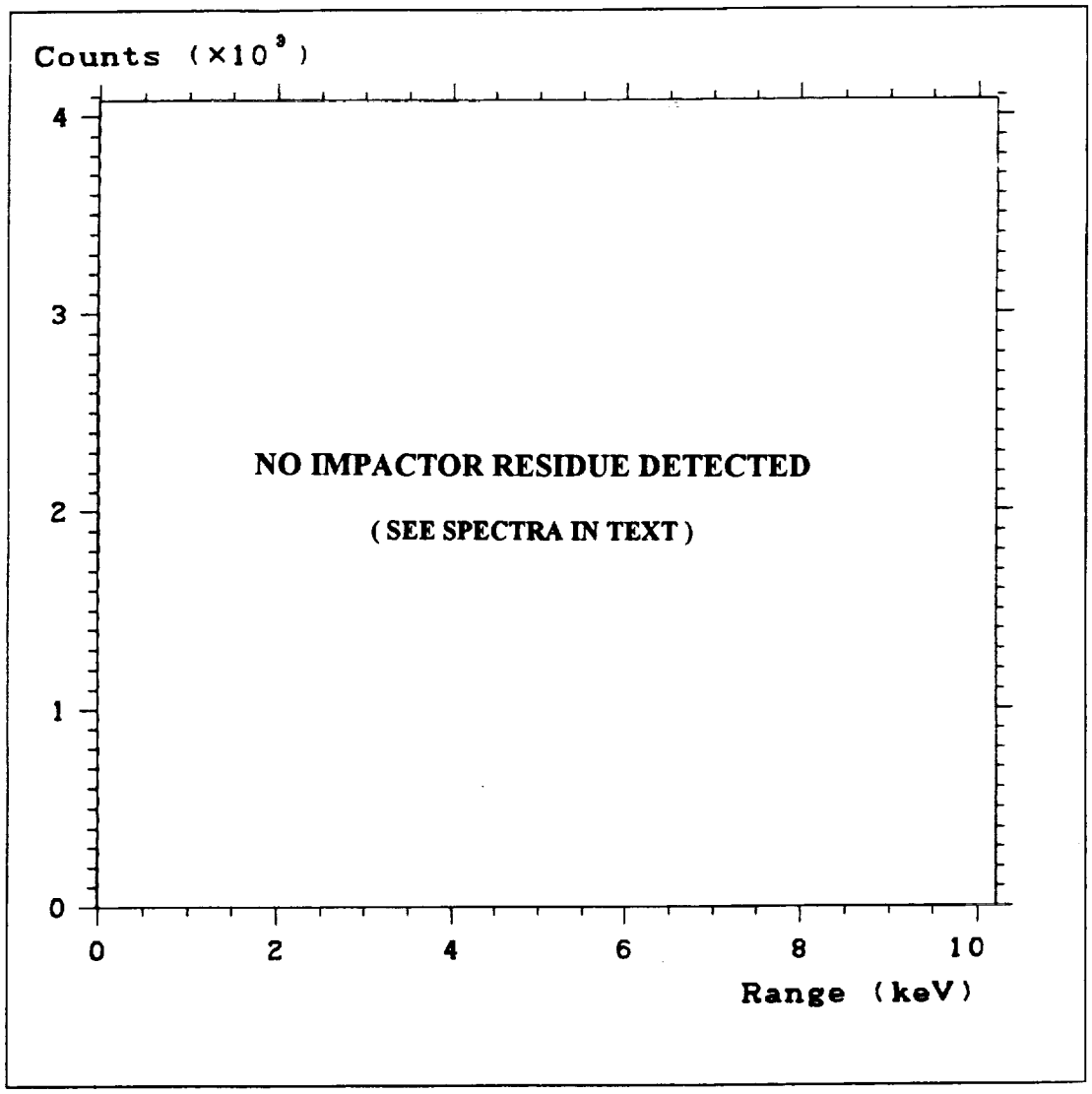
CLAMP NUMBER A08 CO7

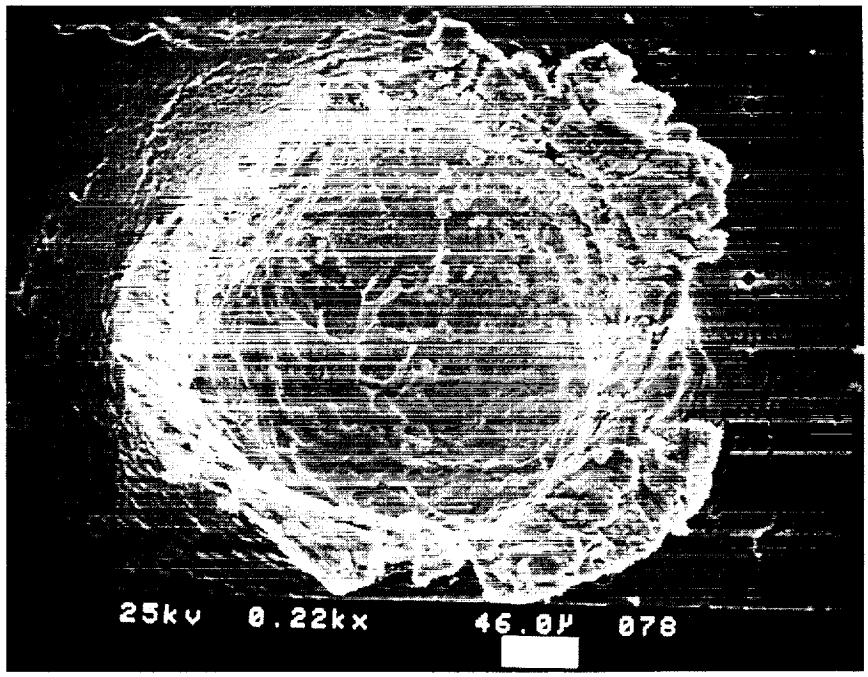
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	360	Paint Patch
002	350	Unkown
003	270	Paint
004	470	Unkown
005	130	Si, Mg, Ca, Fe
006	60	Unkown
007	160	Contamination
008	60	Paint Patch
009	130	Unkown
010	170	Unkown
011	140	Paint Patch
012	230	Paint Patch
013	40	Paint Patch
014	100	Unknown

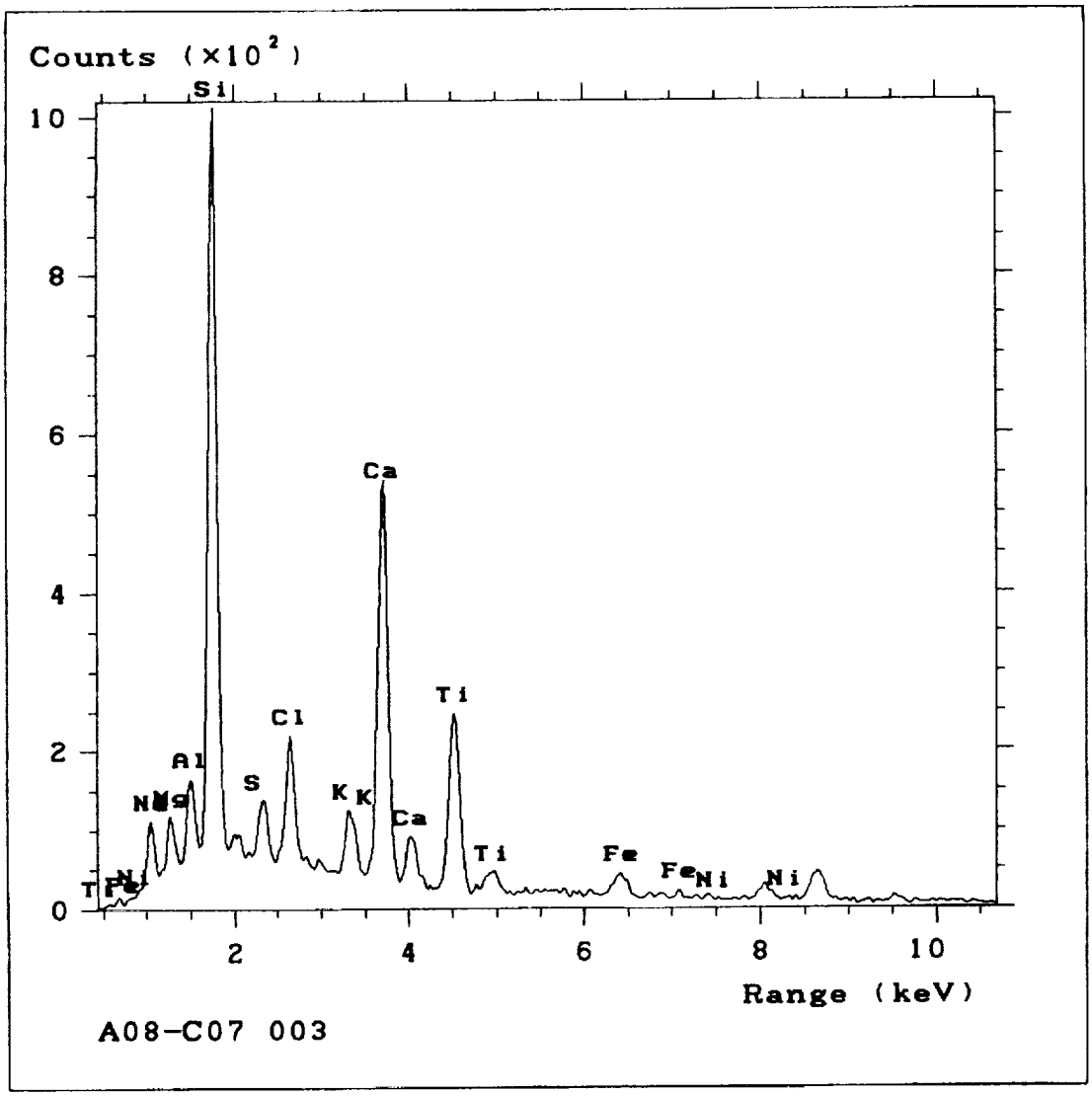


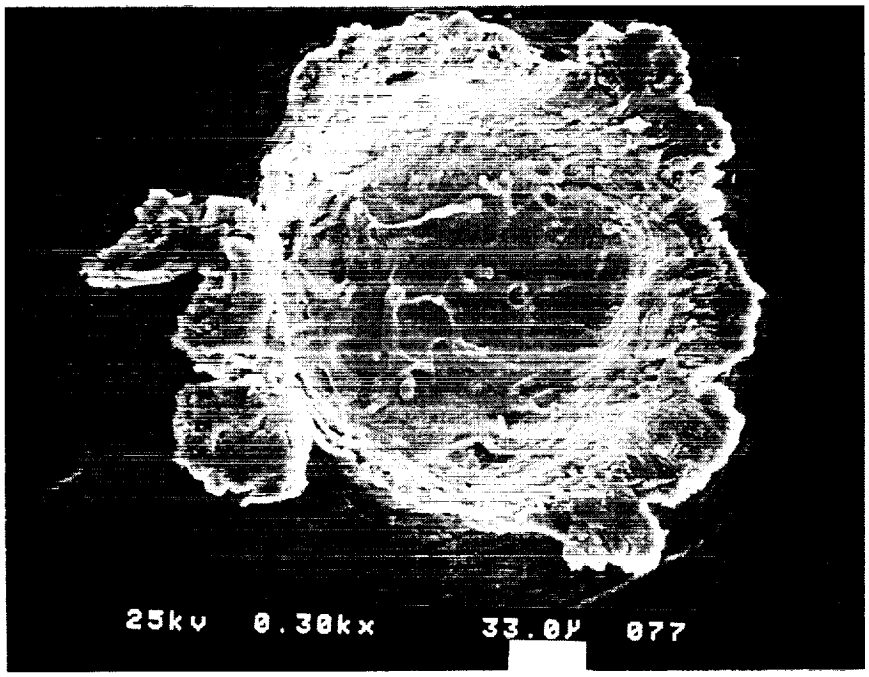

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

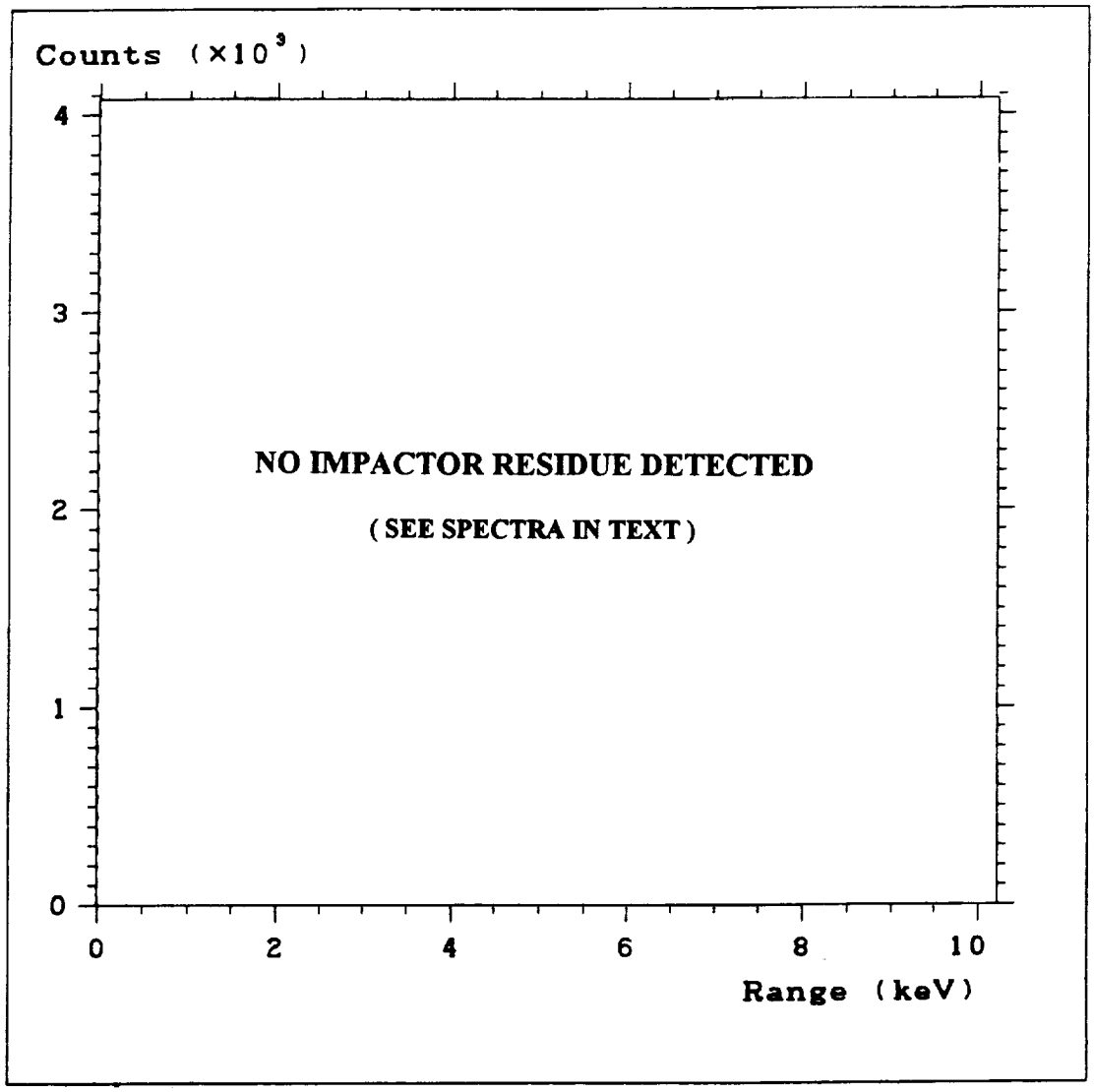

25kv .056kx 180µ 069

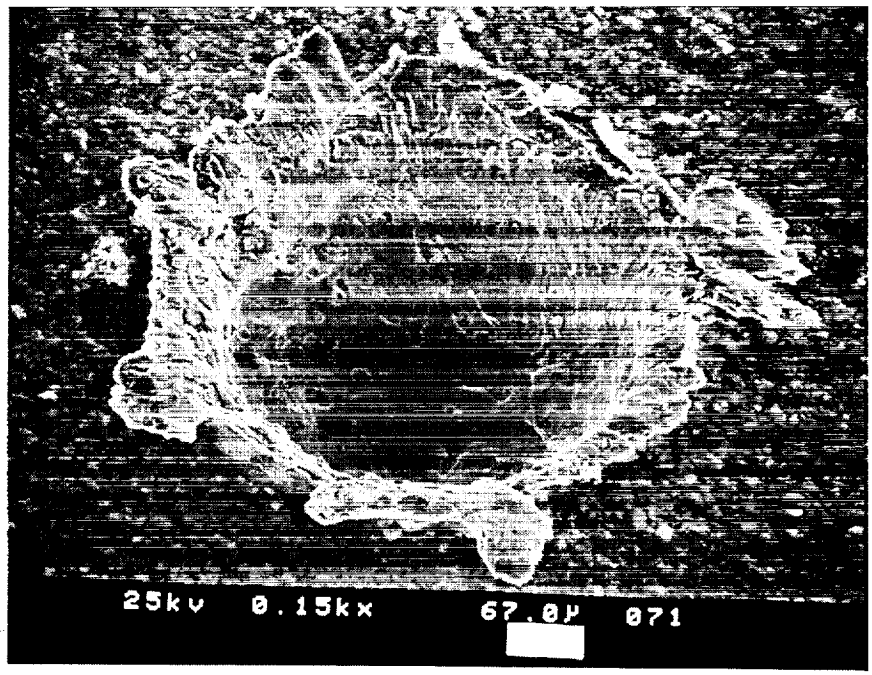

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

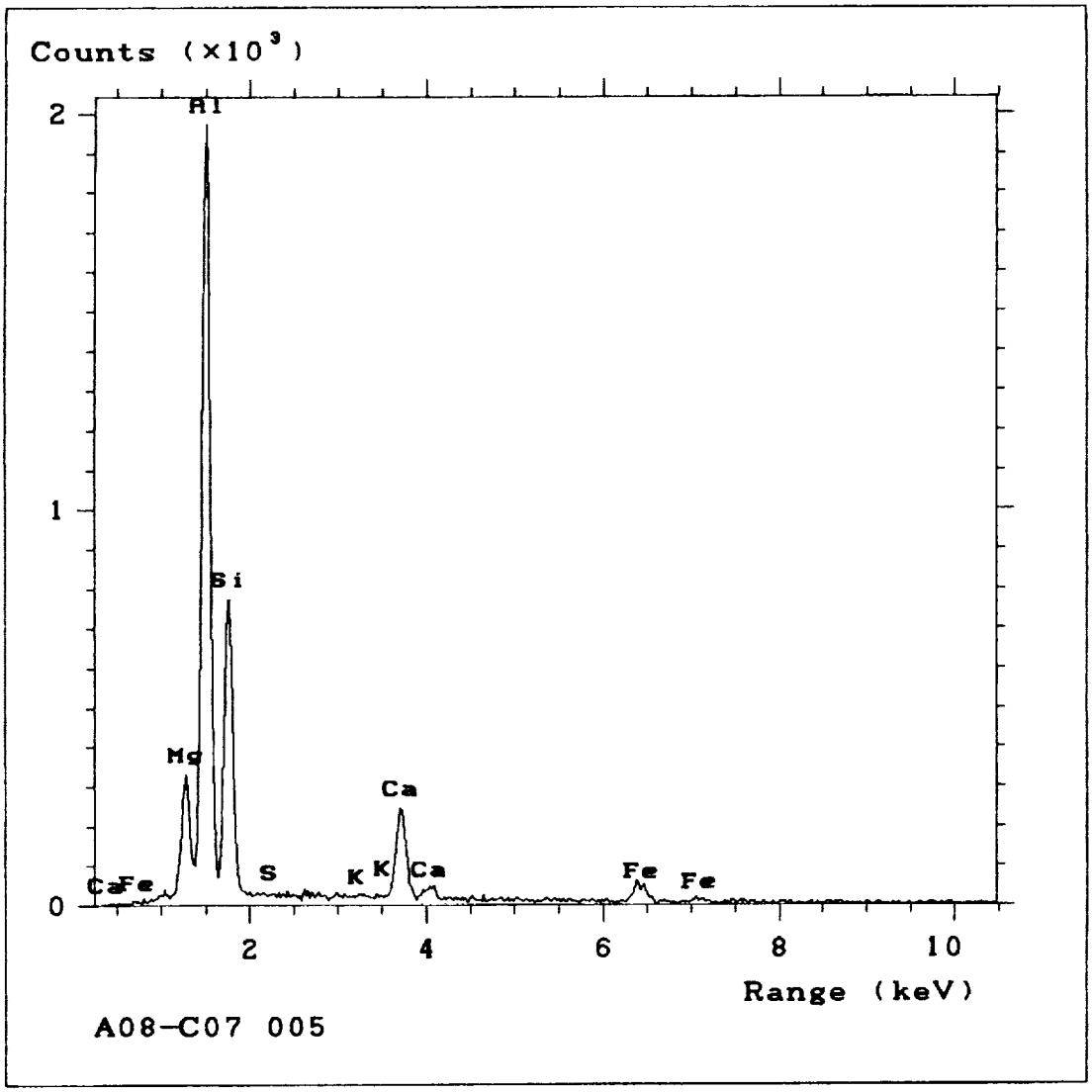

25kv 0.22kx 46.0µ 078

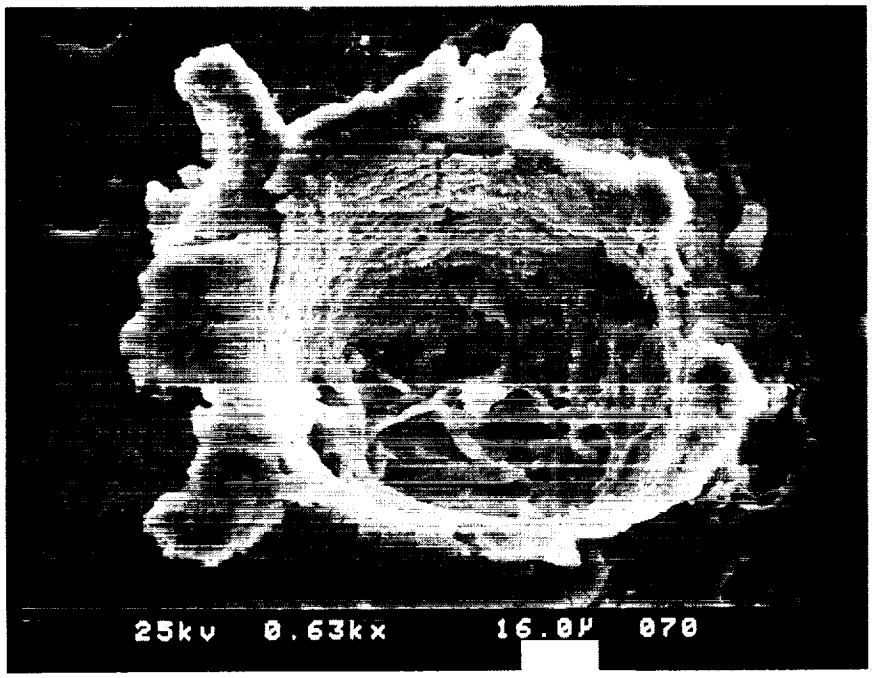

Counts (×10²)
Si
Ca
Cl
Al
S
K
K
Ti
Ca
Ti
Fe
Fe
Ni
Ni
Ni
Mg
Ni
Fe
10
8
6
4
2
0
2
4
6
8
10
Range (keV)
A08-C07 003

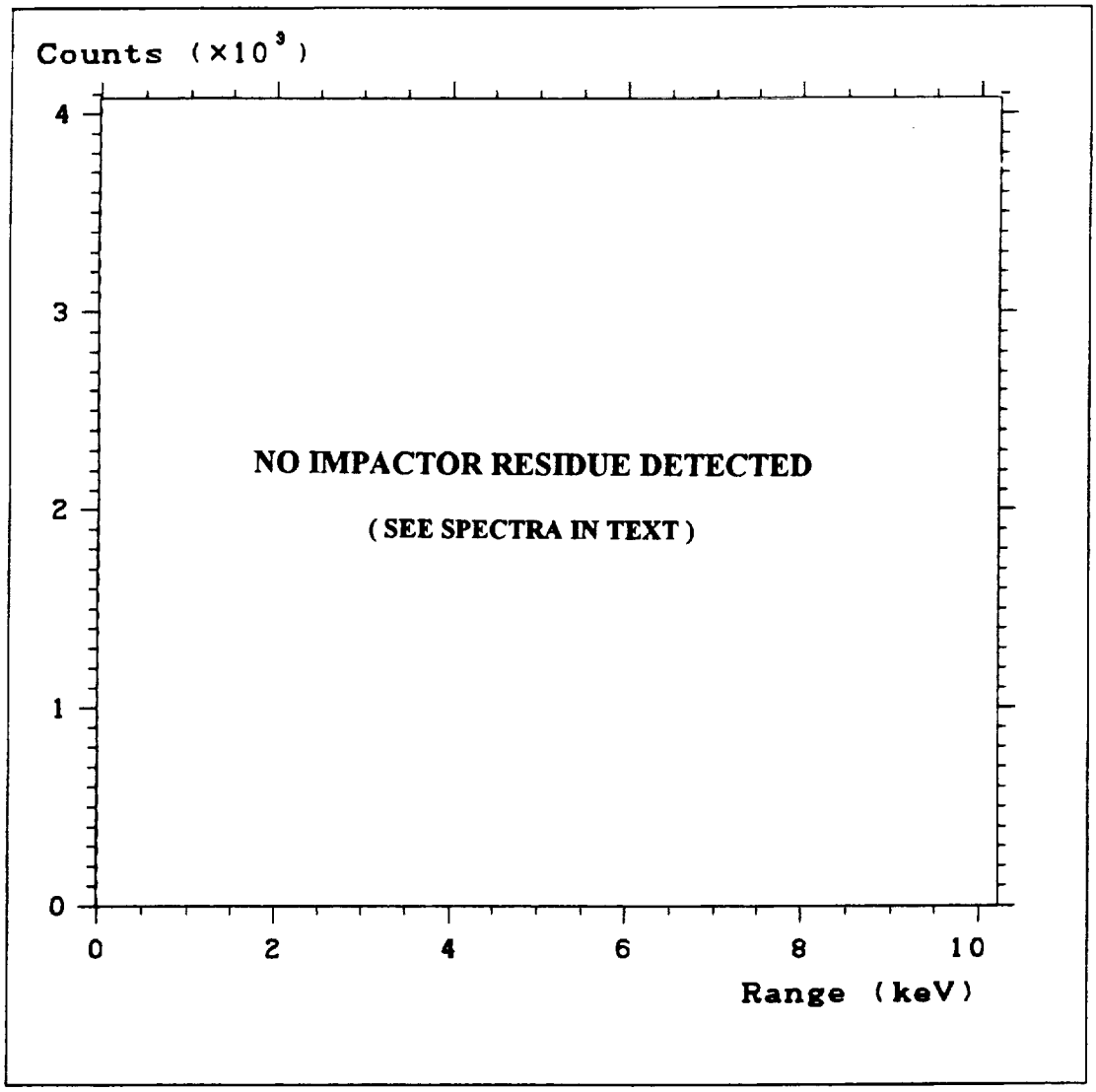

25kv 0.30kx 33.0µ 077

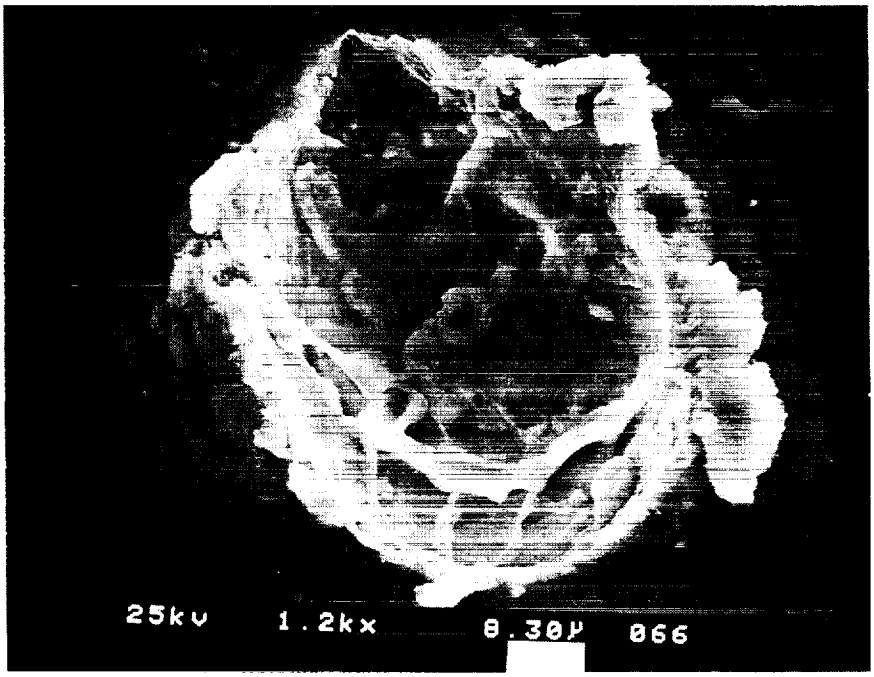

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

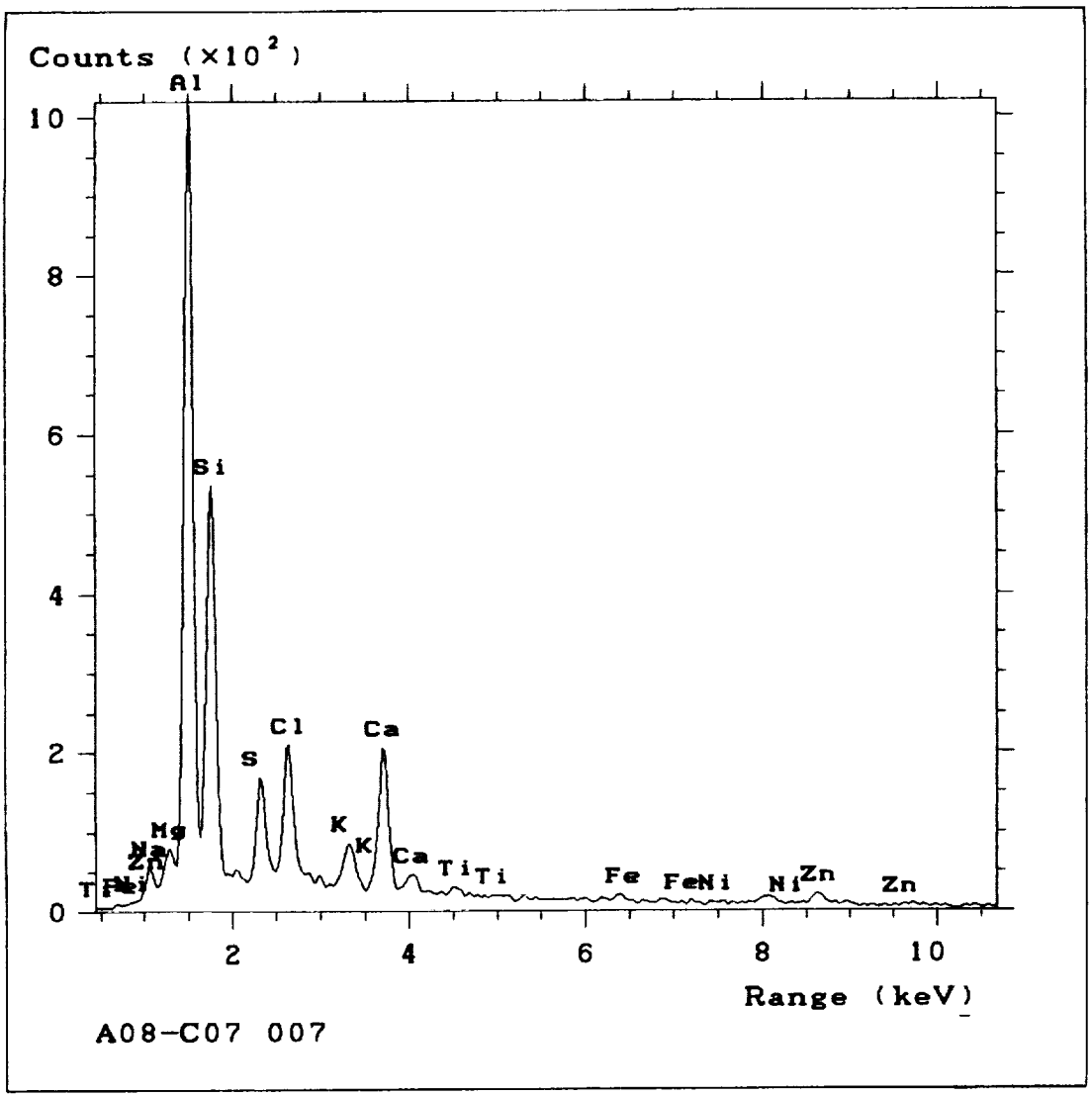

25kv 0.15kx 67.0µ 071

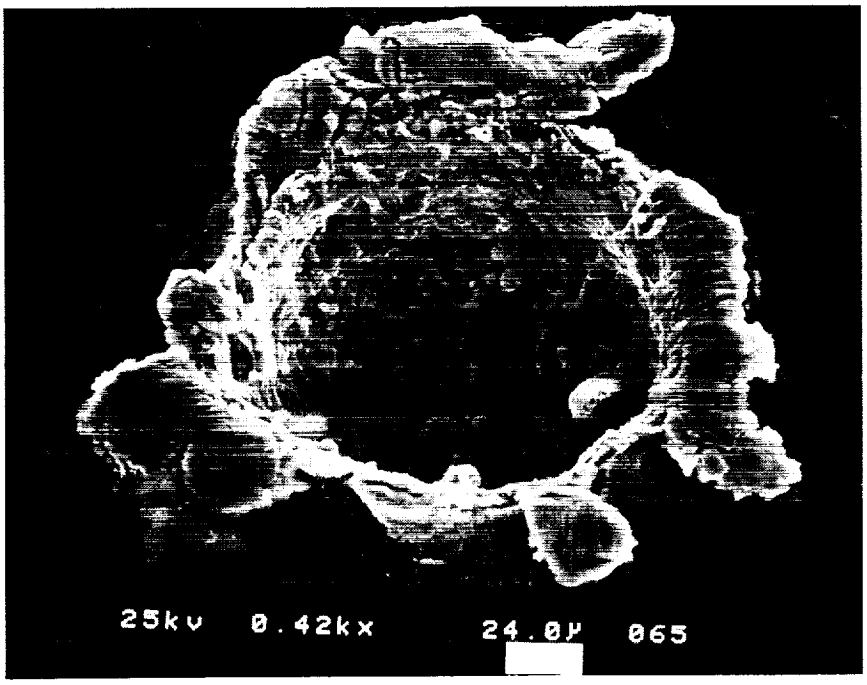

Counts (×10³)
2
1
0
Al
Si
Mg
Ca
Ca
Fe
S
K
K
Ca
Fe
Fe
2
4
6
8
10
Range (keV)
A08-C07 005

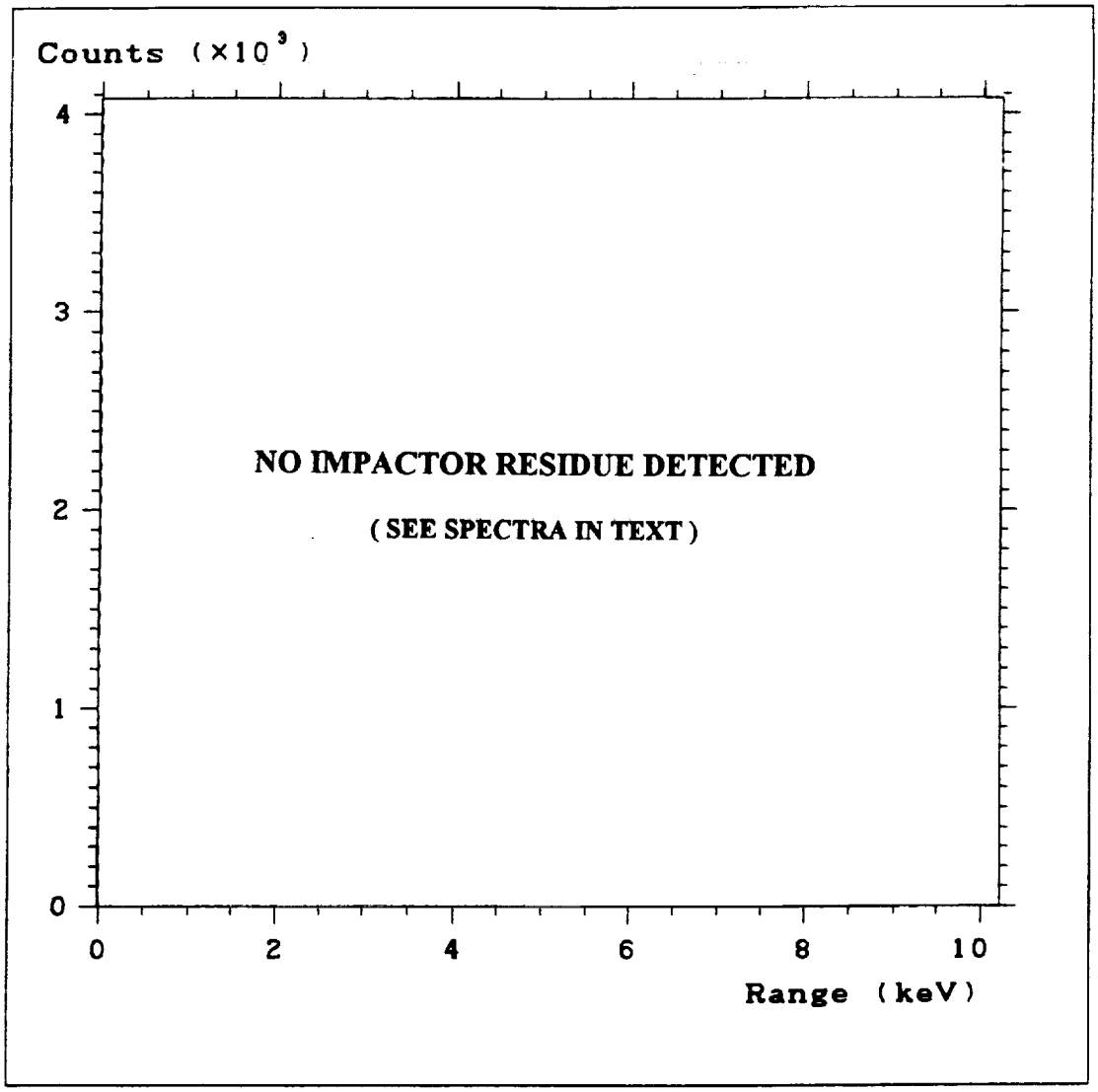

25kv 0.63kx 16.0μ 070

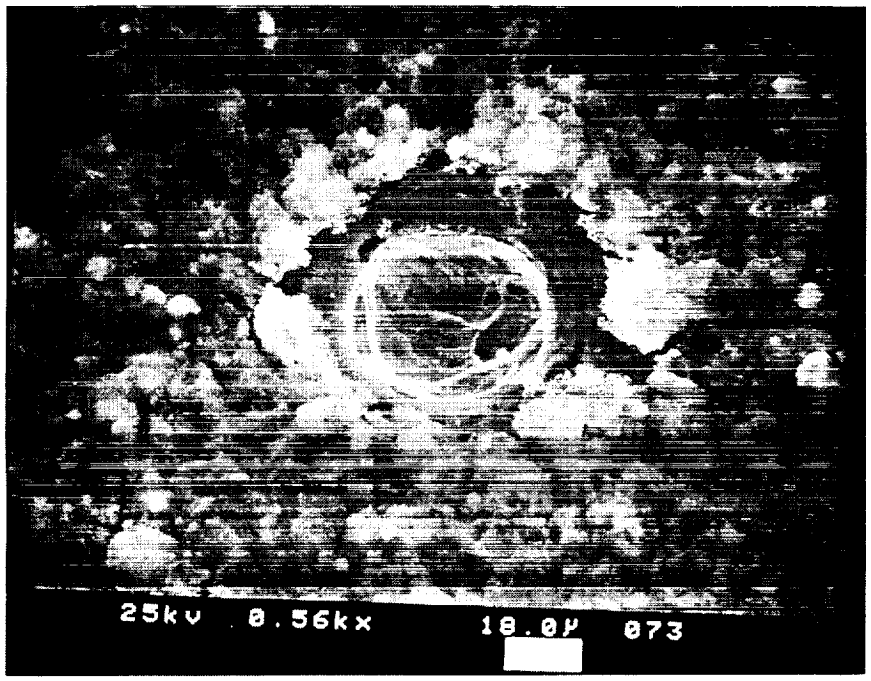

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

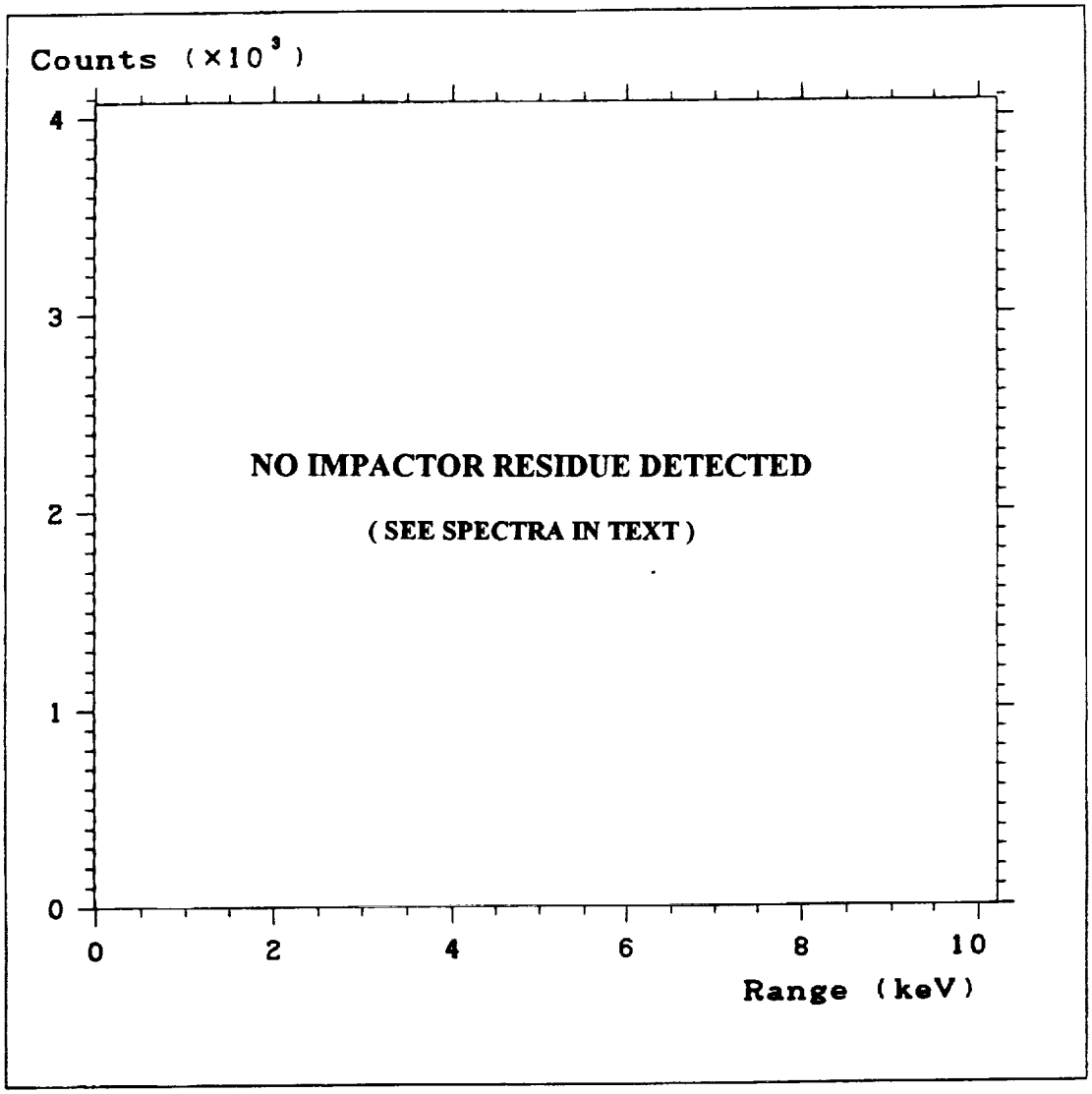

25kv
1.2kx
8.30µ
066

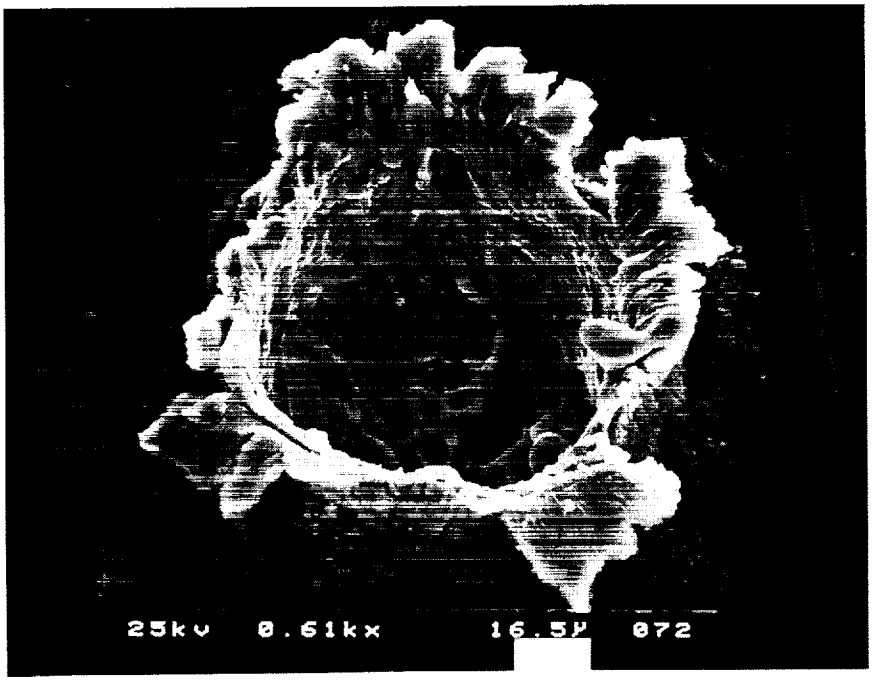

Counts (×10²)
Al
Si
S
Cl
Ca
K
K
Ca
Ti
Ti
Fe
FeNi
Ni
Zn
Zn
Mg
Na
Zn
10
8
6
4
2
0
2
4
6
8
10
Range (keV)
A08-C07 007

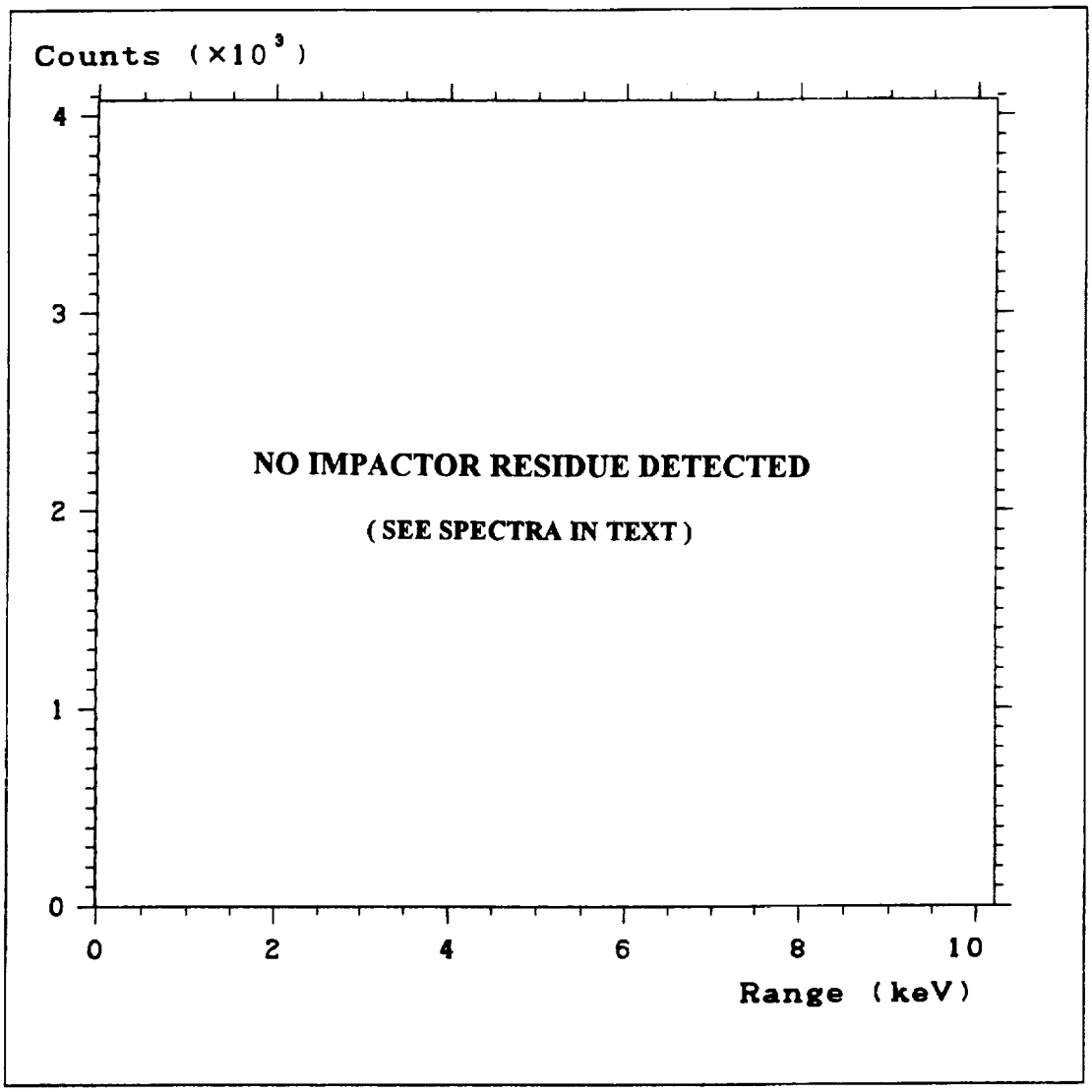

25kv 0.42kx 24.0µ 065

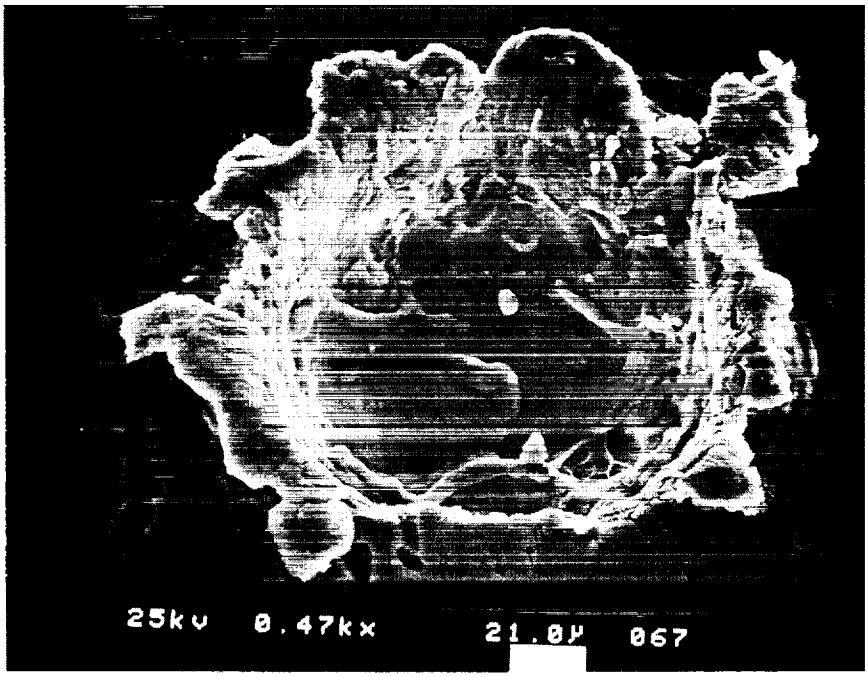

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

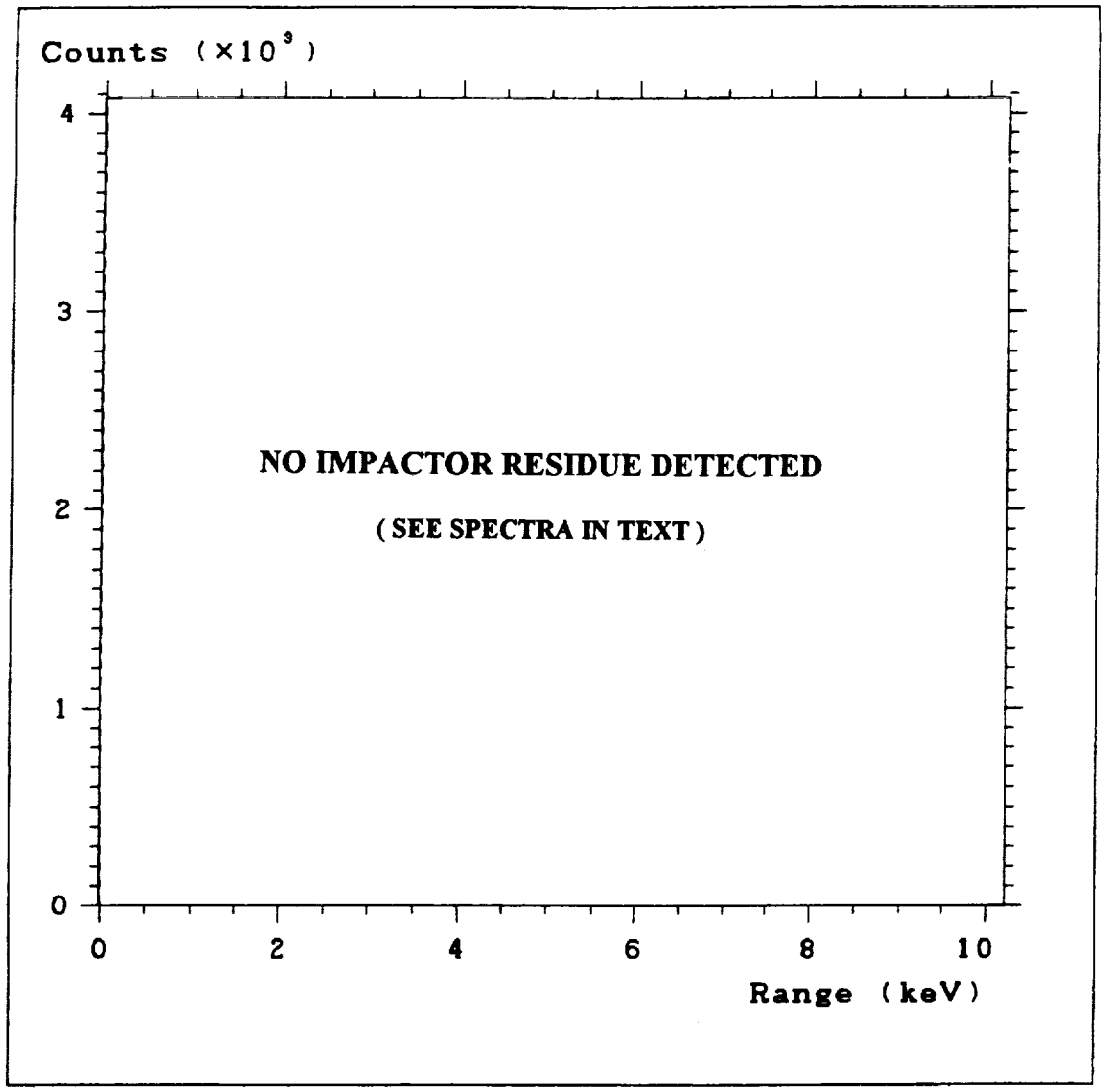

25kv 0.56kx 18.0µ 073

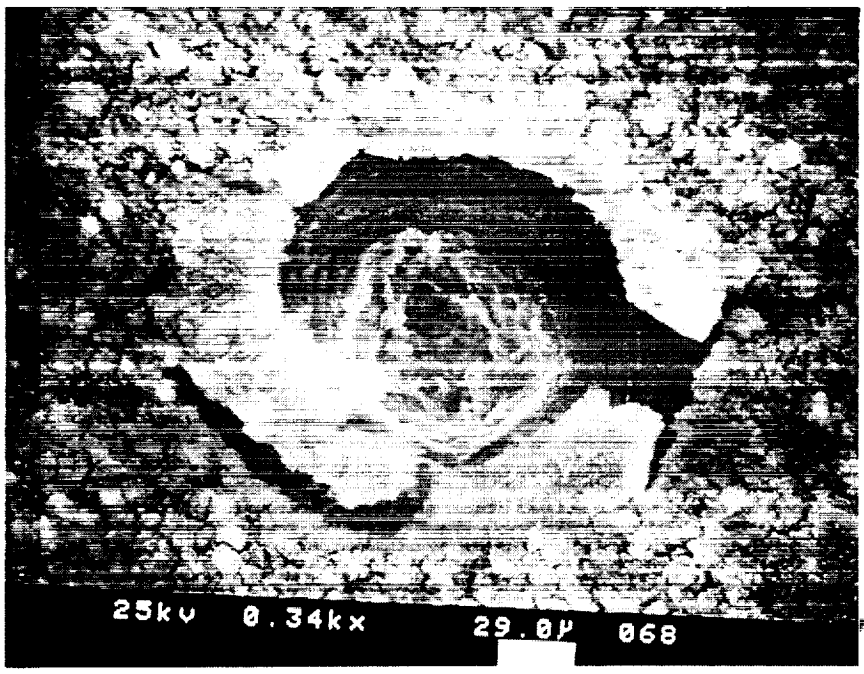

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

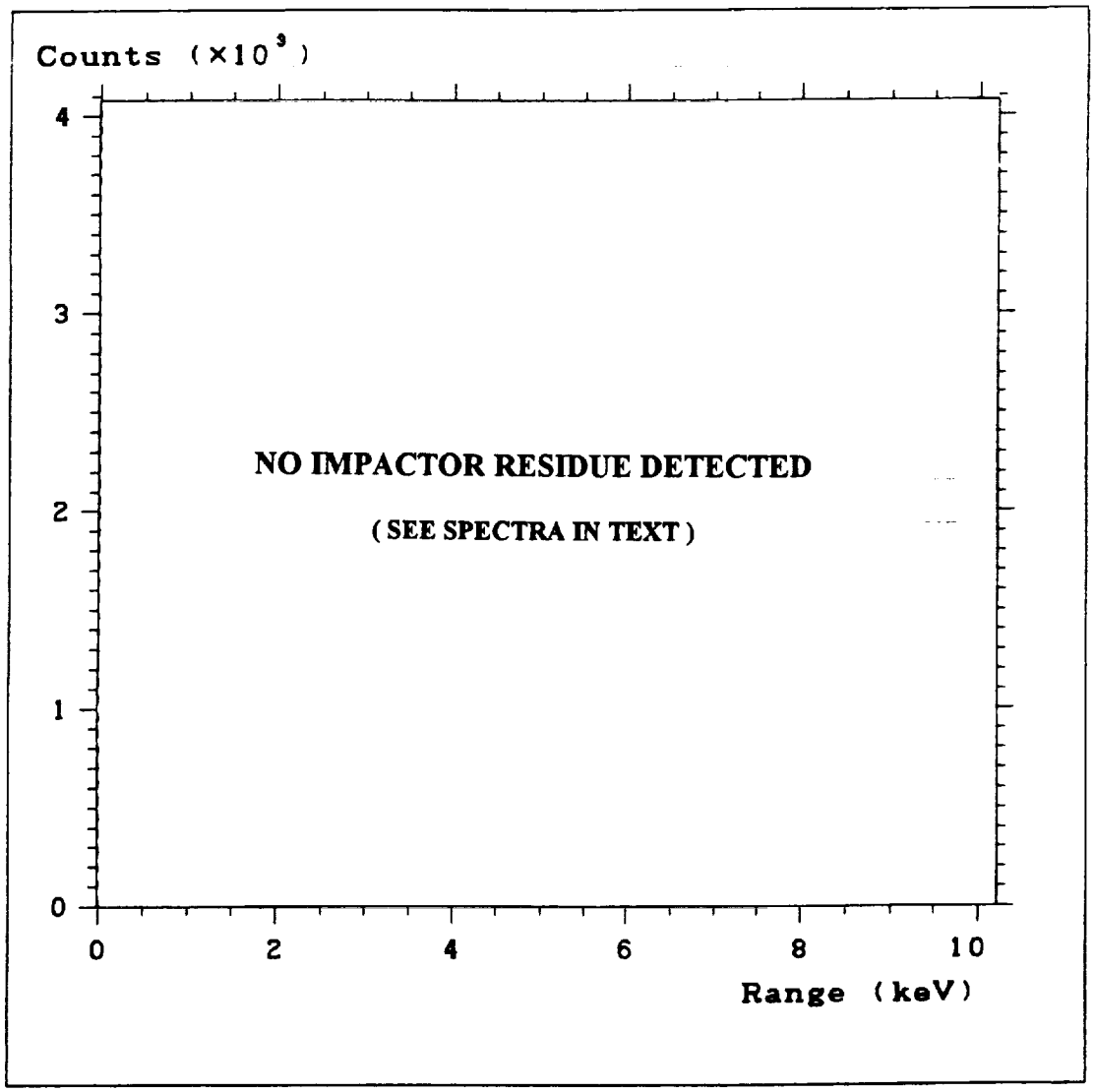

25kv 0.61kx 16.5µ 072

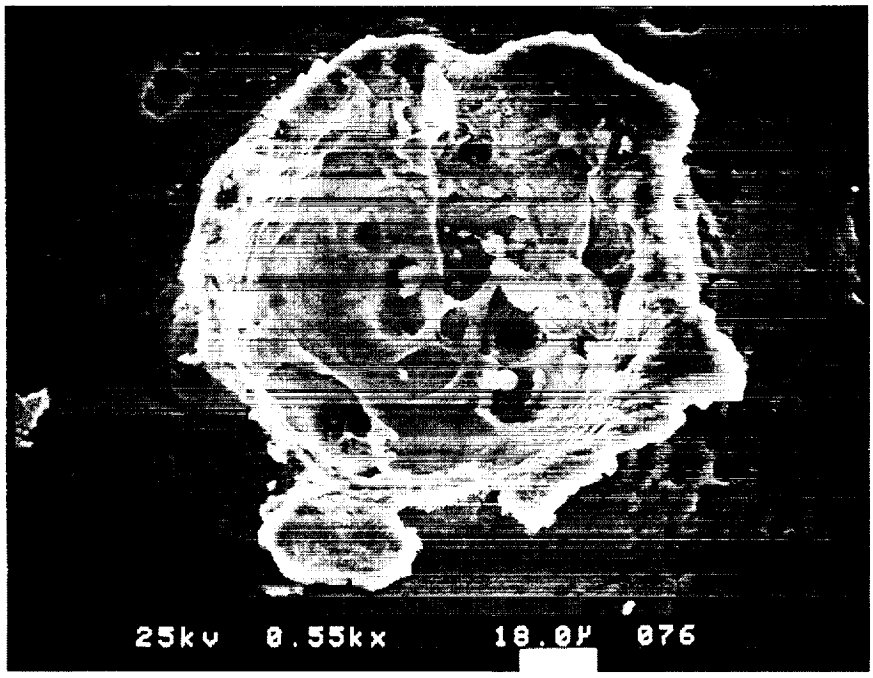

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 0.47kx 21.0µ 067


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

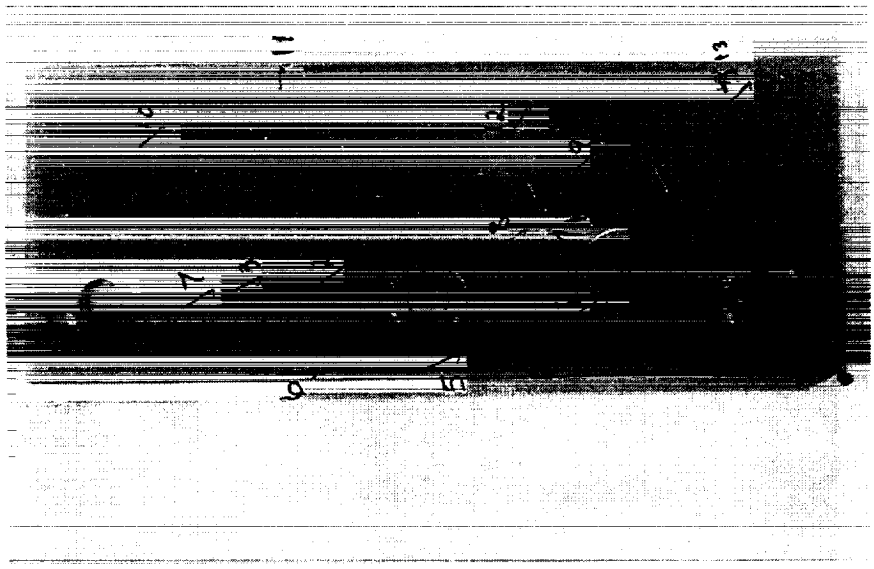

25kv 0.34kx 29.0µ 068

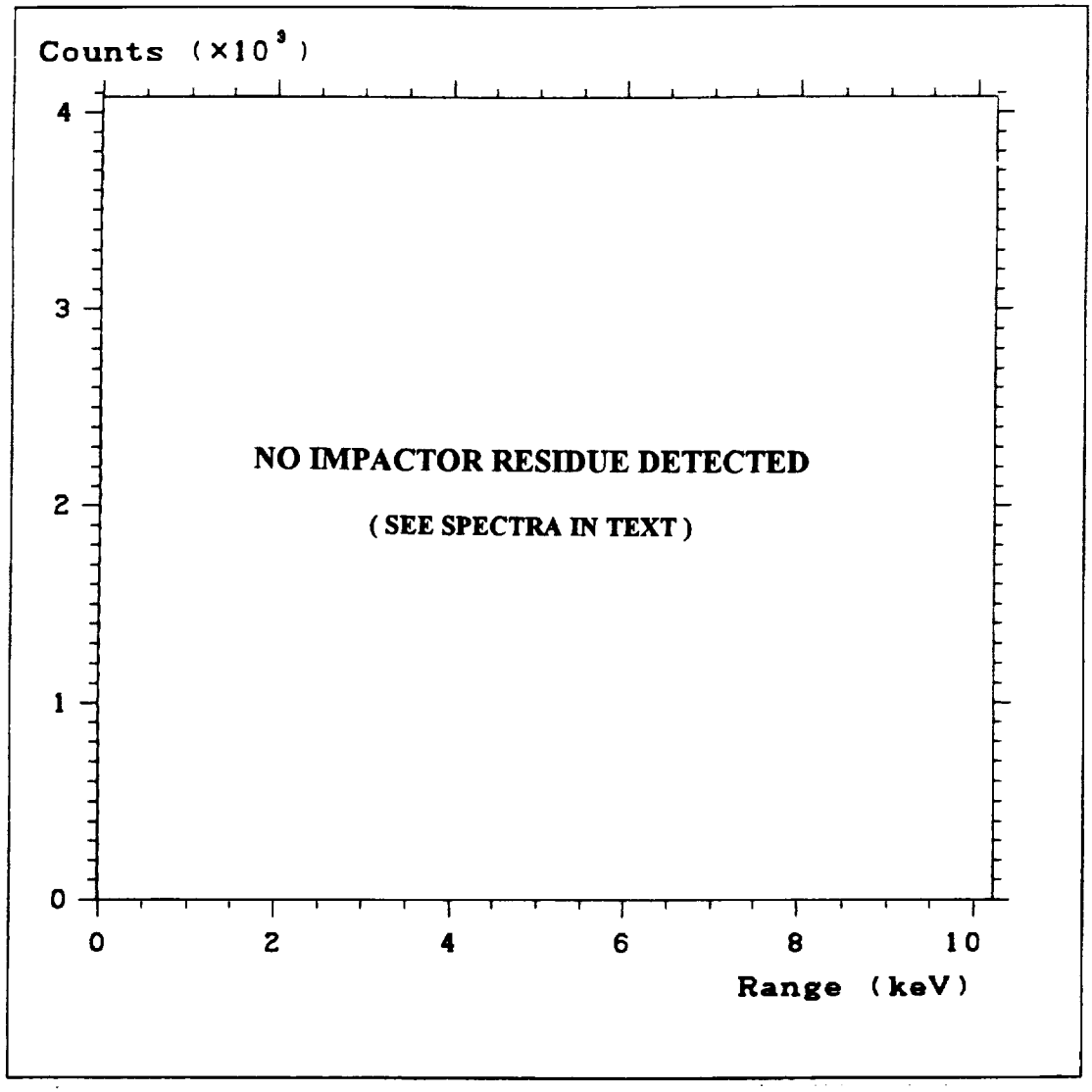

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

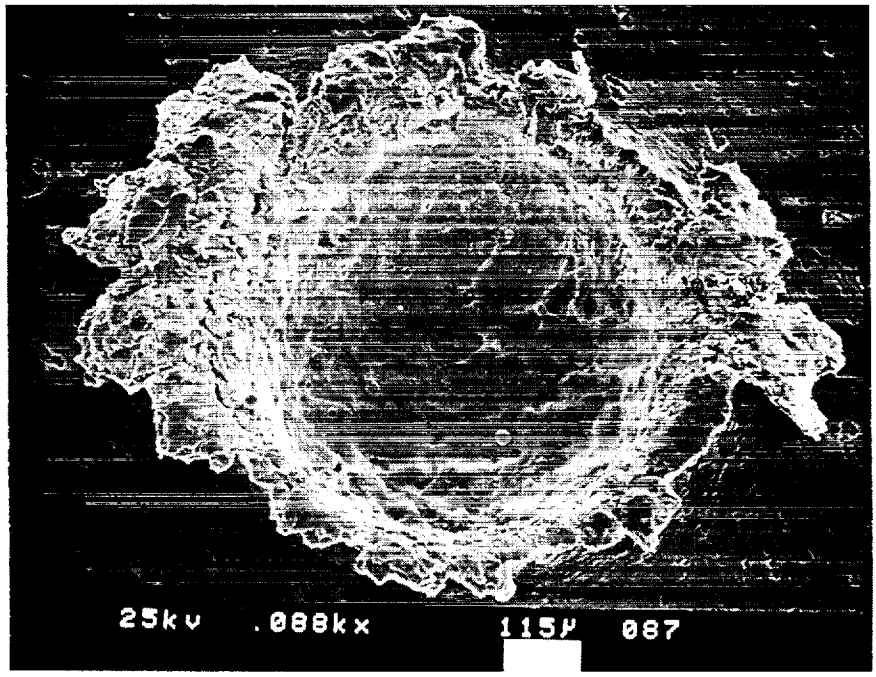

25kv 0.55kx 18.0µ 076

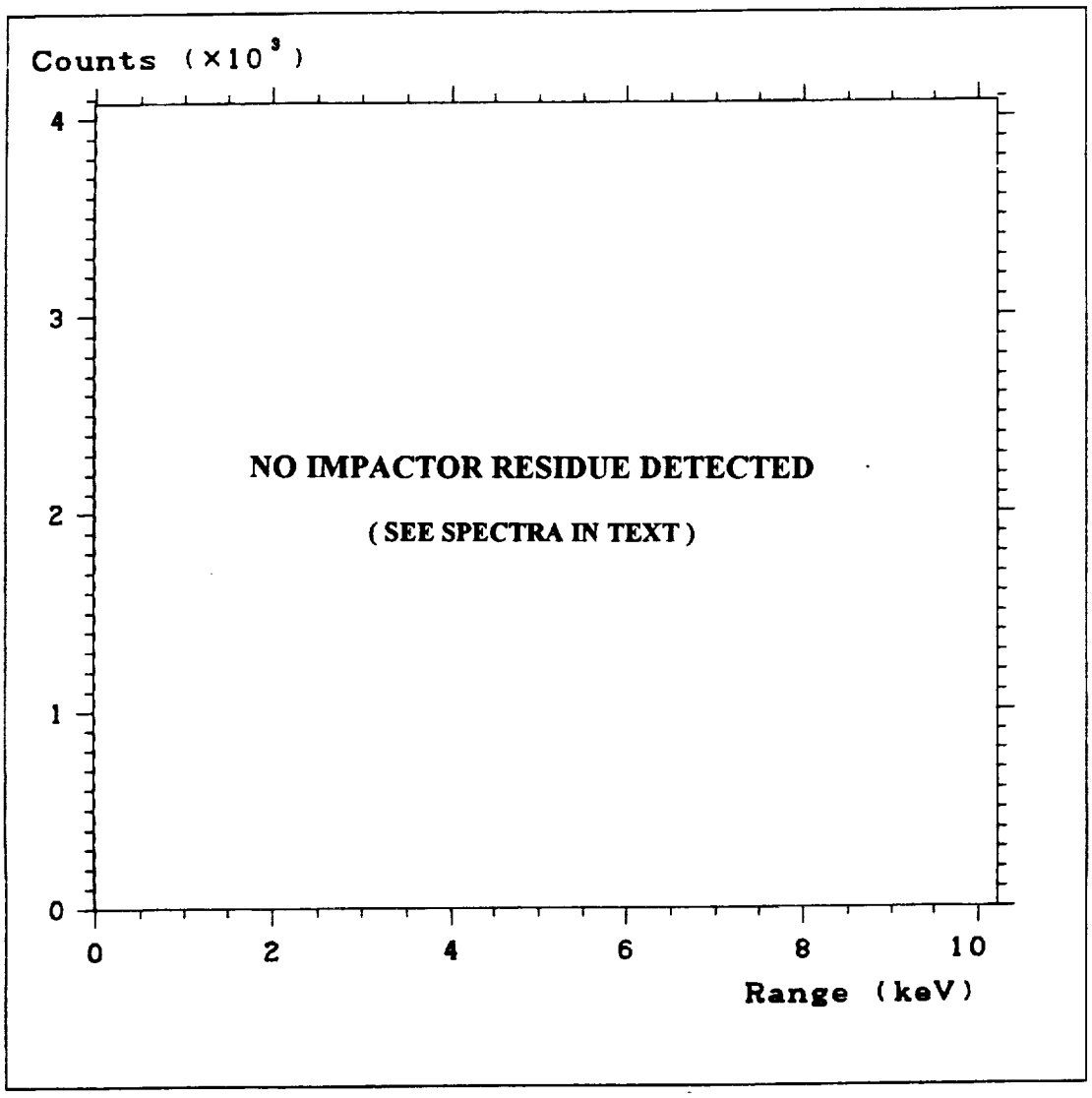
CLAMP NUMBER A08 CO8

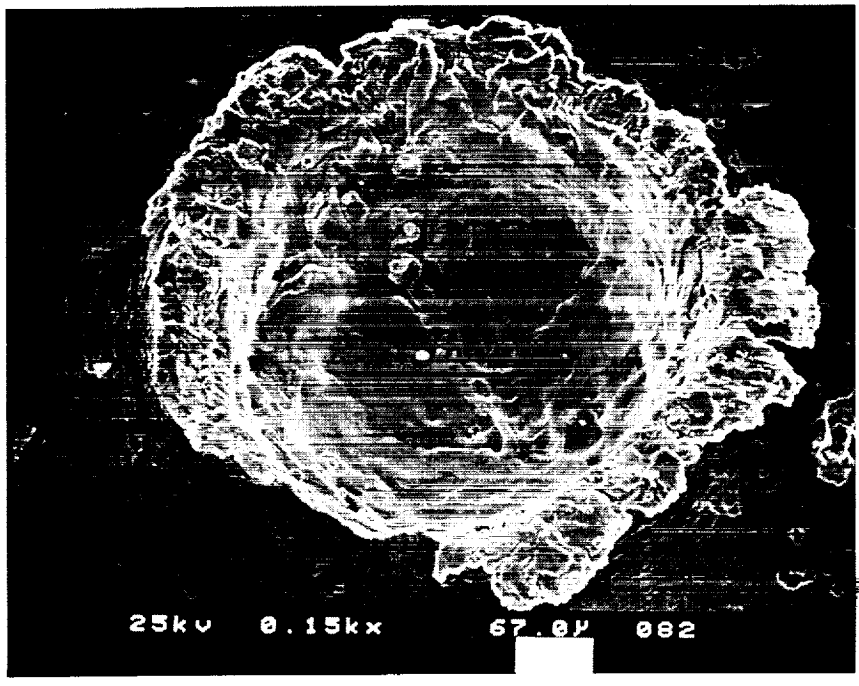
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	700	Unknown
002	500	Unknown
003	500	Trace
004	150	Unknown
005	200	Unknown
006	120	Si, Mg, Ca, Fe
007	190	Unknown
008	90	Unknown
009	110	Unknown
010	100	Paint
011	400	Unknown
012	350	Si, Mg, Ca
013	120	Si, Mg, Ca

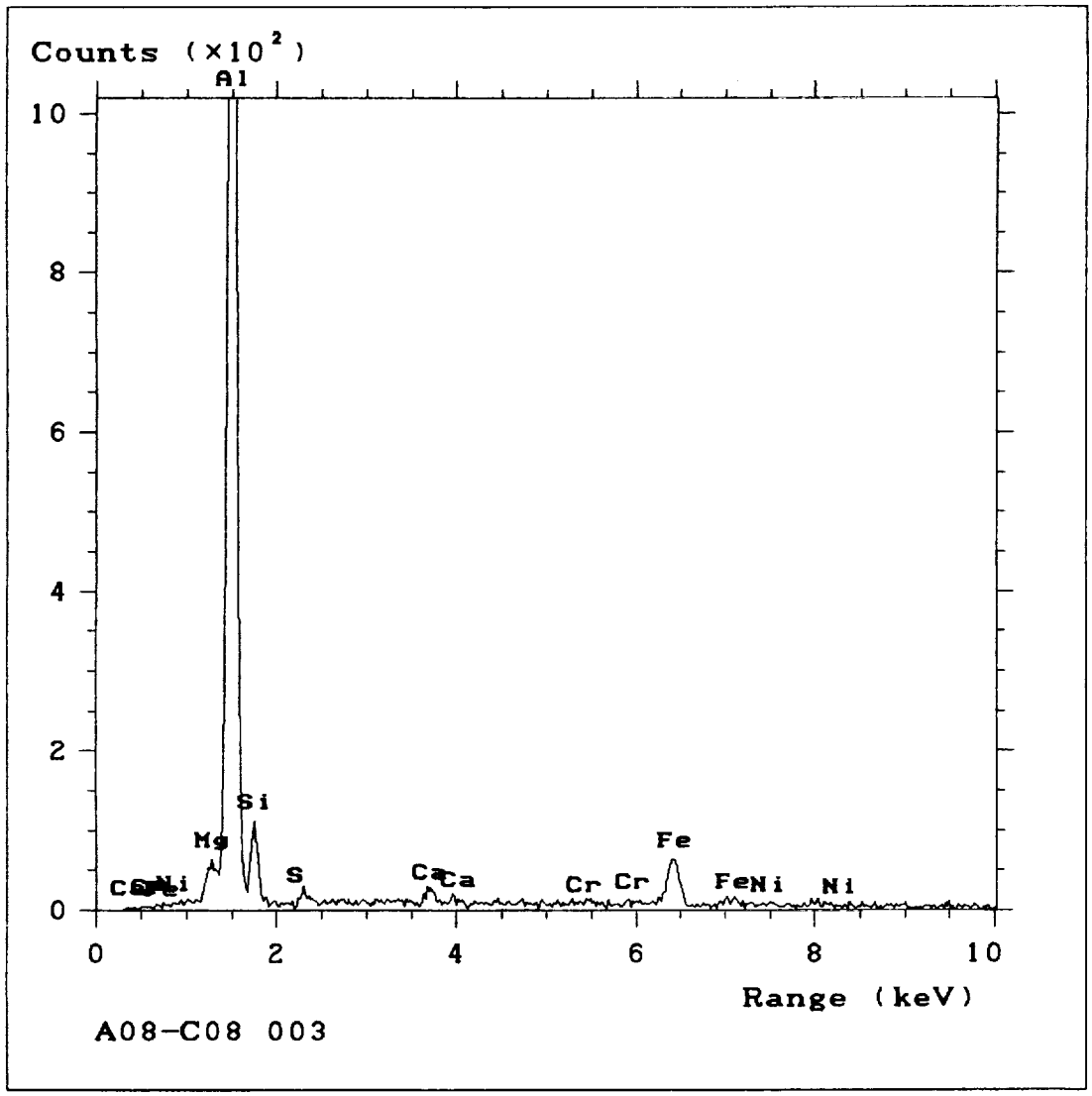


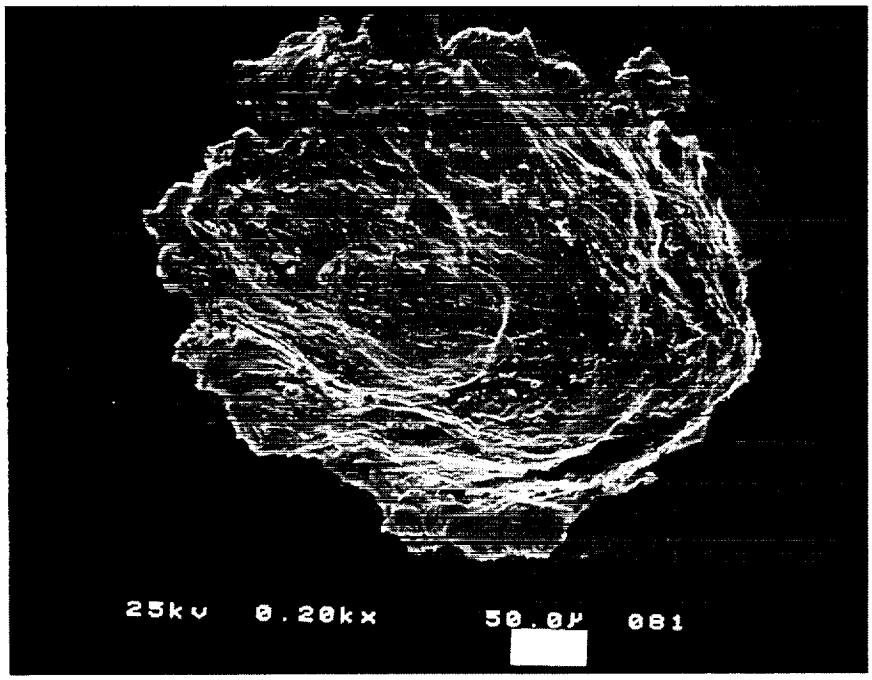

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

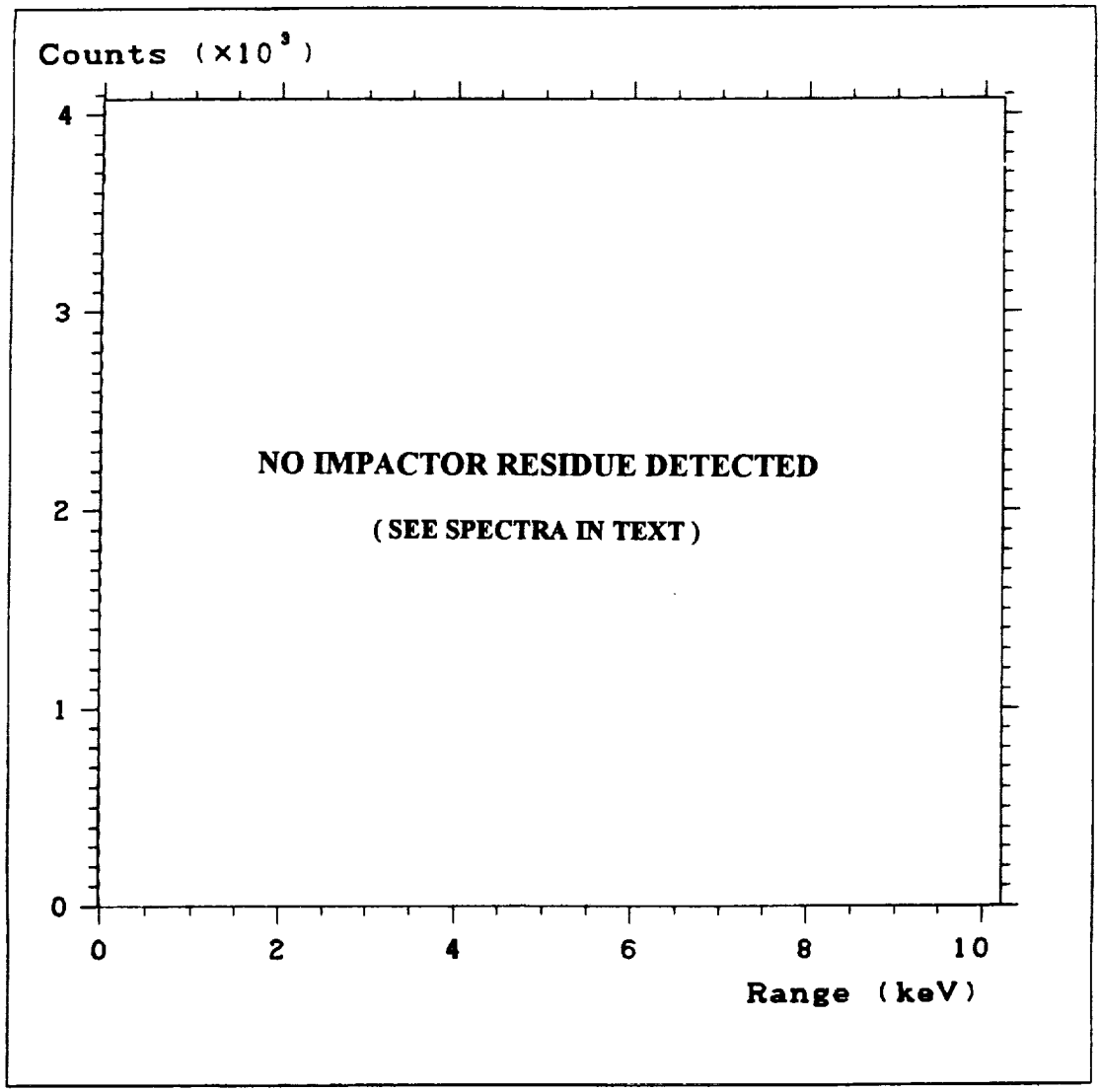

25kv .088kx 115µ 087

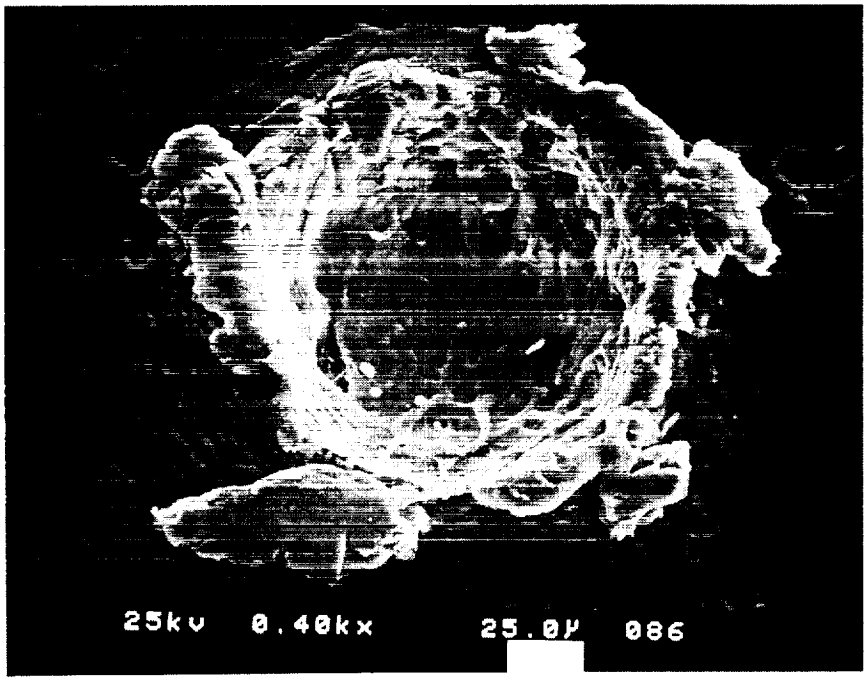

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

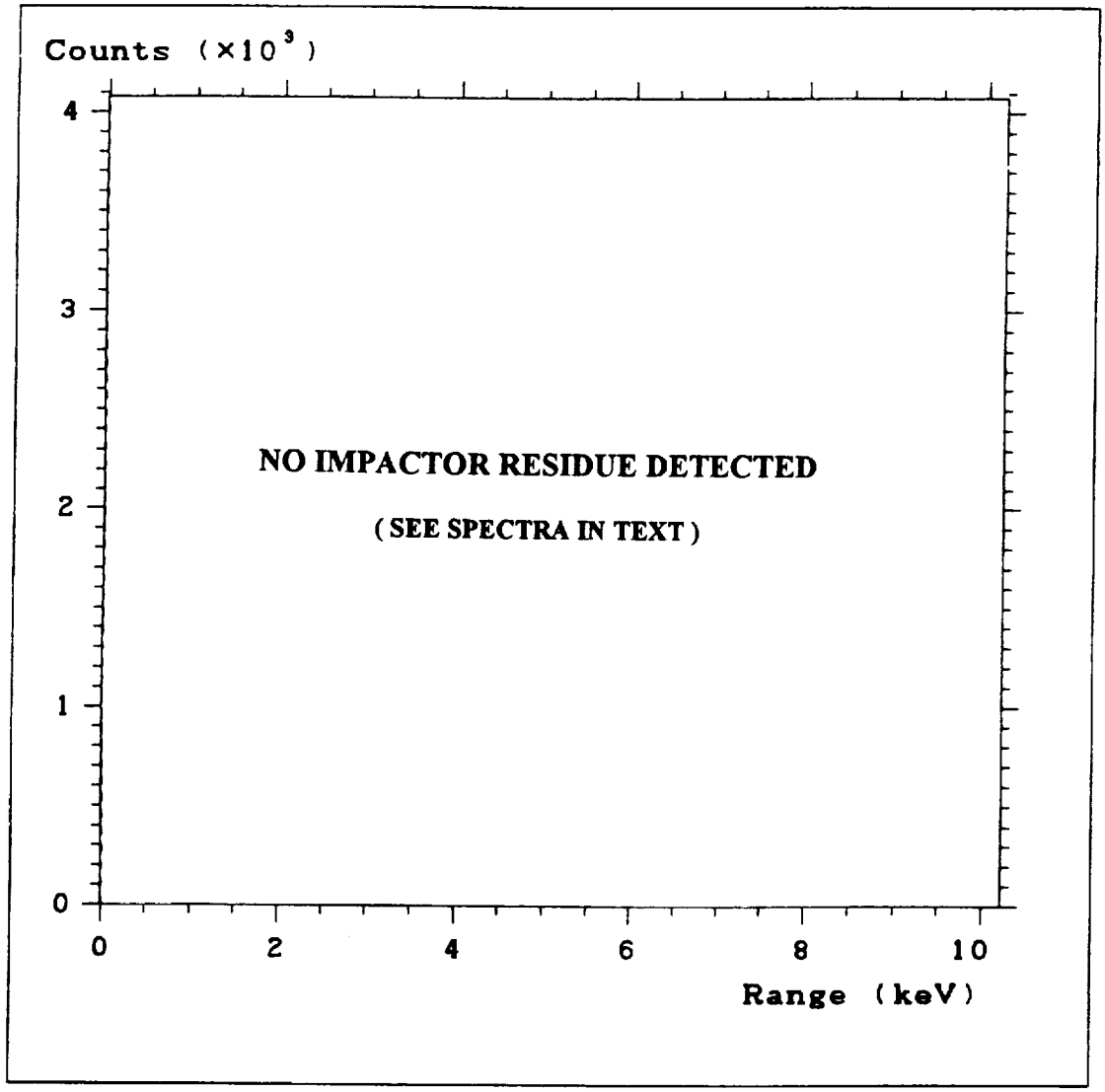

25kv 0.15kx 67.0µ 082

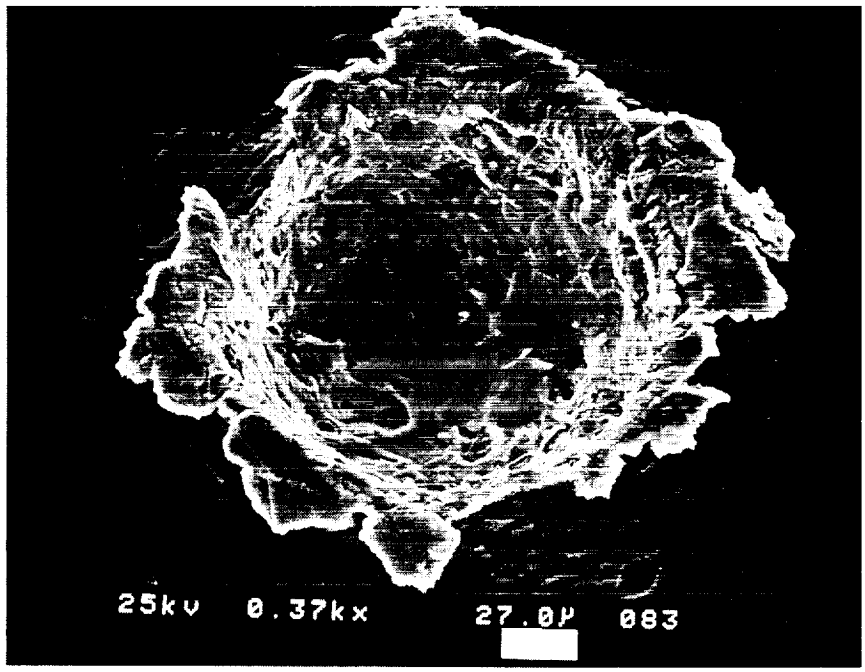

Counts (×10²)
Al
Si
Mg
S
Ca
Ca
Cr
Cr
Fe
Ni
Ni
10
8
6
4
2
0
0
2
4
6
8
10
Range (keV)
A08-C08 003

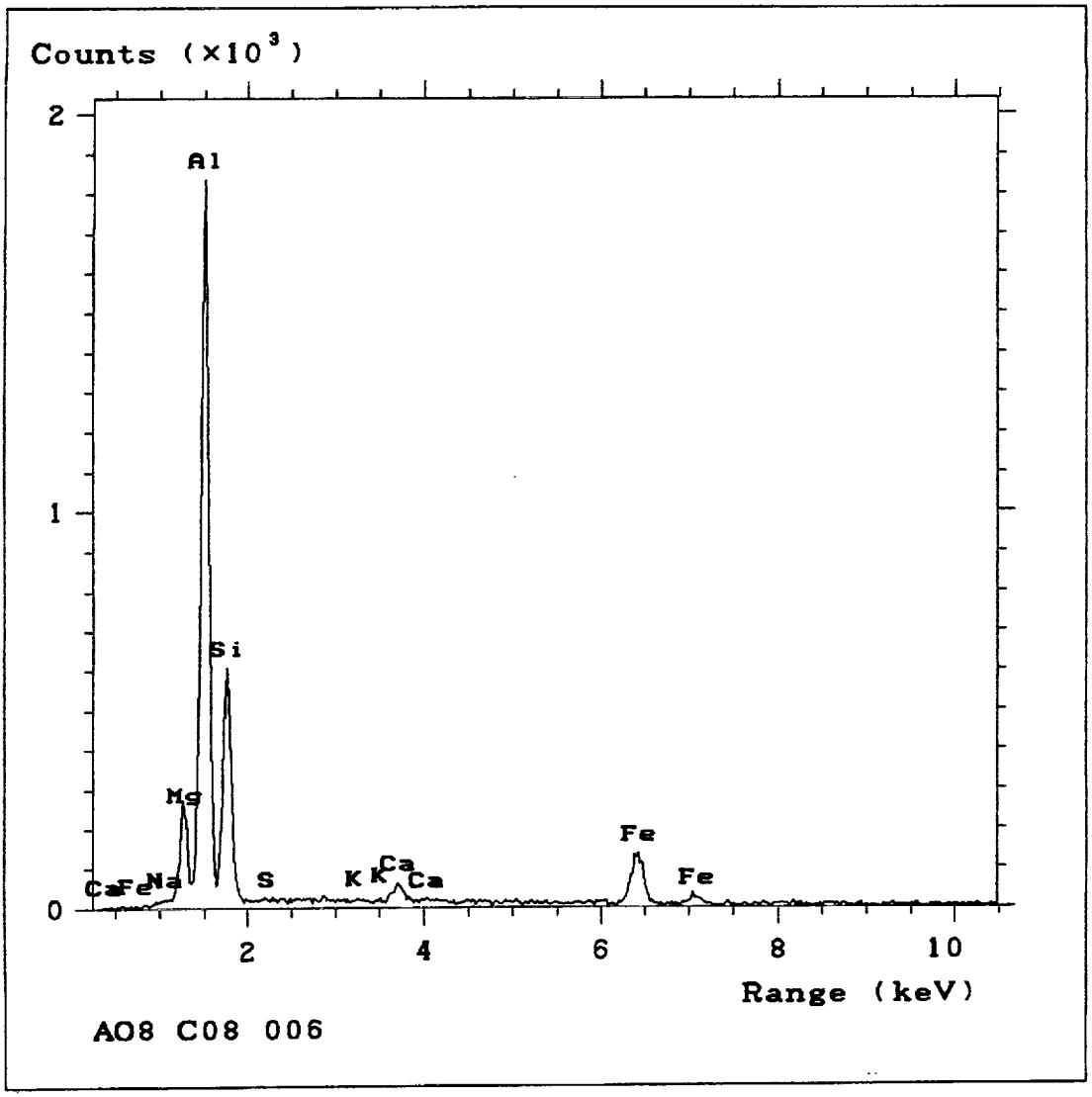

25kv 0.20kx 50.0μ 081

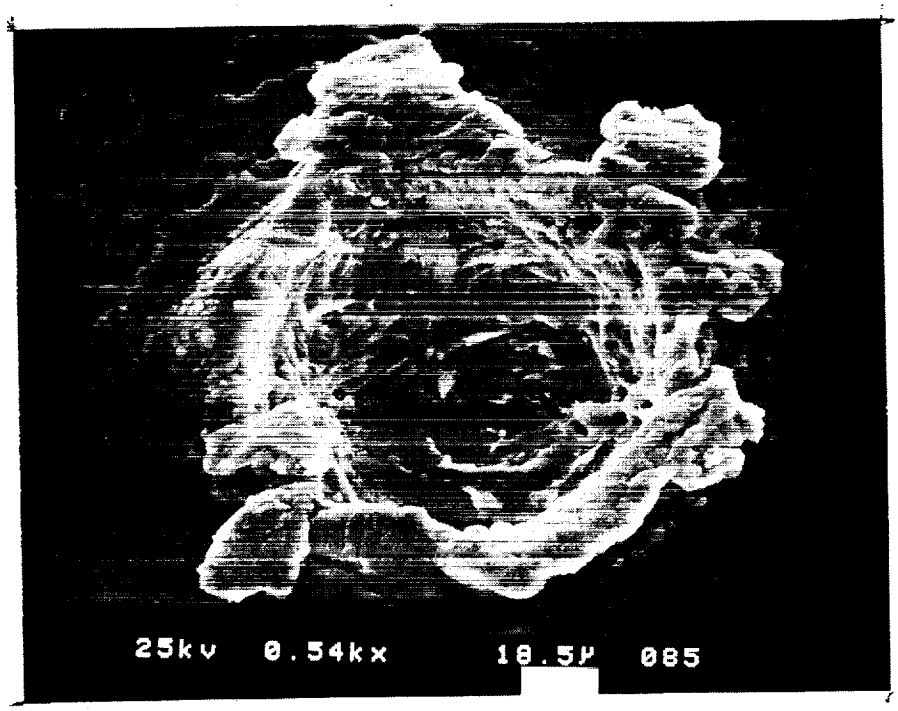

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

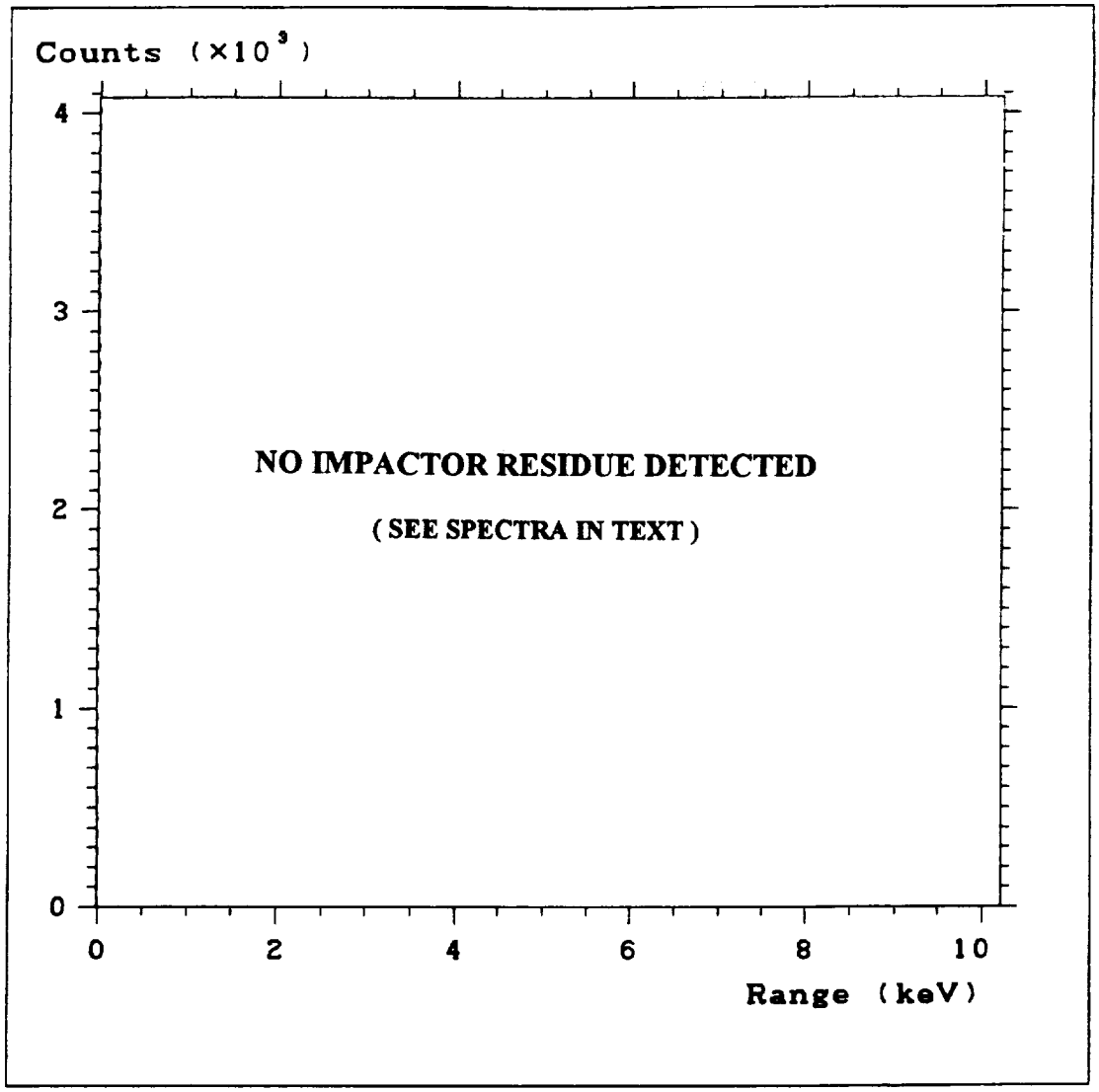

25kv 0.40kx 25.0µ 086

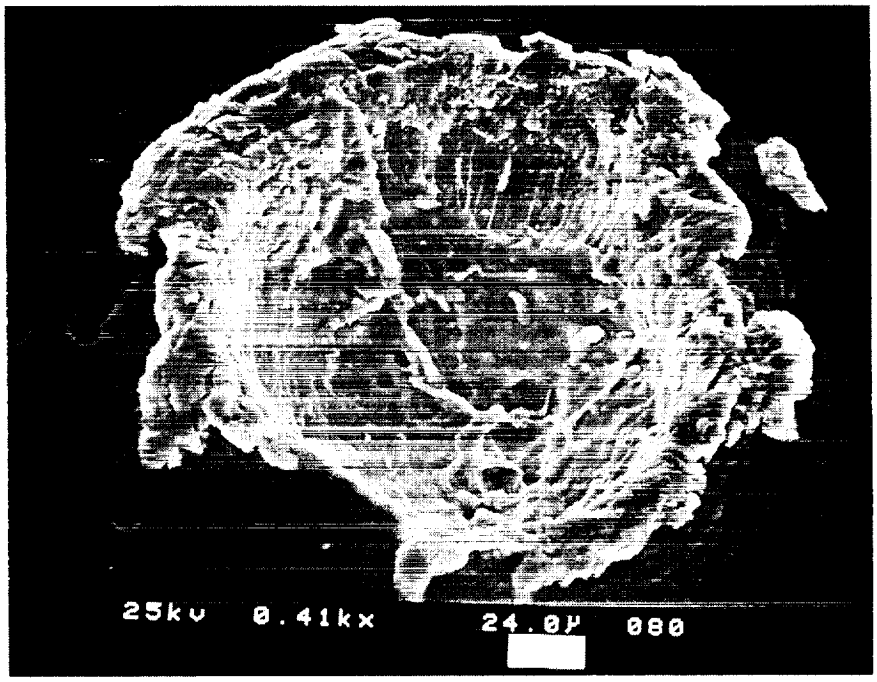

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

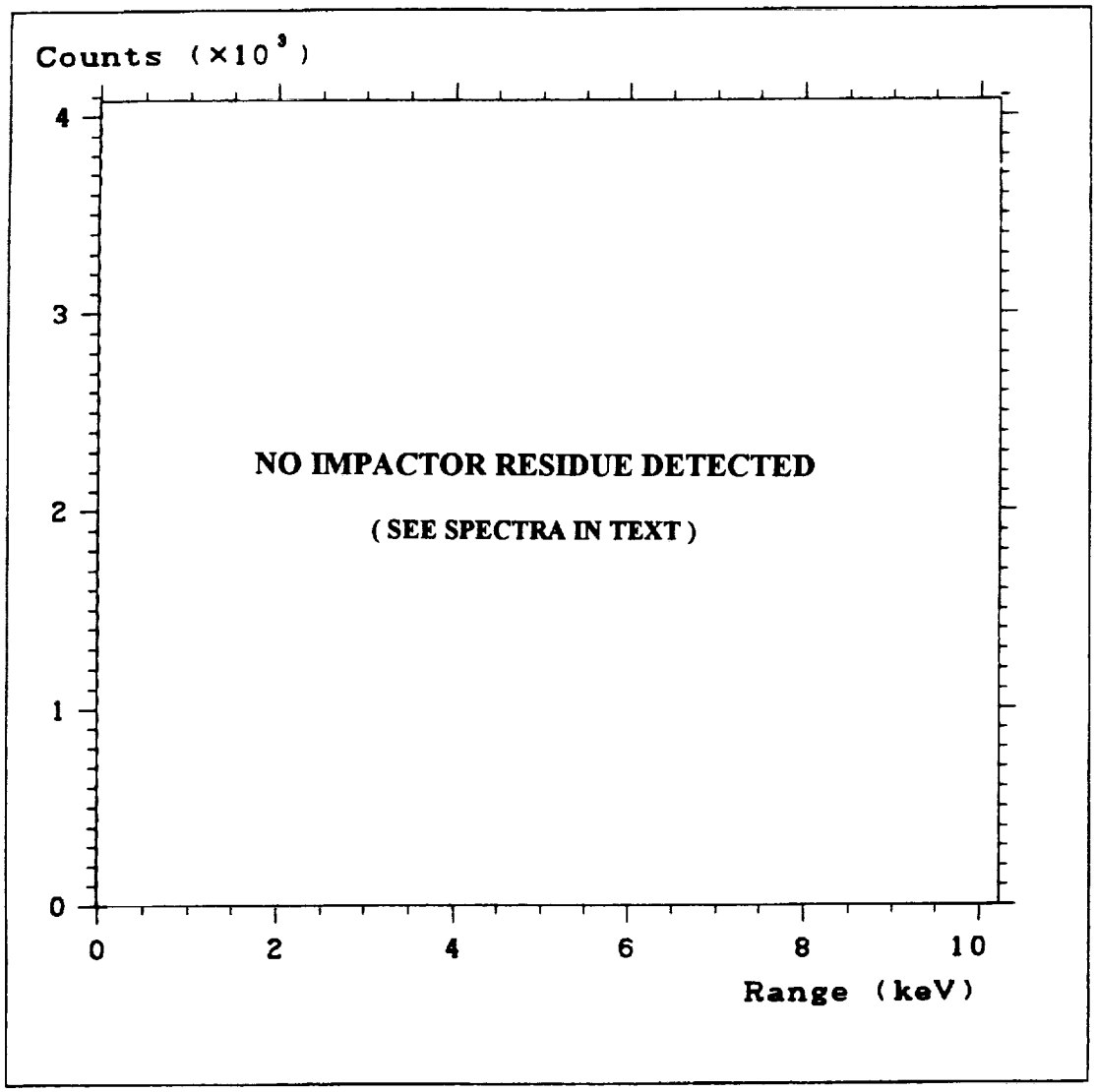

25kv 0.37kx 27.0µ 083

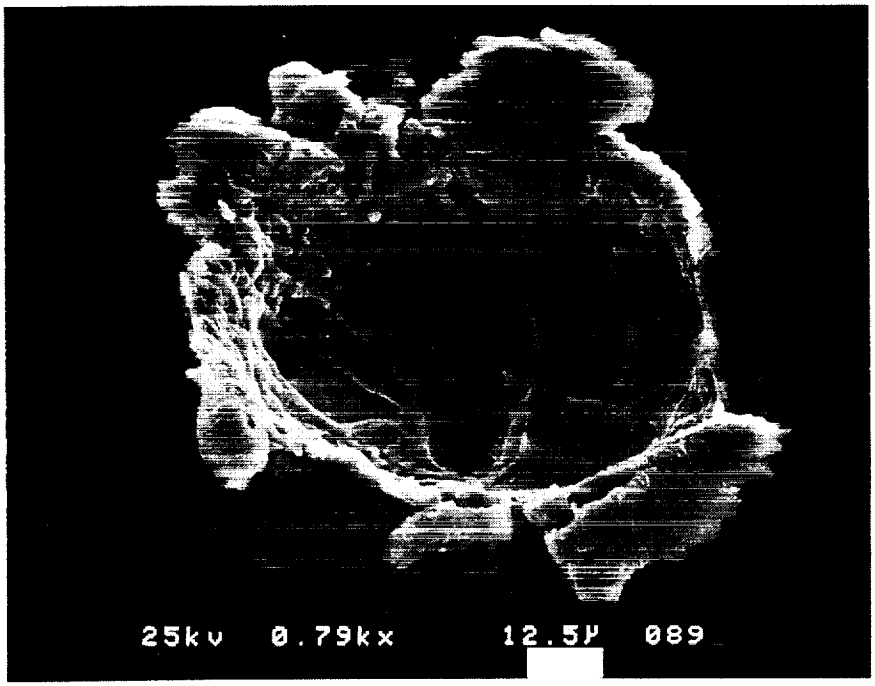

Counts (×10³)
2
1
0
Al
Si
Mg
Ca Fe Na
S
K K Ca Ca
Fe
Fe
2
4
6
8
10
Range (keV)
AO8 C08 006

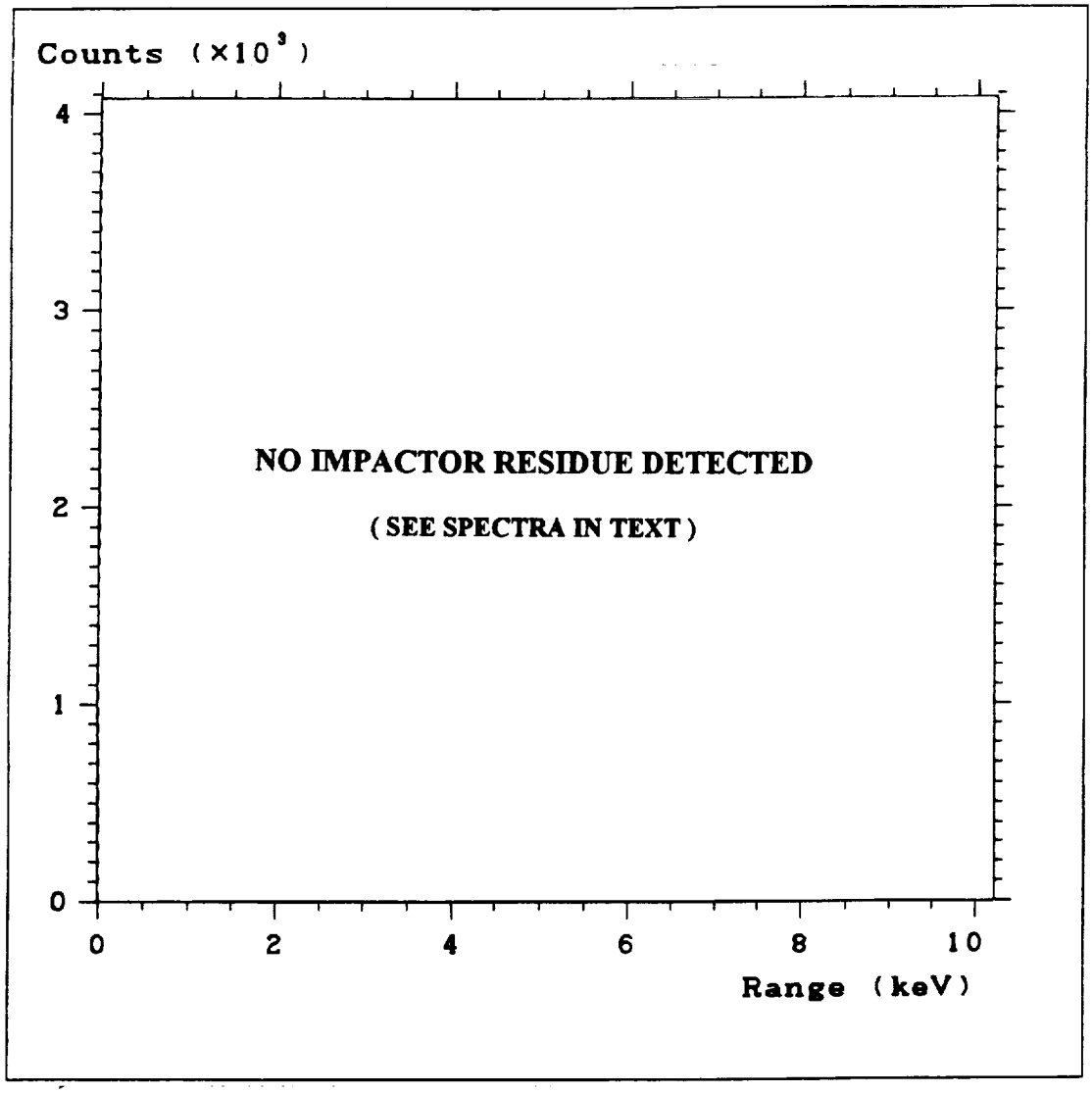

25kv 0.54kx 18.5µ 085

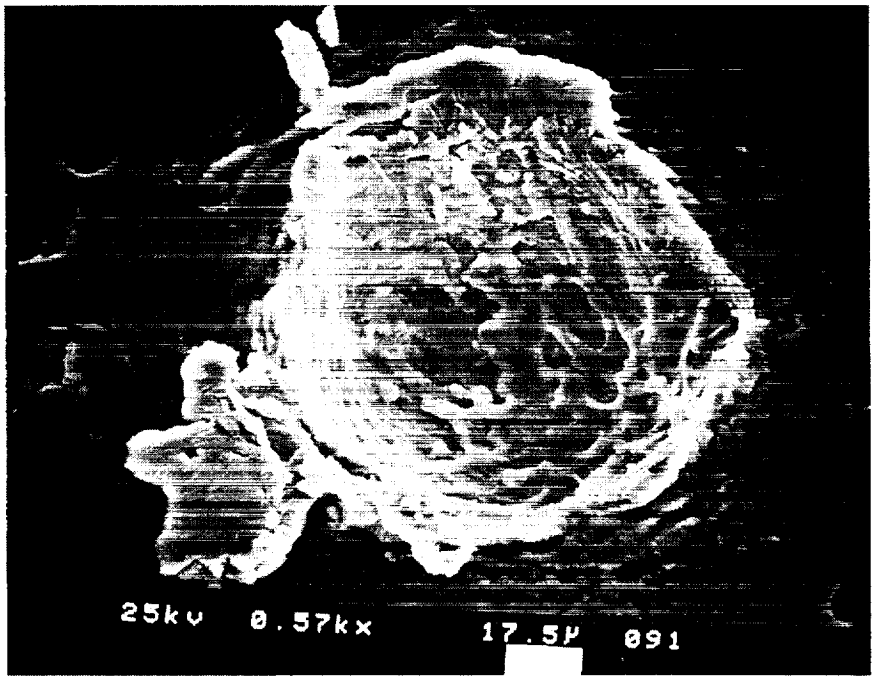

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

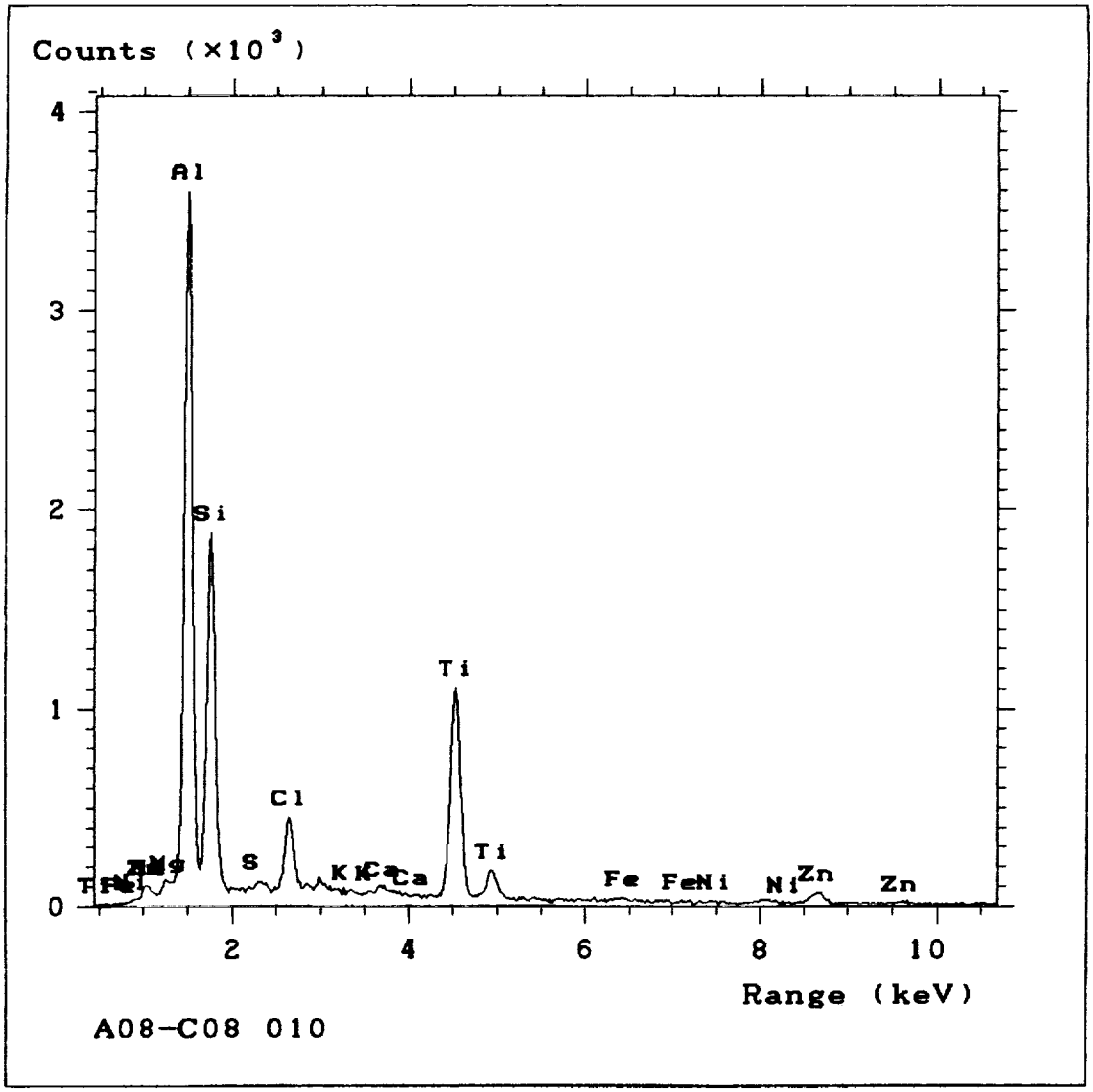

25kv 0.41kx 24.0µ 080

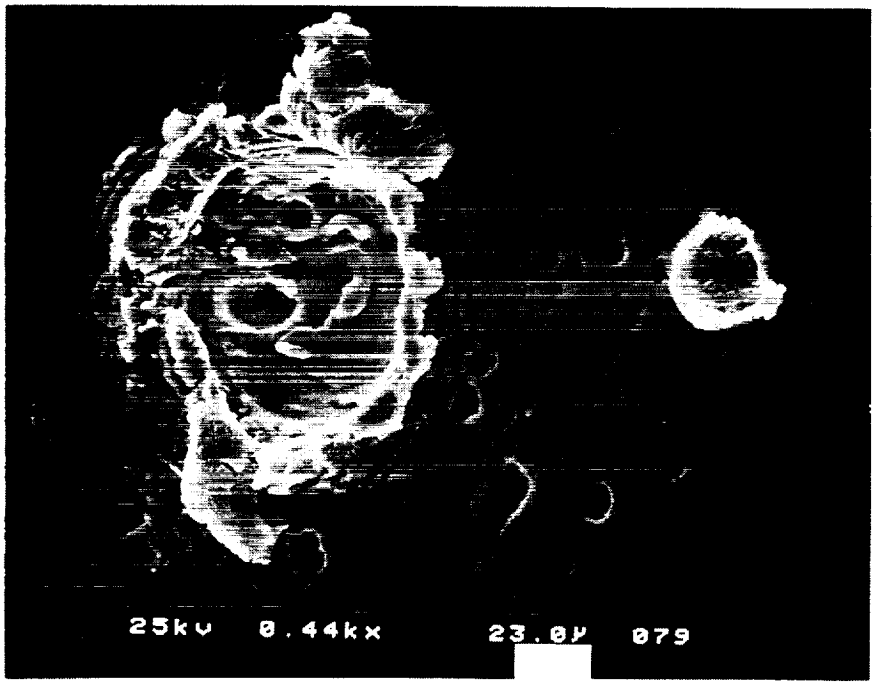

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

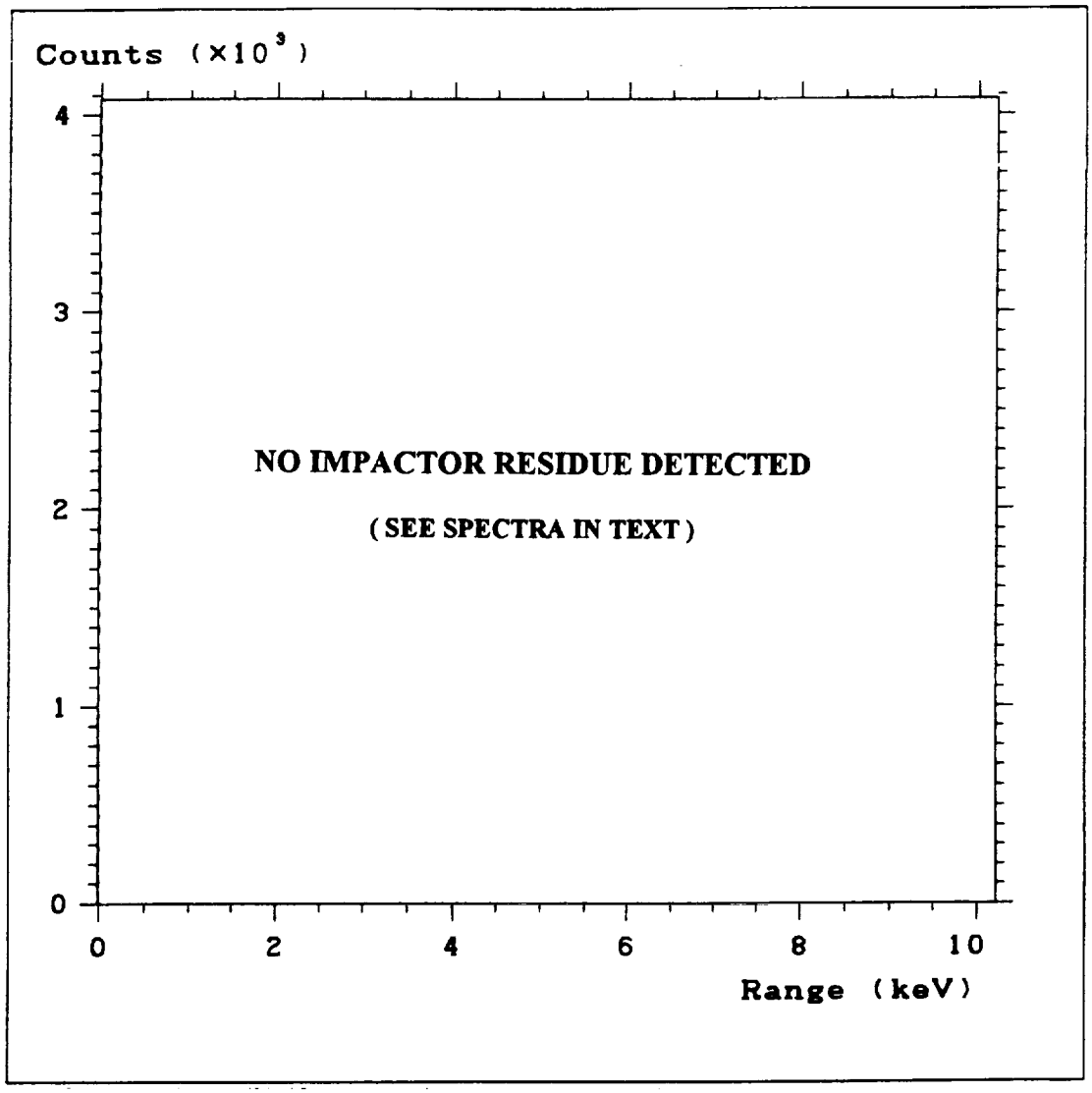

25kv 0.79kx 12.5µ 089

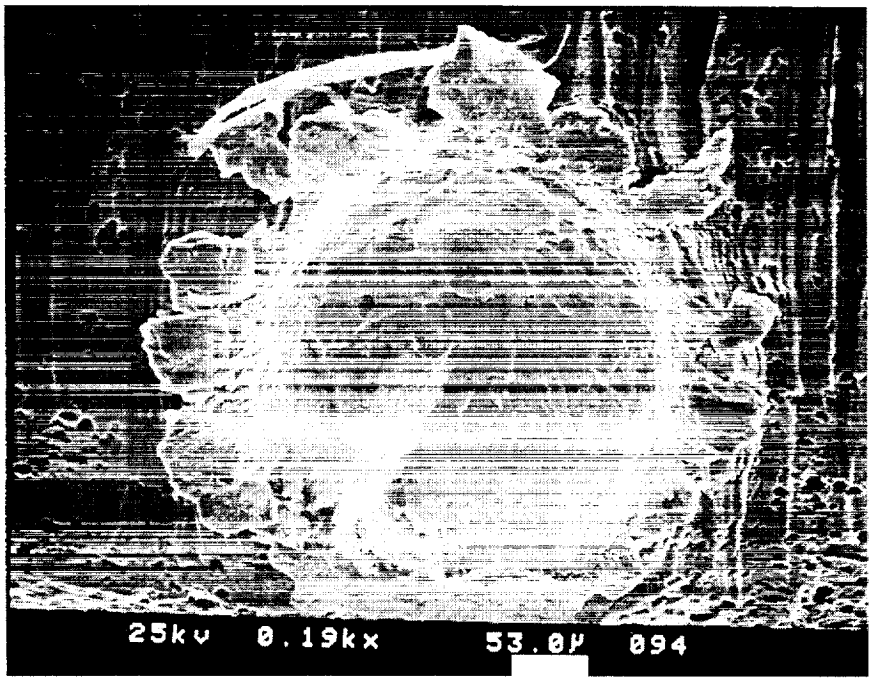

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

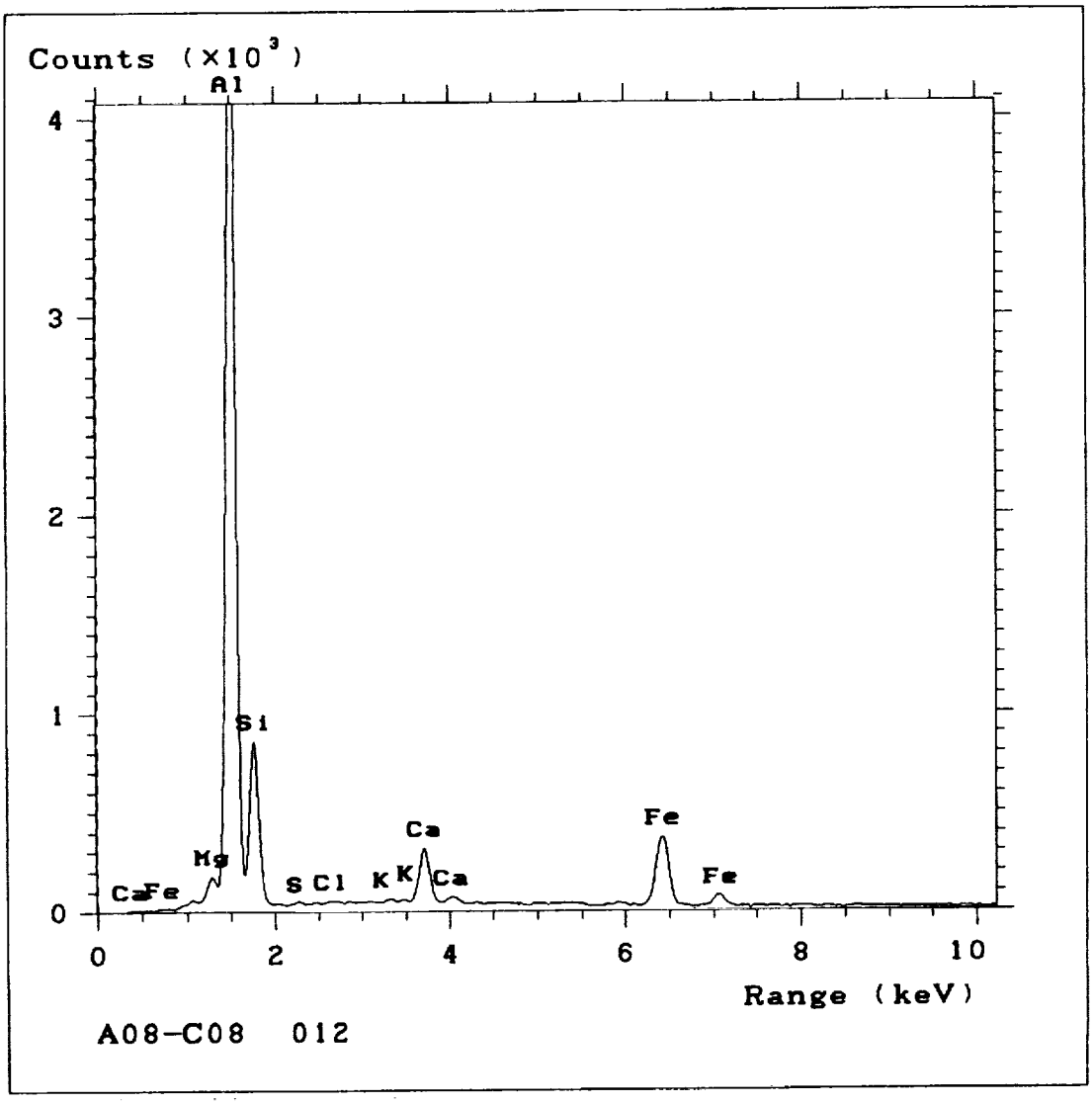

25kv 0.57kx 17.5µ 091

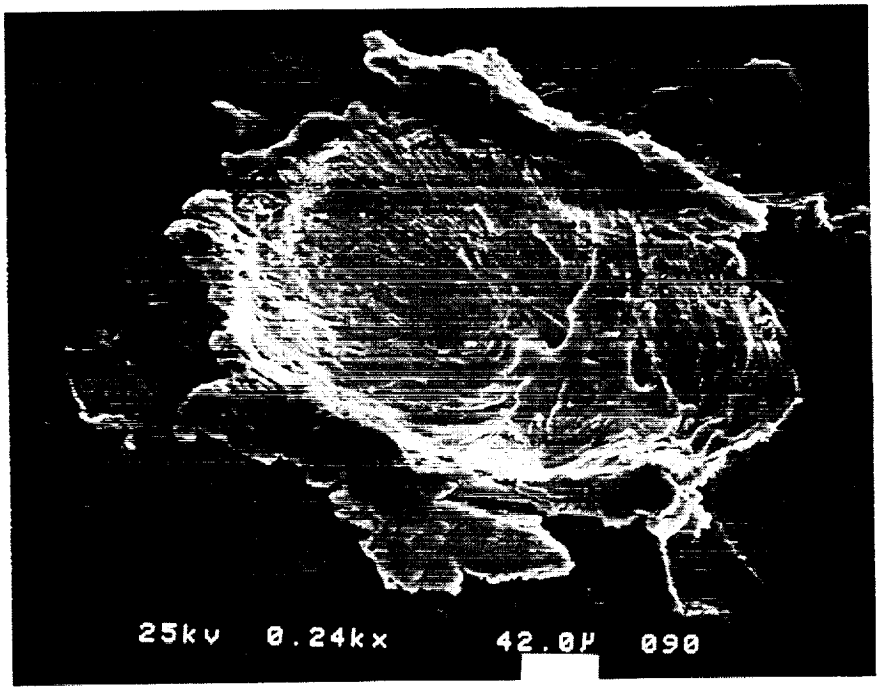

Counts (×10³)
4
3
2
1
0
Al
Si
S
Cl
K
Ca
Ca
Ti
Ti
Fe
FeNi
Ni
Zn
Zn
2
4
6
8
10
Range (keV)
A08–C08 010

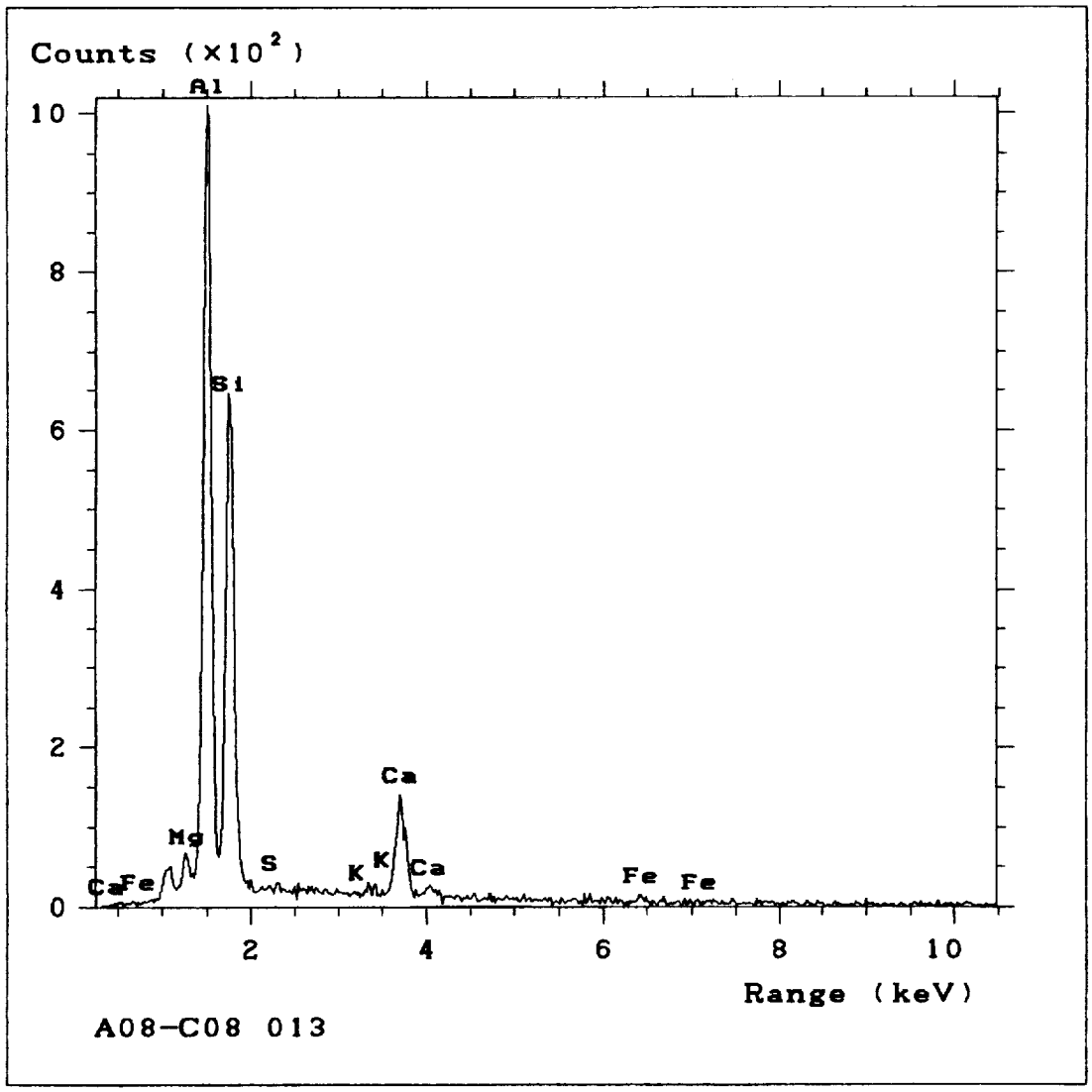

25kv 0.44kx 23.0µ 079

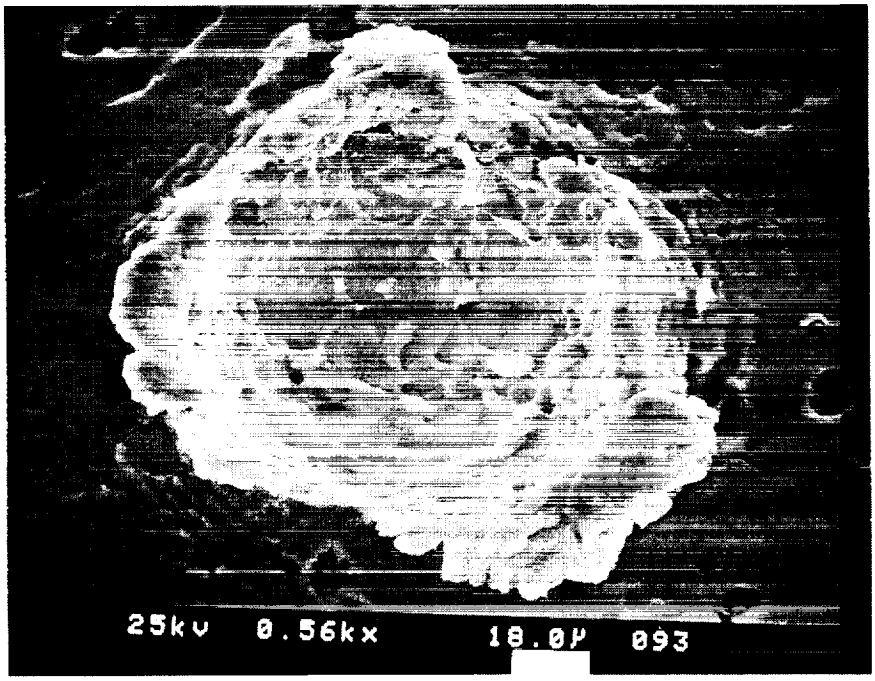

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 0.19kx 53.0µ 094


Counts (×10³)
Al
Si
Mg
Ca
Fe
Ca
Fe
Fe
Ca
S Cl
K K
Ca
0
1
2
3
4
0
2
4
6
8
10
Range (keV)
A08-C08 012

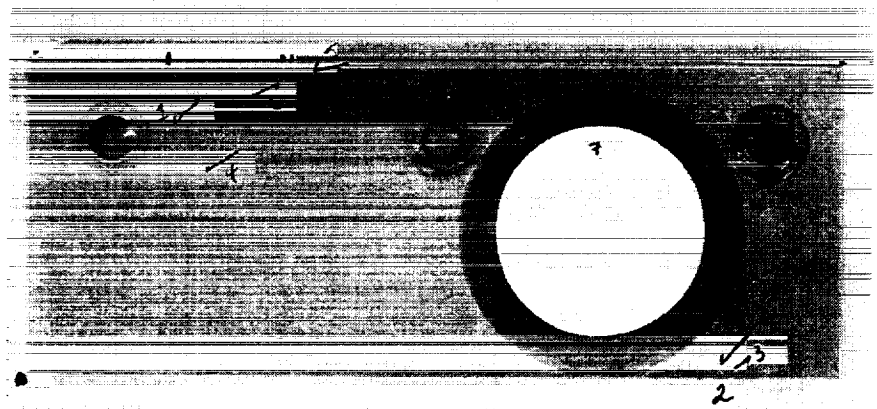

25kv 0.24kx 42.0µ 090

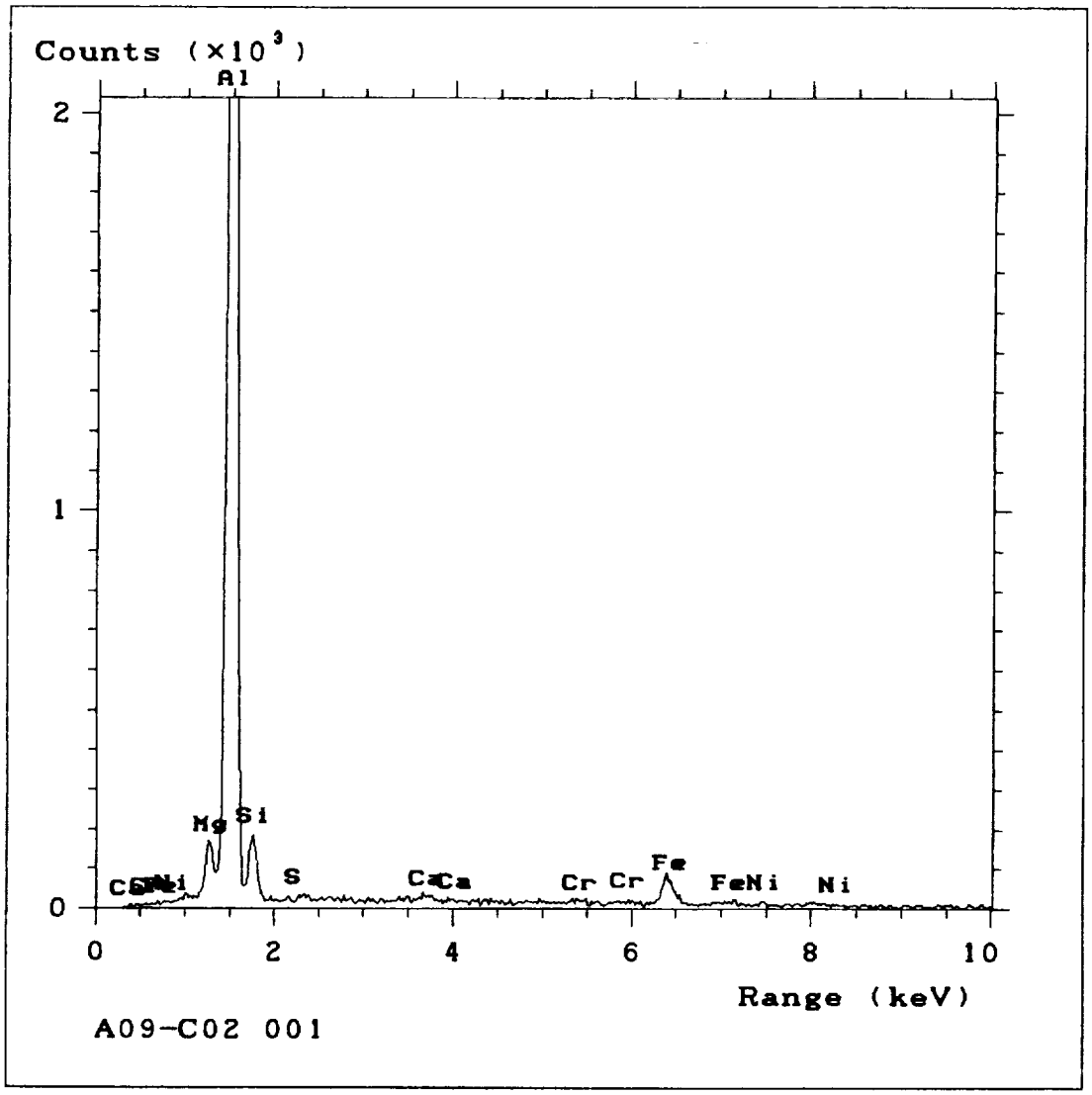

Counts (×10²)
Al
Si
Mg
Ca
Fe
S
K
K
Ca
Fe
Fe
Ca
10
8
6
4
2
0
2
4
6
8
10
Range (keV)
A08-C08 013

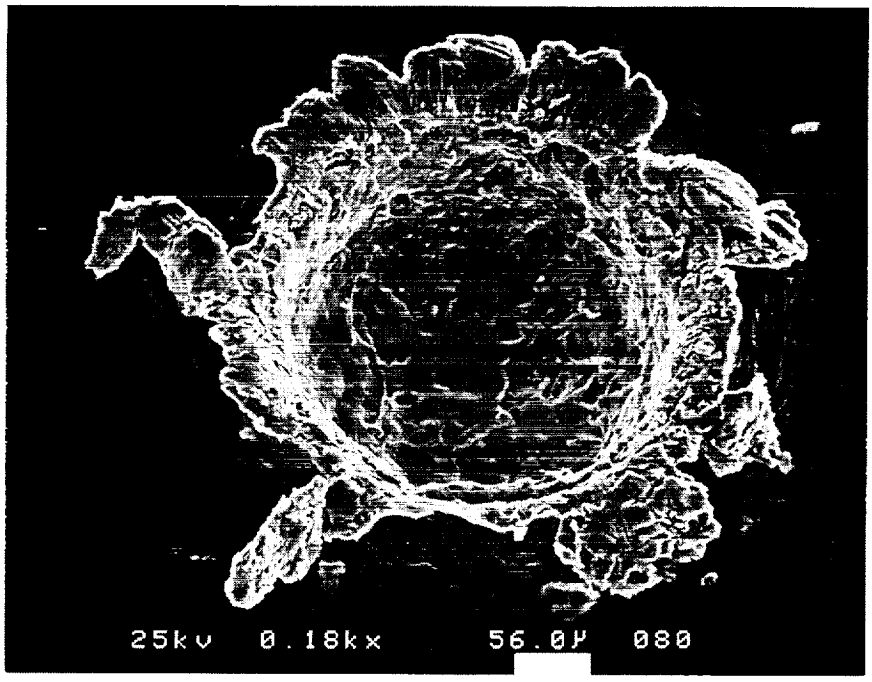

25kv 0.56kx 18.0µ 093

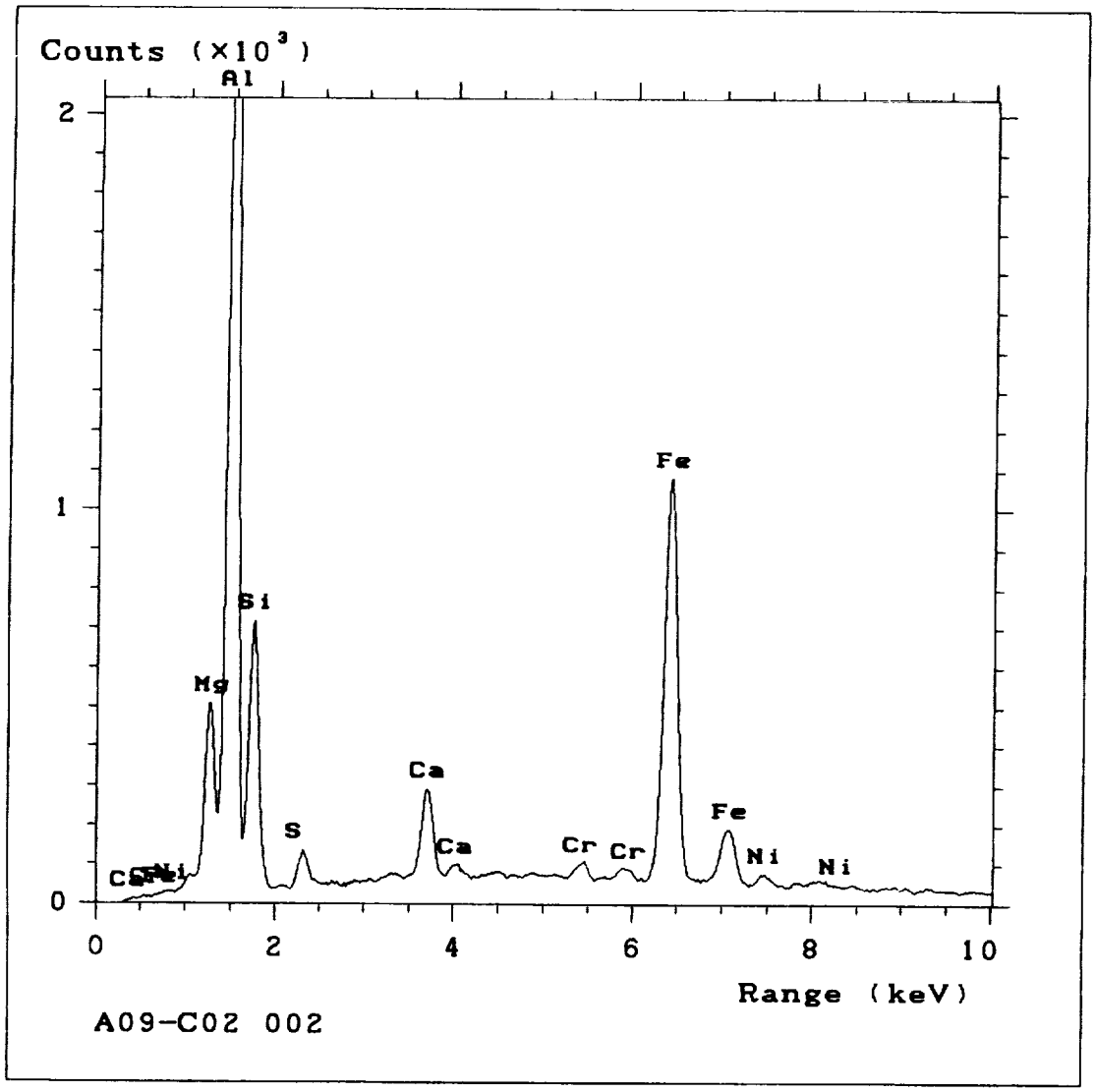
CLAMP NUMBER A09 CO2

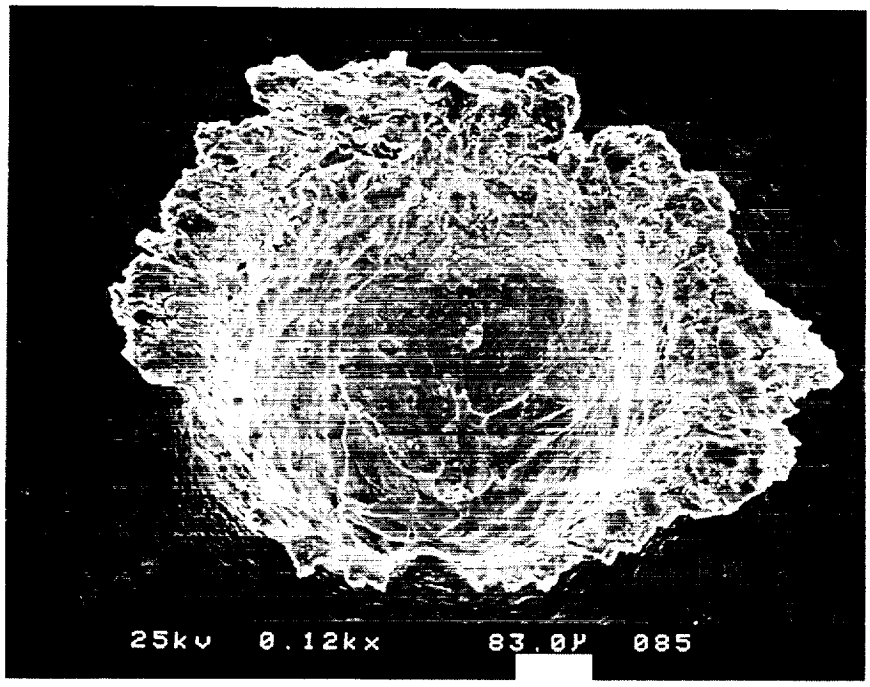
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	400	Trace
002	700	Micrometeoritic
003	60	Trace
004	160	Unknown
005	180	Unknown
006	100	Unknown
007	150	Paint Patch

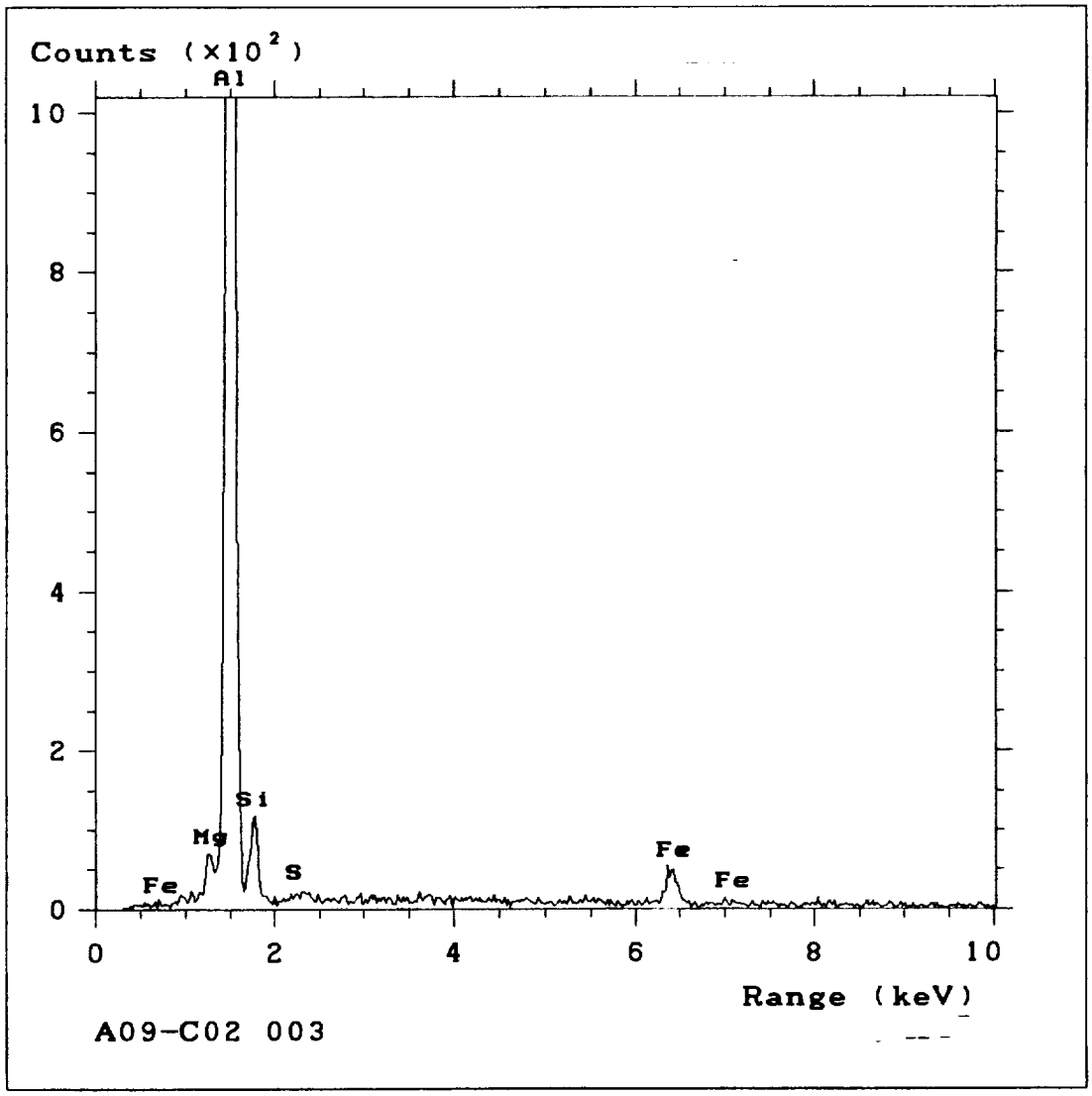


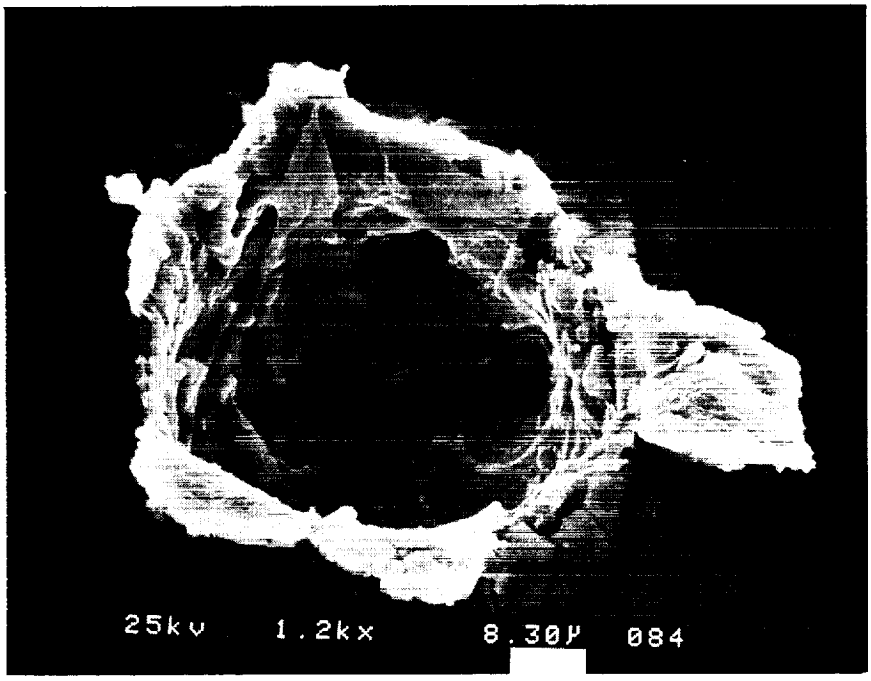

Counts (×10³)
Al
2
1
0
Mg
Si
S
Ca
Cr
Fe
FeNi
Ni
0
2
4
6
8
10
Range (keV)
A09-C02 001

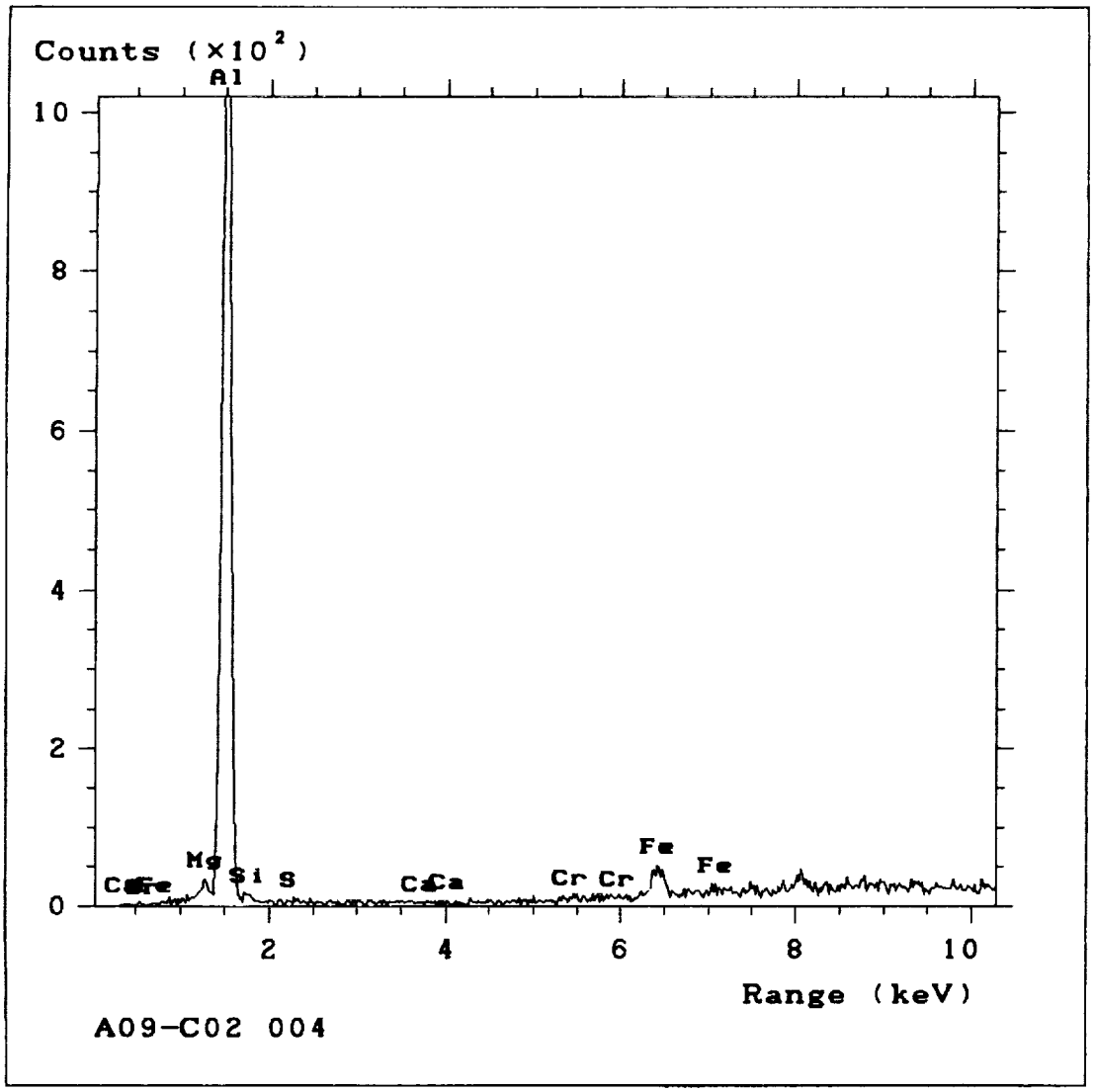

25kv 0.18kx 56.0µ 080

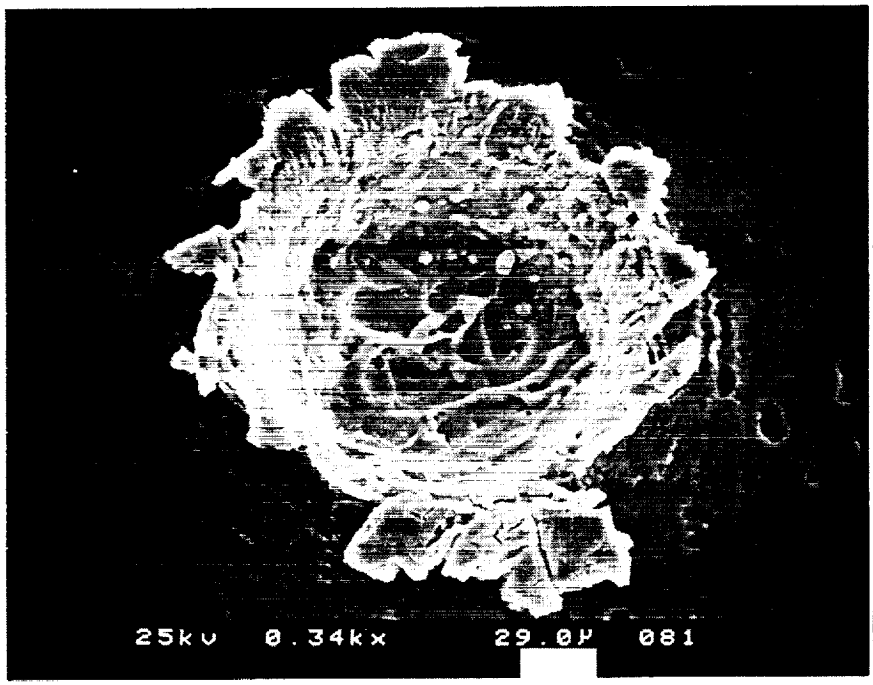

Counts (×10³)
Al
Si
Mg
S
Ca
Ca
Cr
Cr
Fe
Fe
Ni
Ni
0
1
2
0
2
4
6
8
10
Range (keV)
A09-C02 002

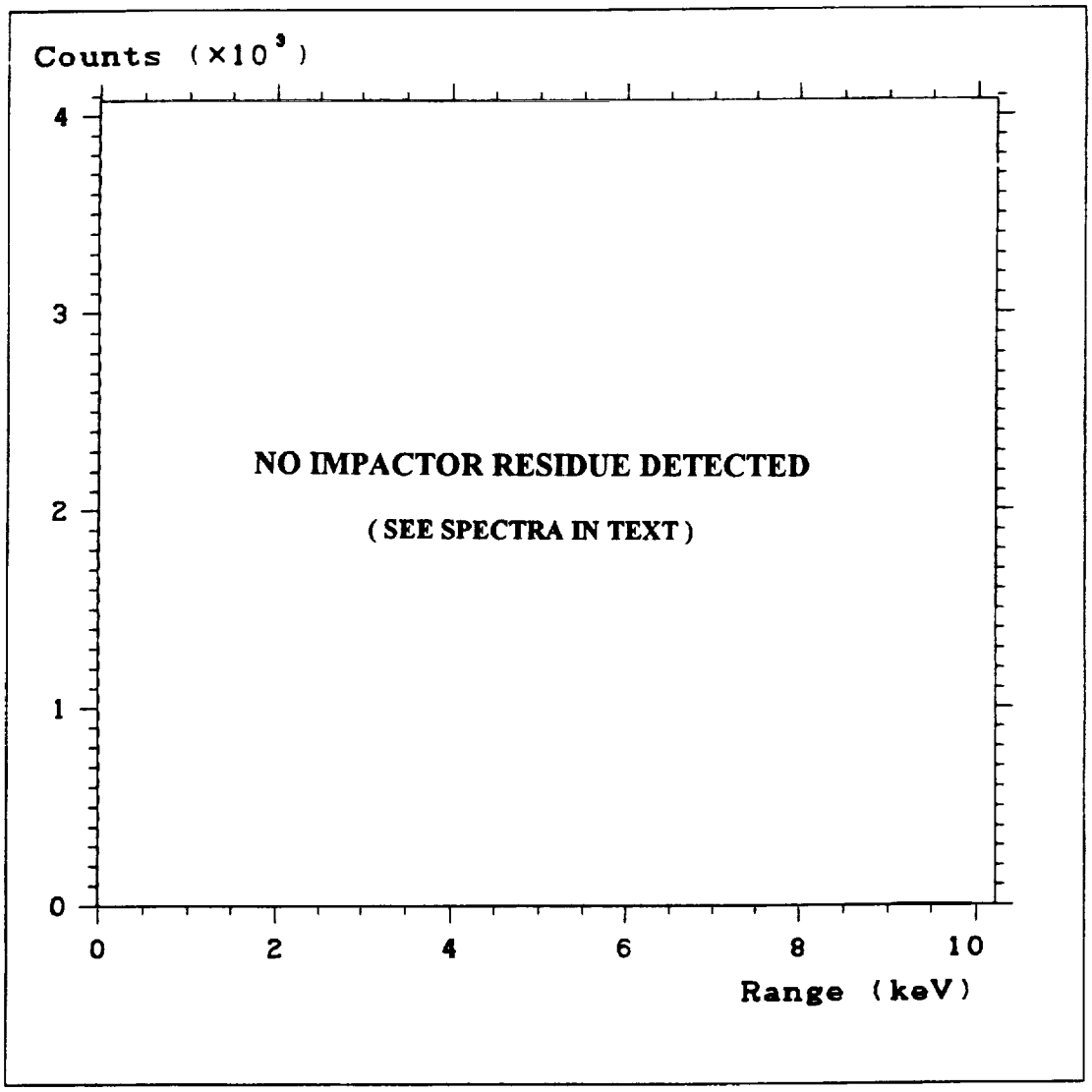

25kv 0.12kx 83.0µ 085

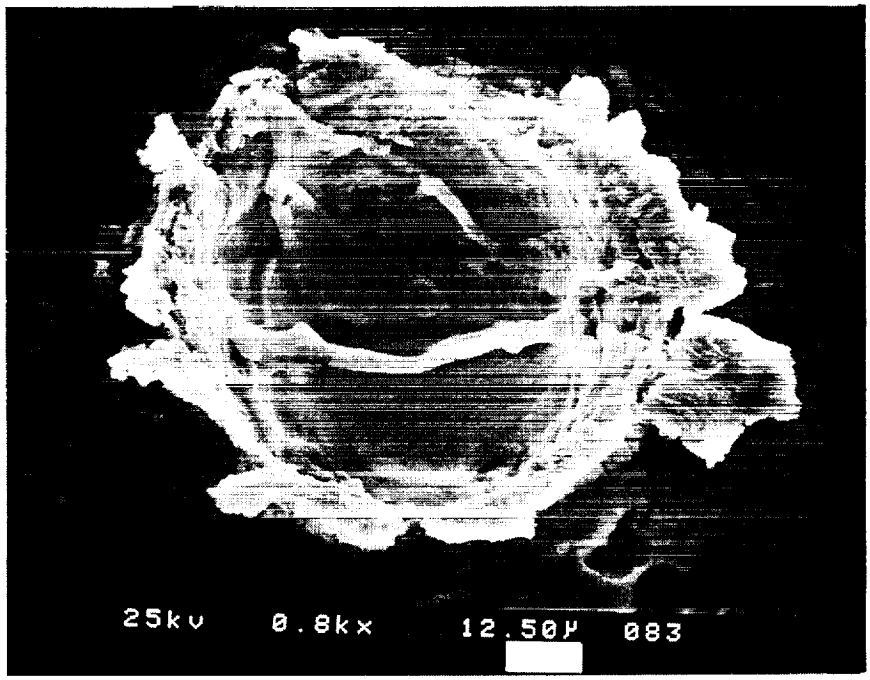

Counts (x10²)
Al
Si
Mg
Fe
S
Fe
Fe
0
2
4
6
8
10
0
2
4
6
8
10
Range (keV)
A09-C02 003

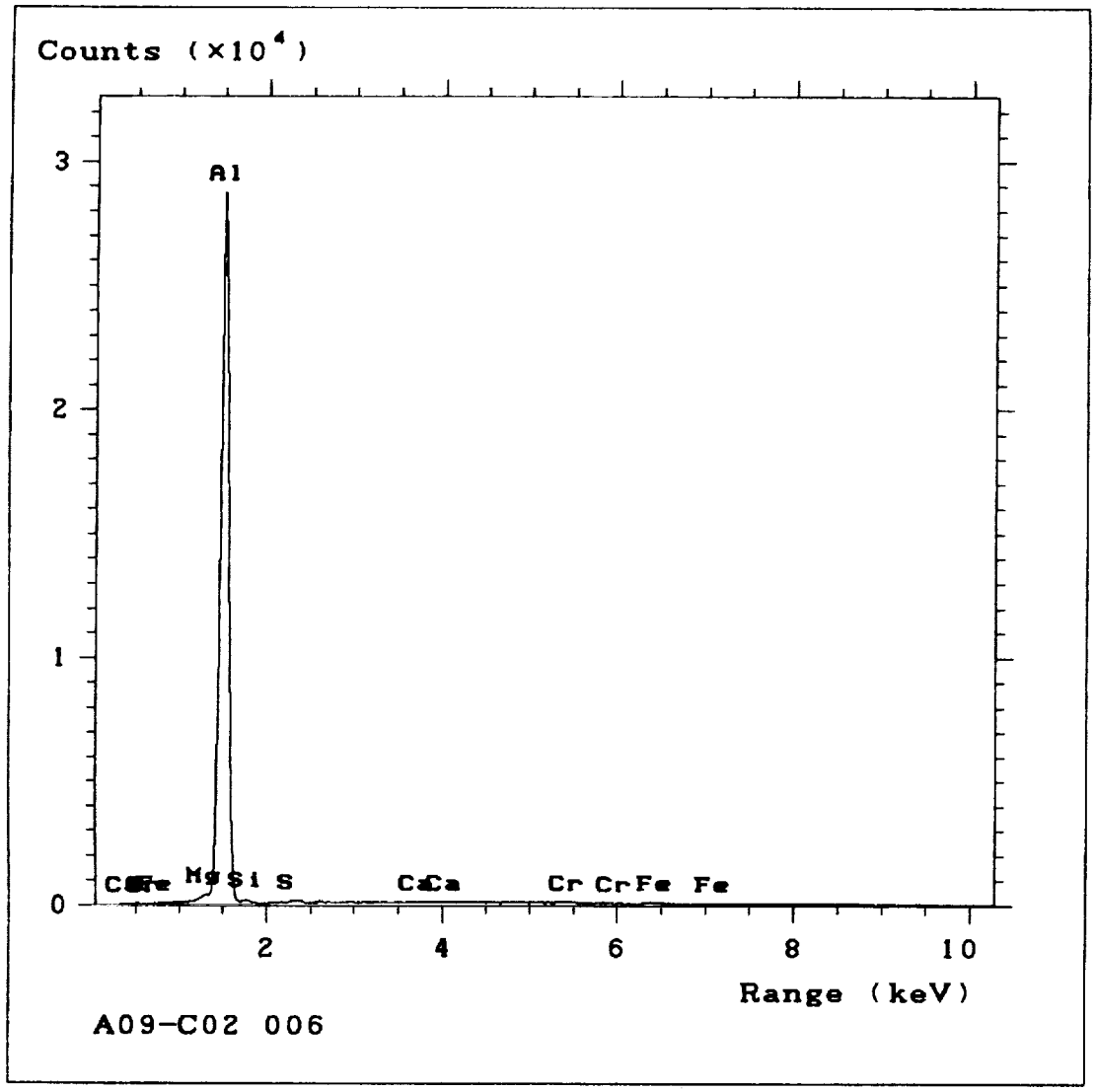

25kv 1.2kx 8.30µ 084

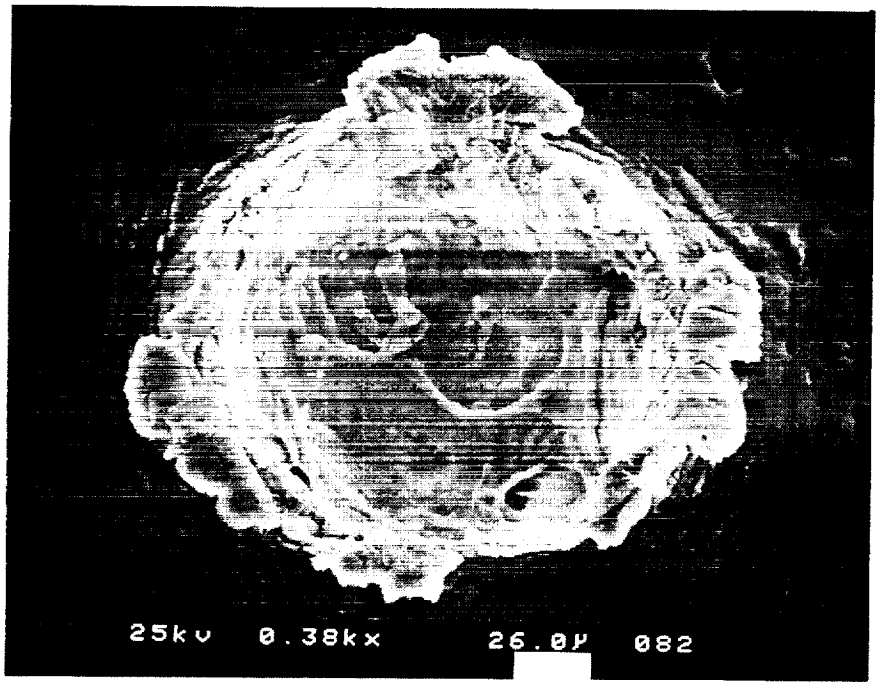

Counts (×10²)
Al
10
8
6
4
2
0
Mg
Si
S
Ca
Cr
Cr
Fe
Fe
2
4
6
8
10
Range (keV)
A09-C02 004


25kv 0.34kx 29.0µ 081


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

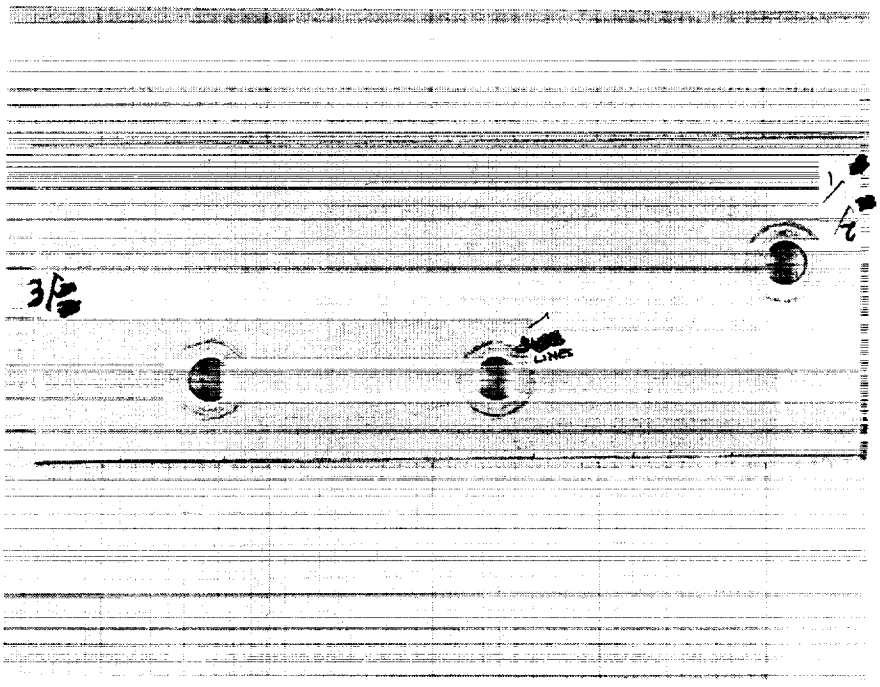

25kv 0.8kx 12.50µ 083

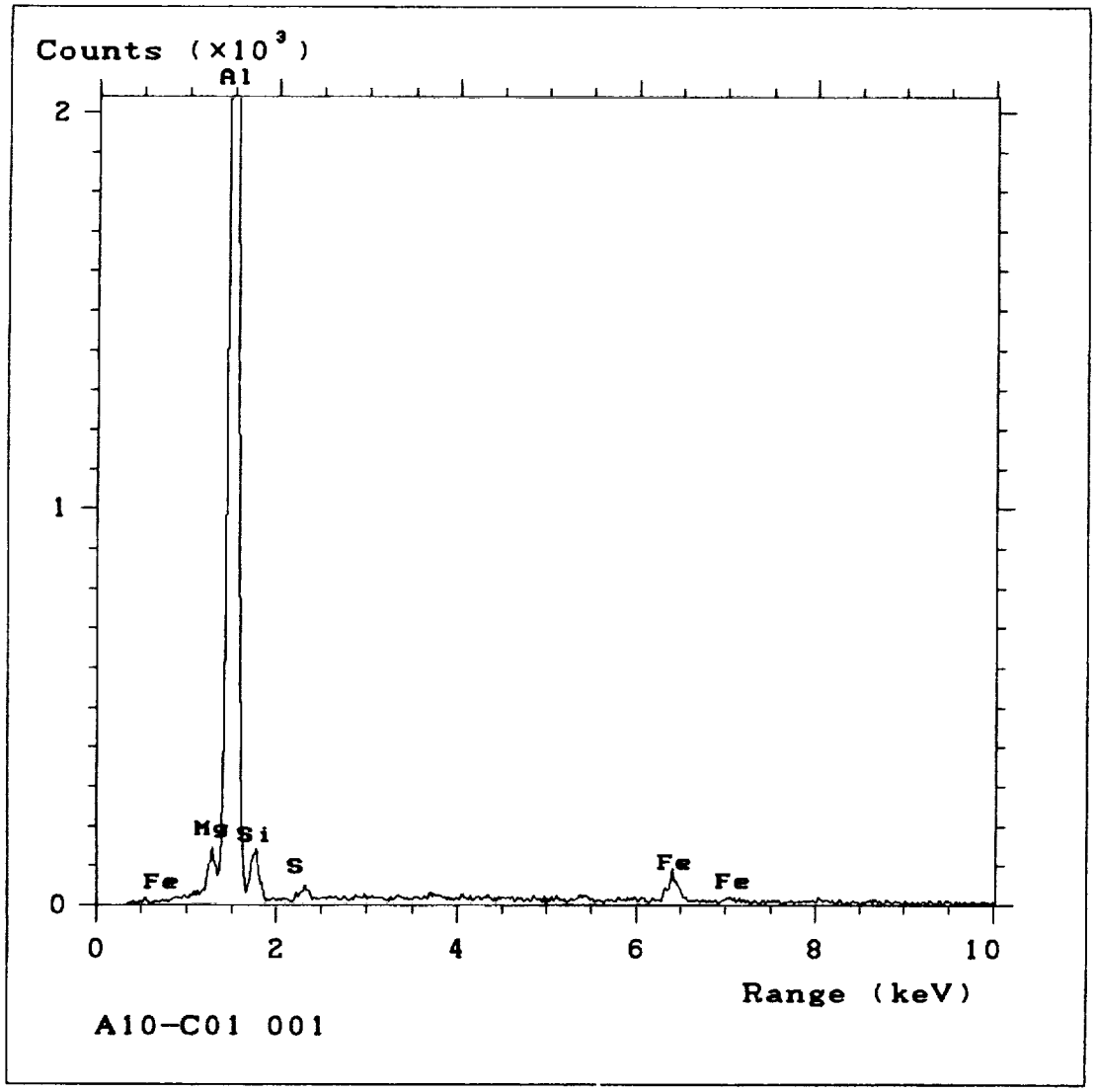

Counts (×10⁴)
3
2
1
0
Al
Mg Si S
Ca Ca
Cr Cr Fe Fe
2
4
6
8
10
Range (keV)
A09-C02 006

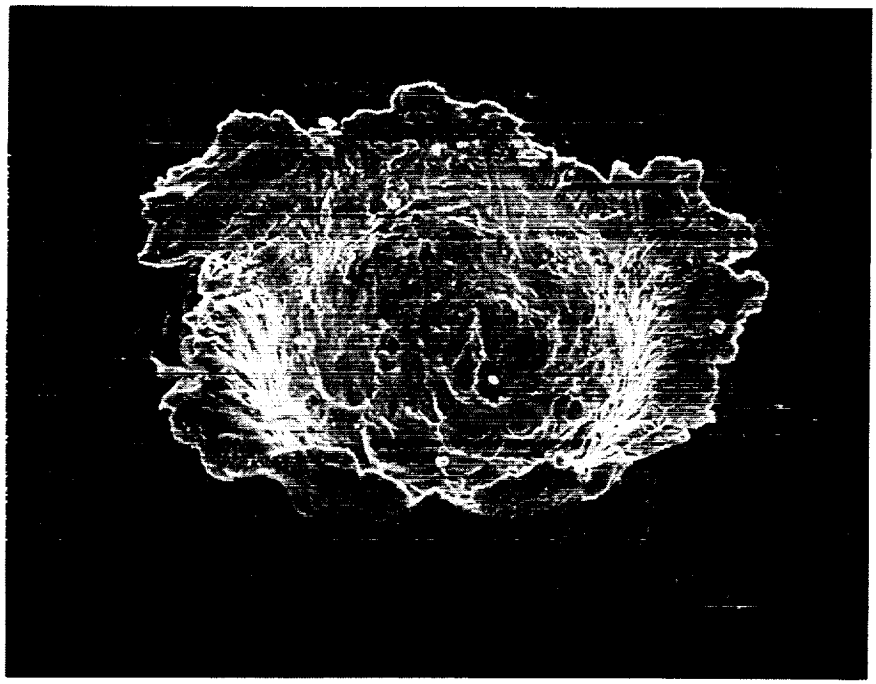

25kv 0.38kx 26.0μ 082

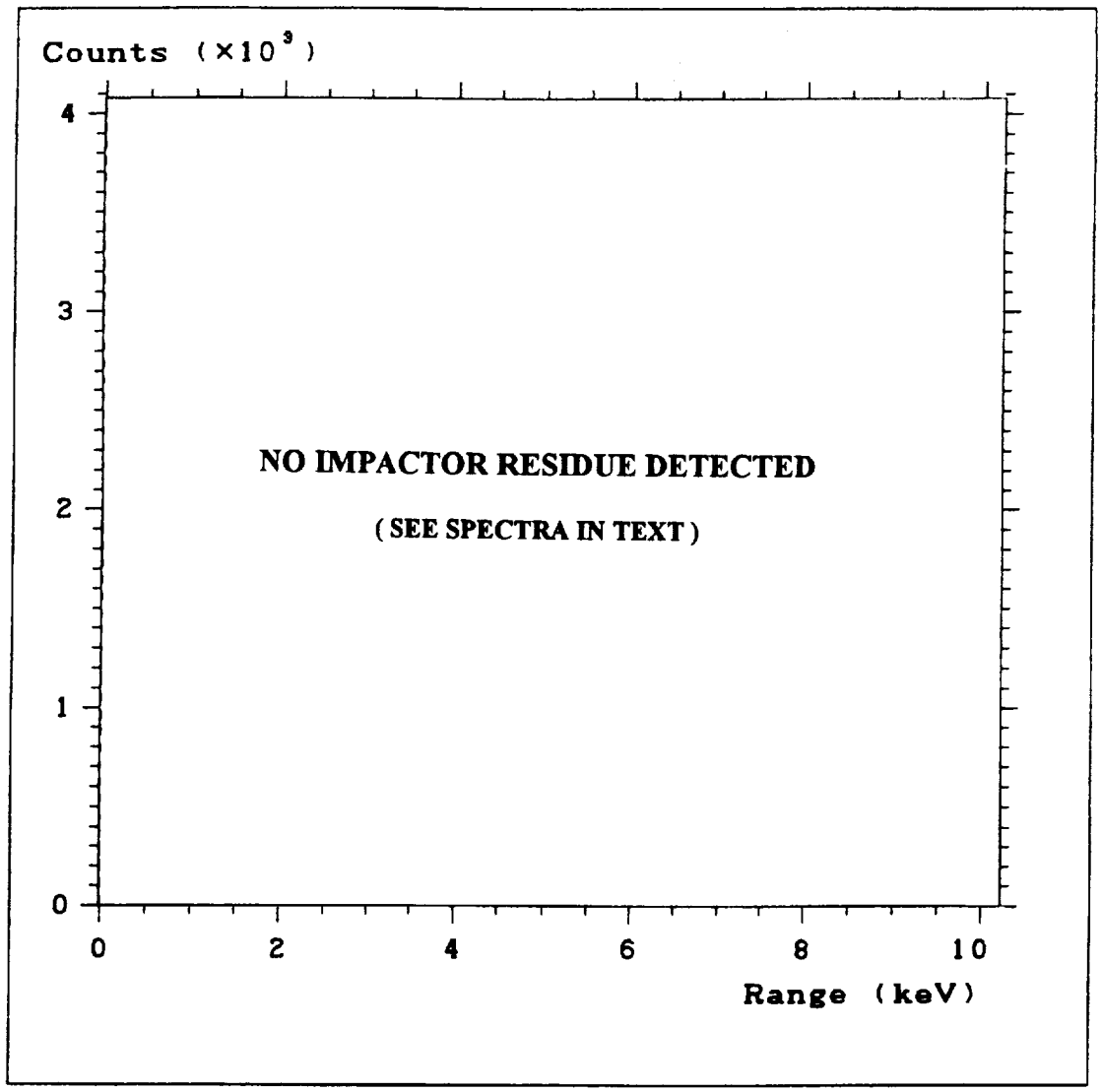
CLAMP NUMBER A10 CO1

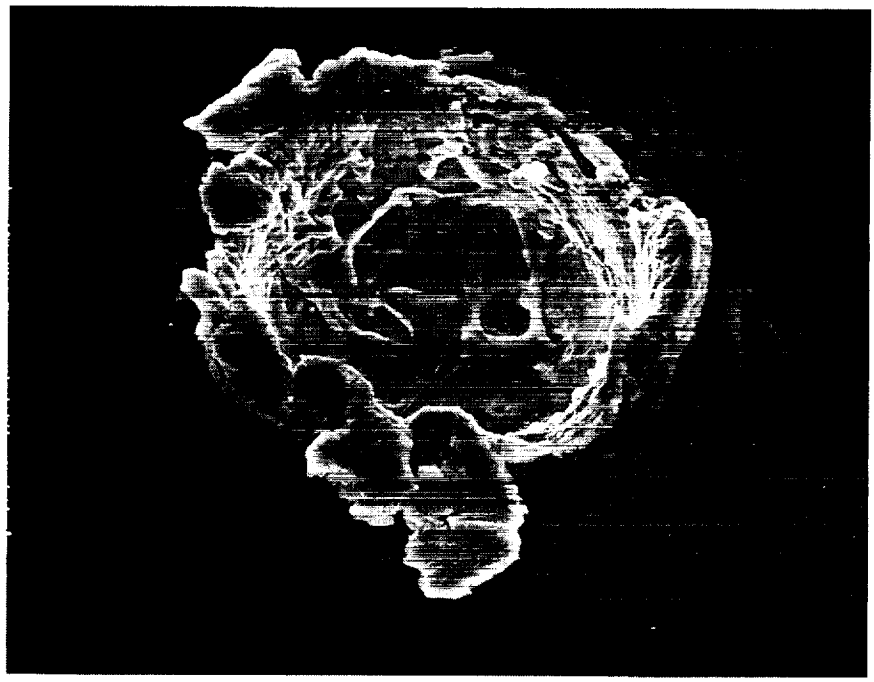
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	250	Trace
002	100	Unknown
003	120	Unknown

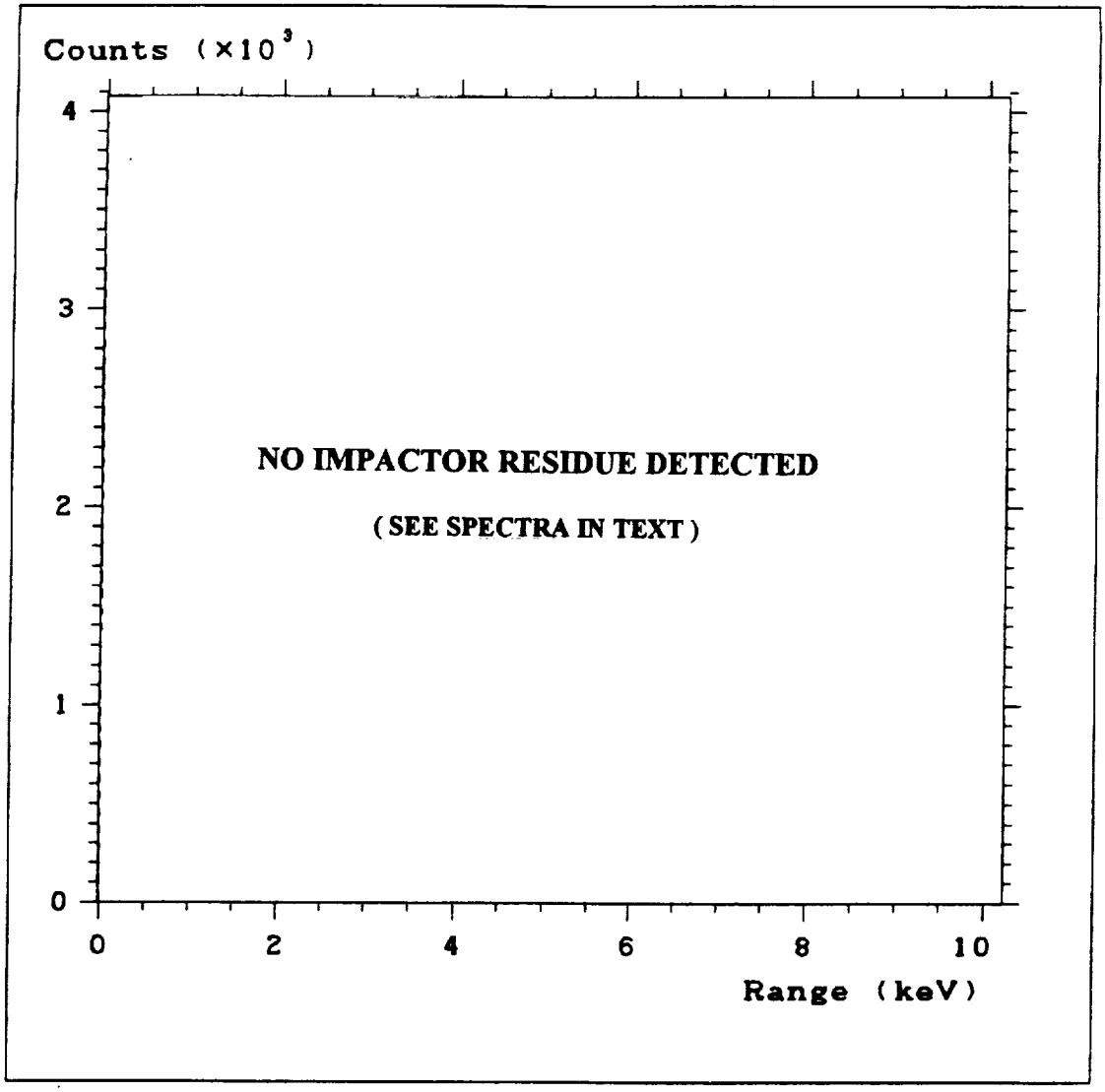


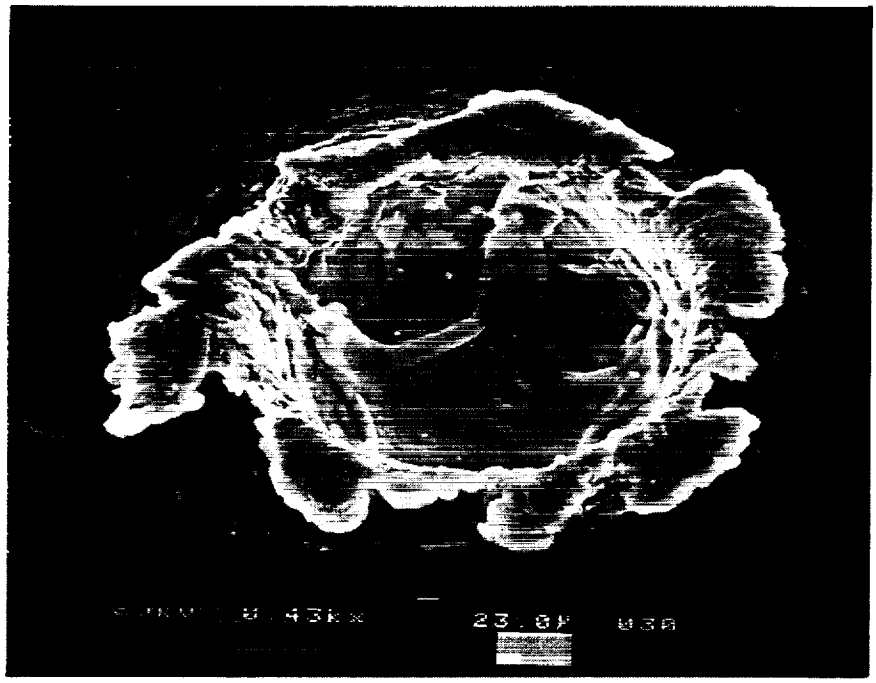

Counts (x10³)
Al
2
1
0
Mg
Si
S
Fe
Fe
Fe
0
2
4
6
8
10
Range (keV)
A10-C01 001




Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

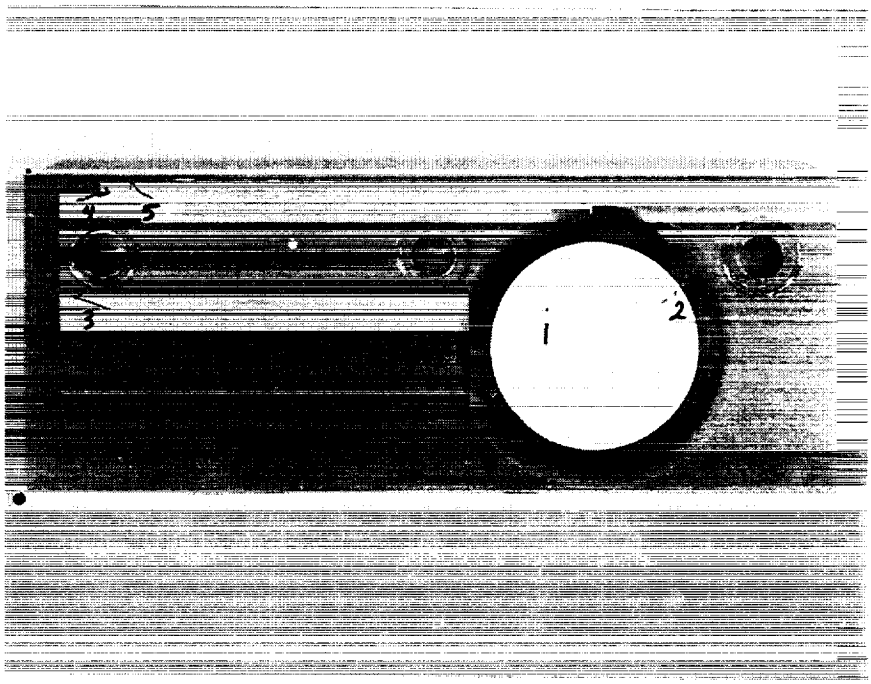


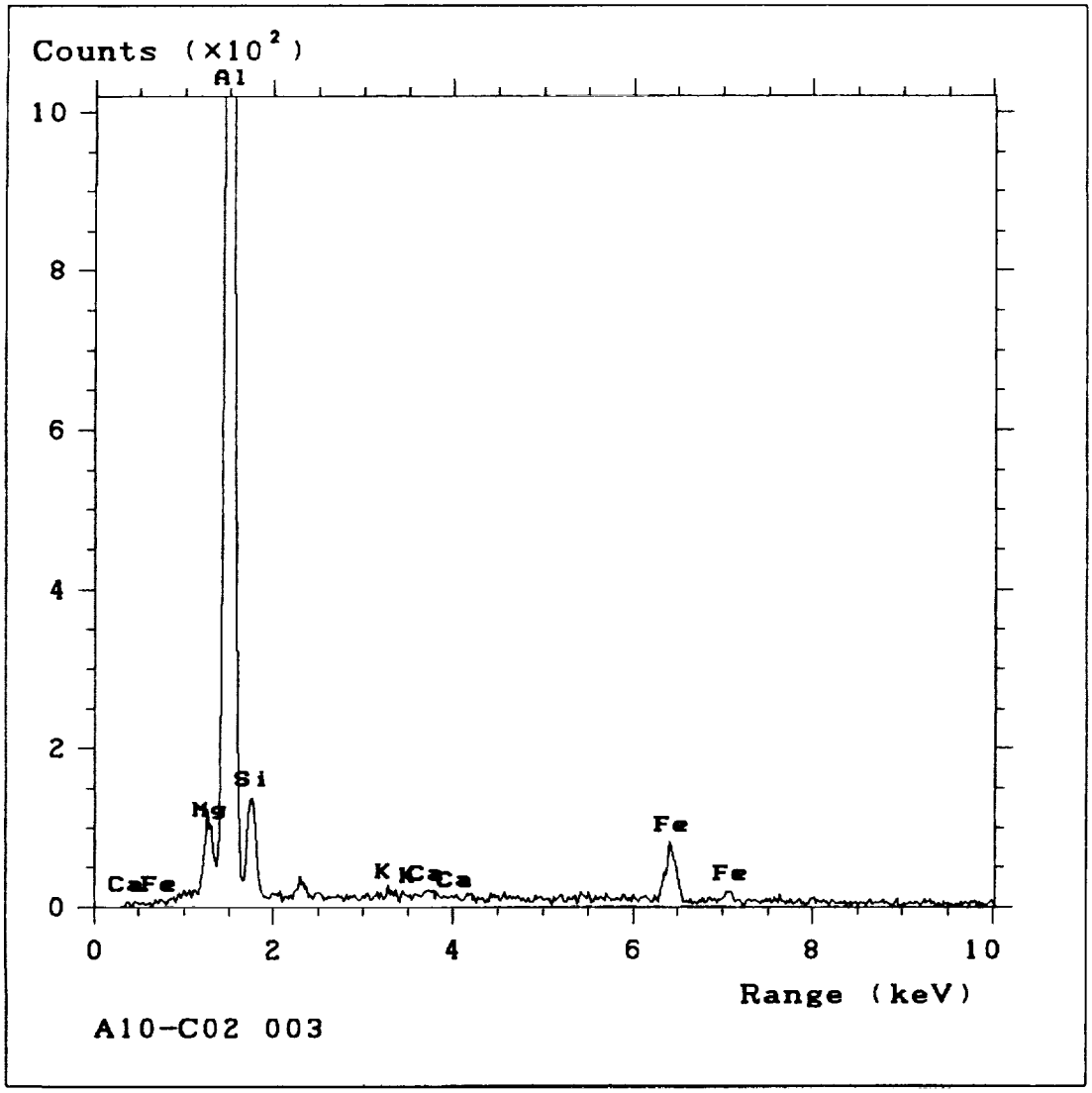

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

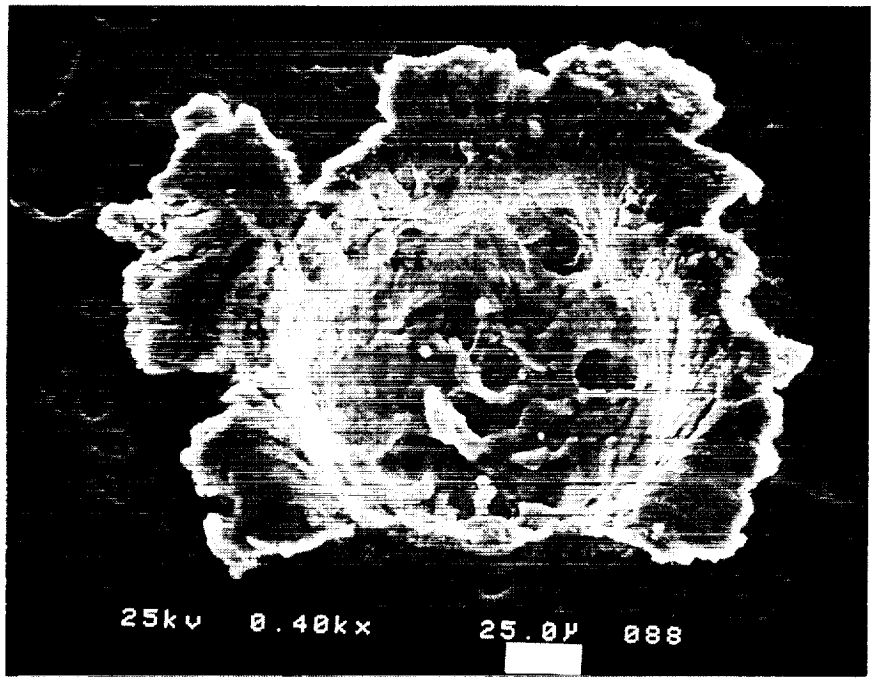


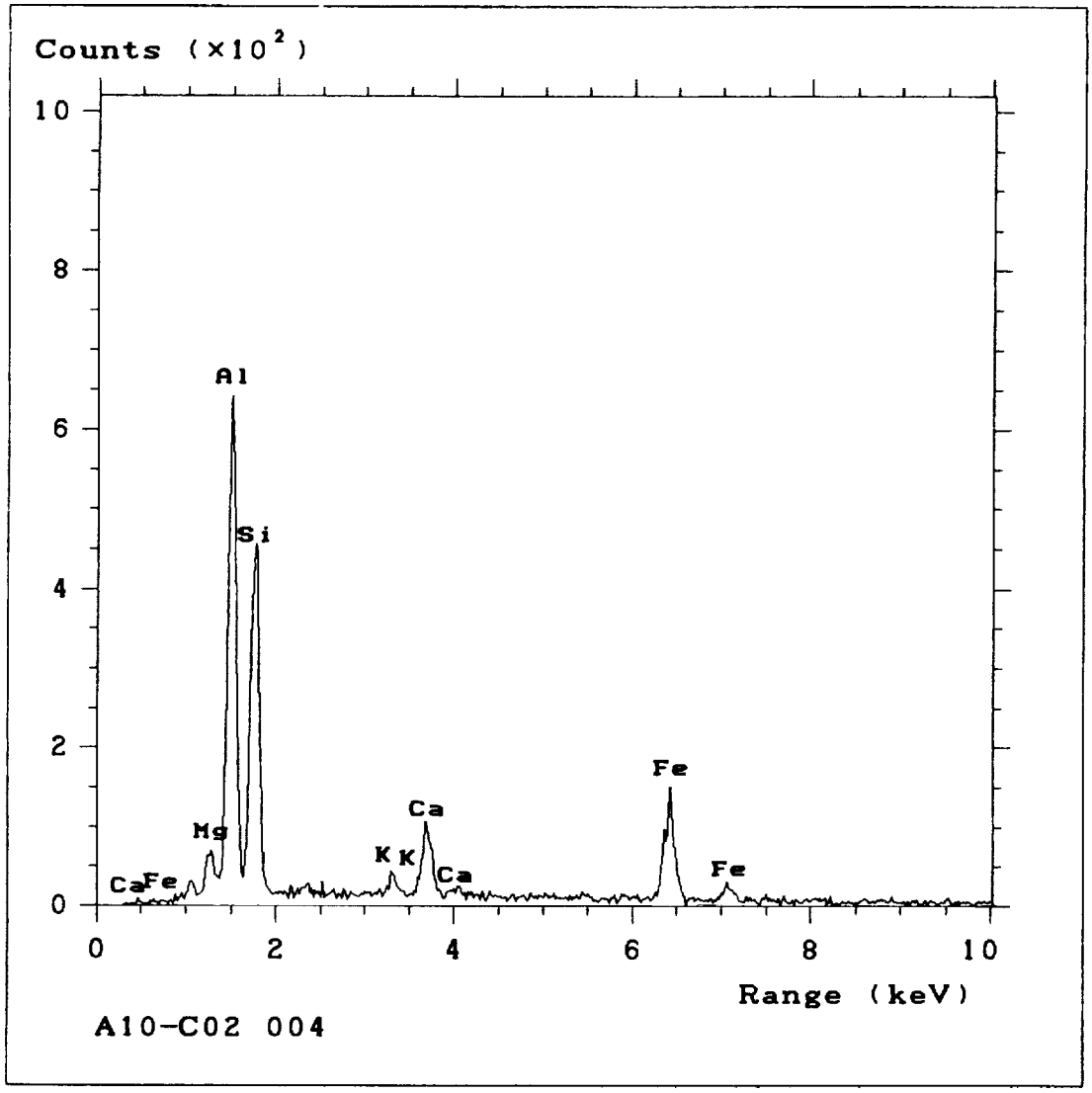
CLAMP NUMBER A10 CO2

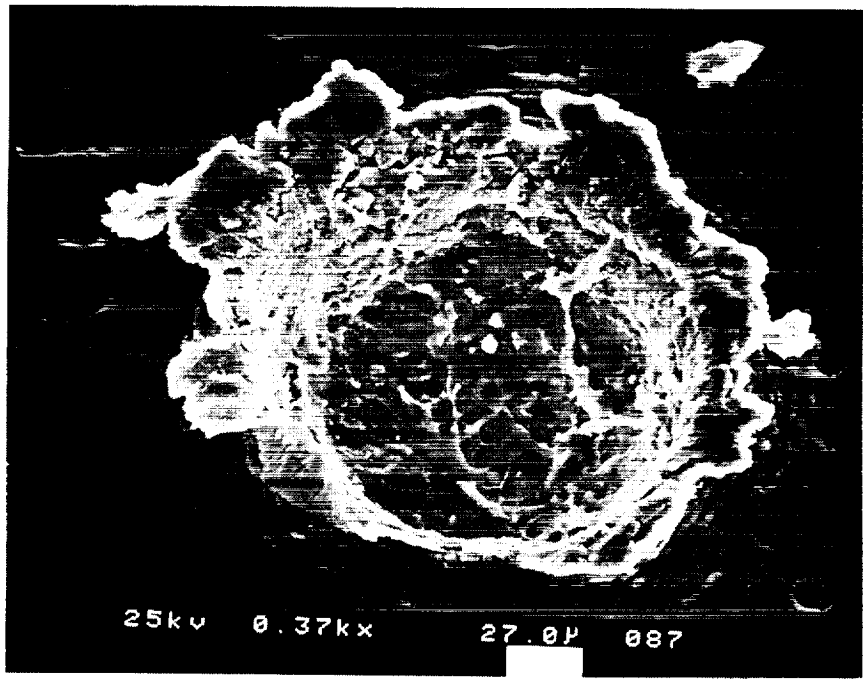
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	400	Paint Patch
002	230	Paint Patch
003	150	Trace
004	180	Si, Mg, Fe
005	60	Contaminated

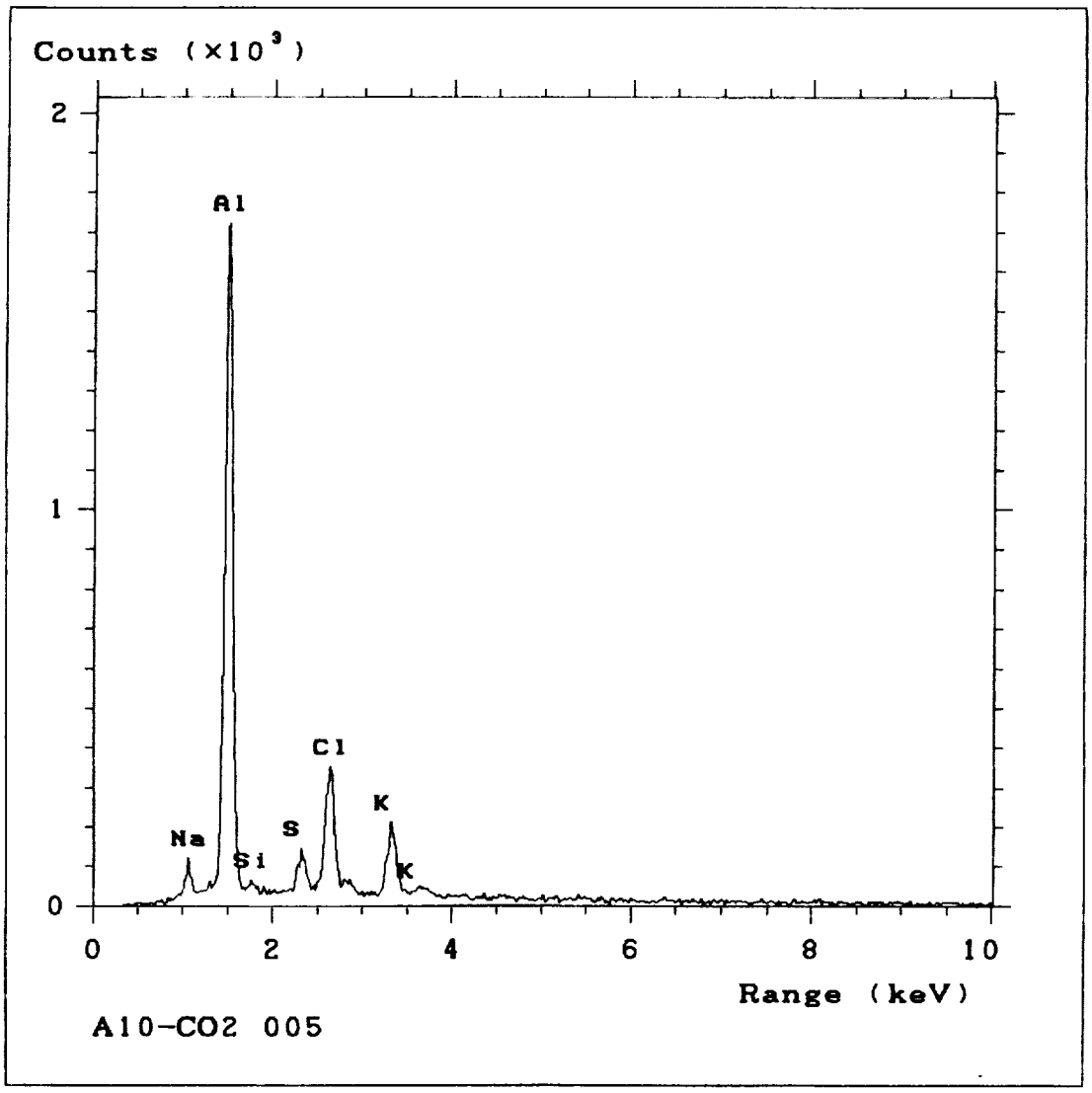


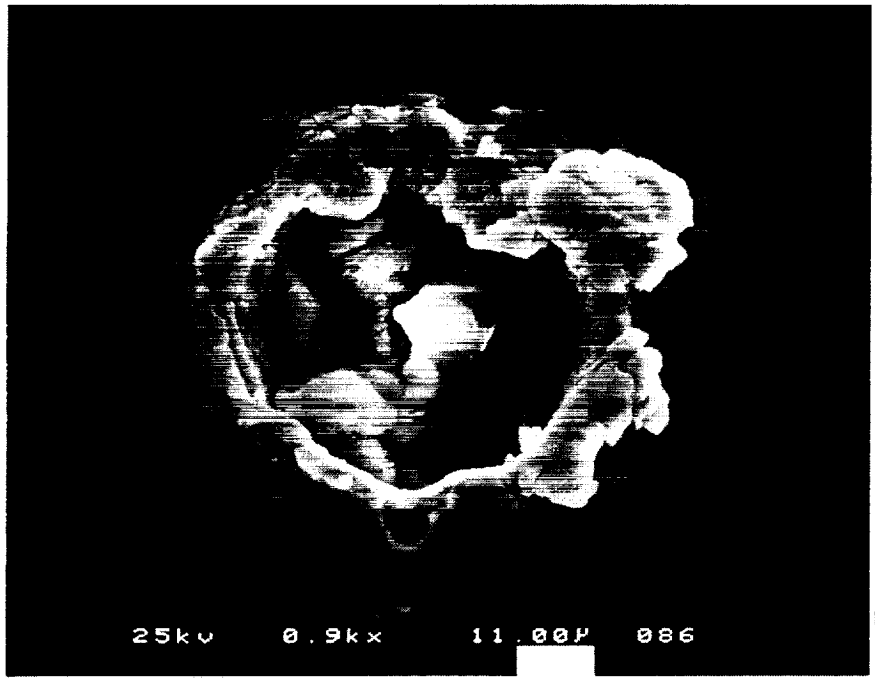

Counts (×10²)
Al
Si
Mg
Fe
Fe
Ca
Ca
Ca
Fe
K
10
8
6
4
2
0
0
2
4
6
8
10
Range (keV)
A10-C02 003


25kv 0.40kx 25.0µ 088


Counts (×10²)
10
8
6
4
2
0
Al
Si
Mg
Ca
Fe
K K
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A10-C02 004

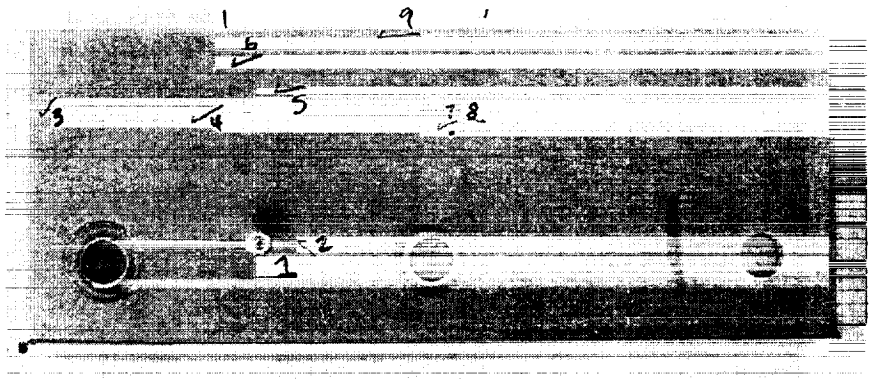

25kv 0.37kx 27.0µ 087

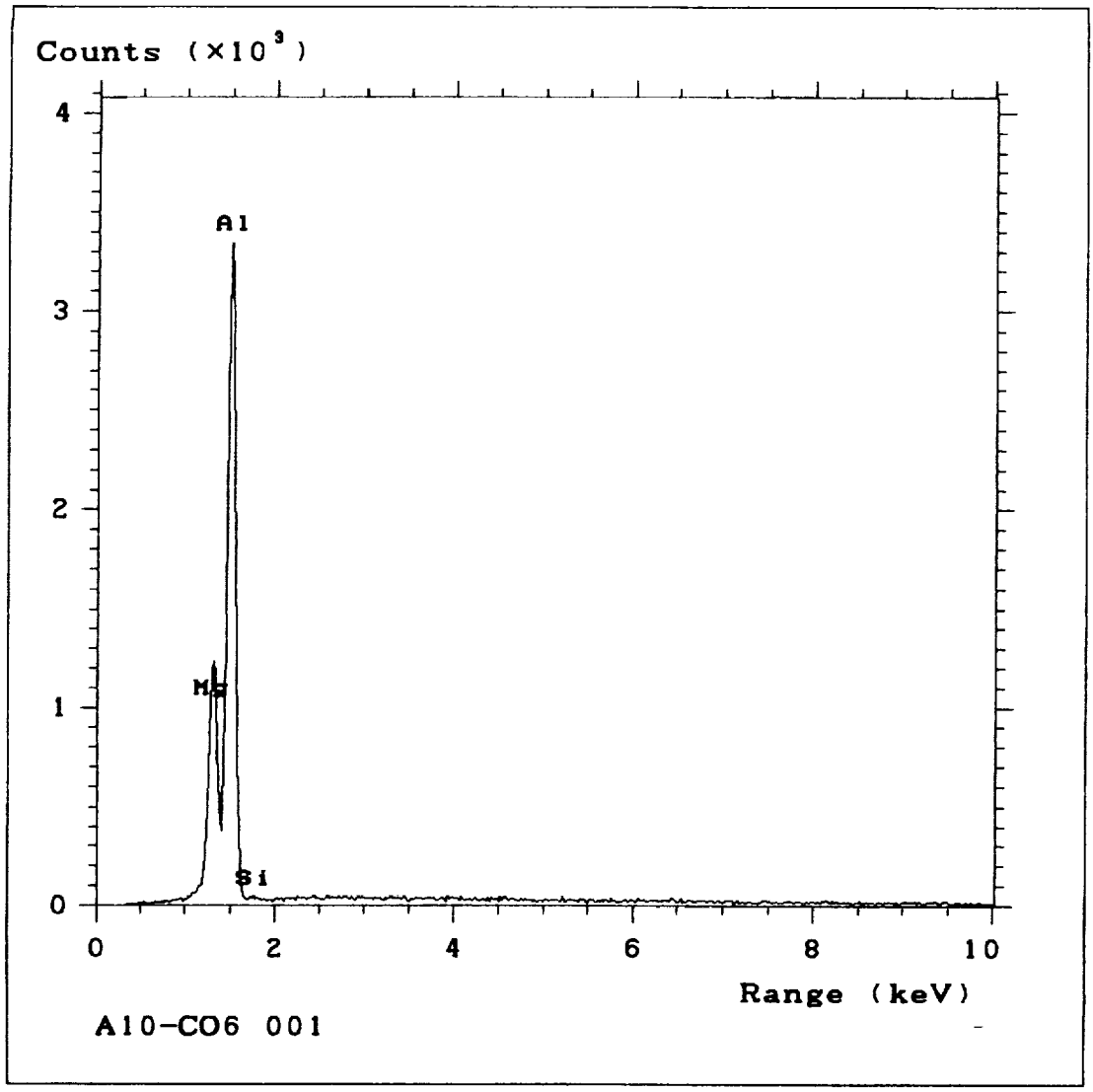

Counts (×10³)
2
1
0
Al
Cl
K
K
S
Na
Si
0
2
4
6
8
10
Range (keV)
A10-CO2 005

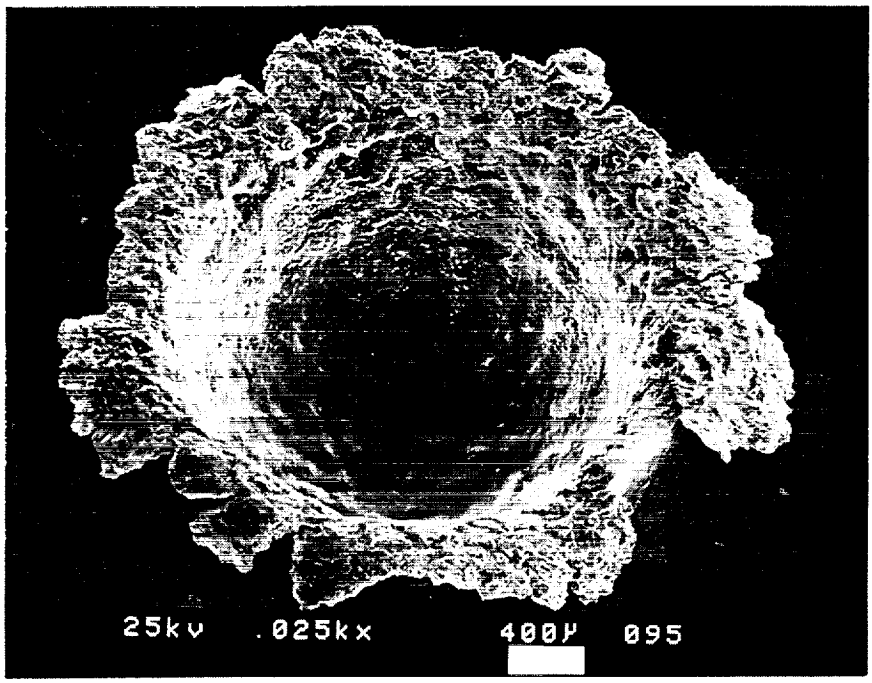

25kv 0.9kx 11.00µ 086

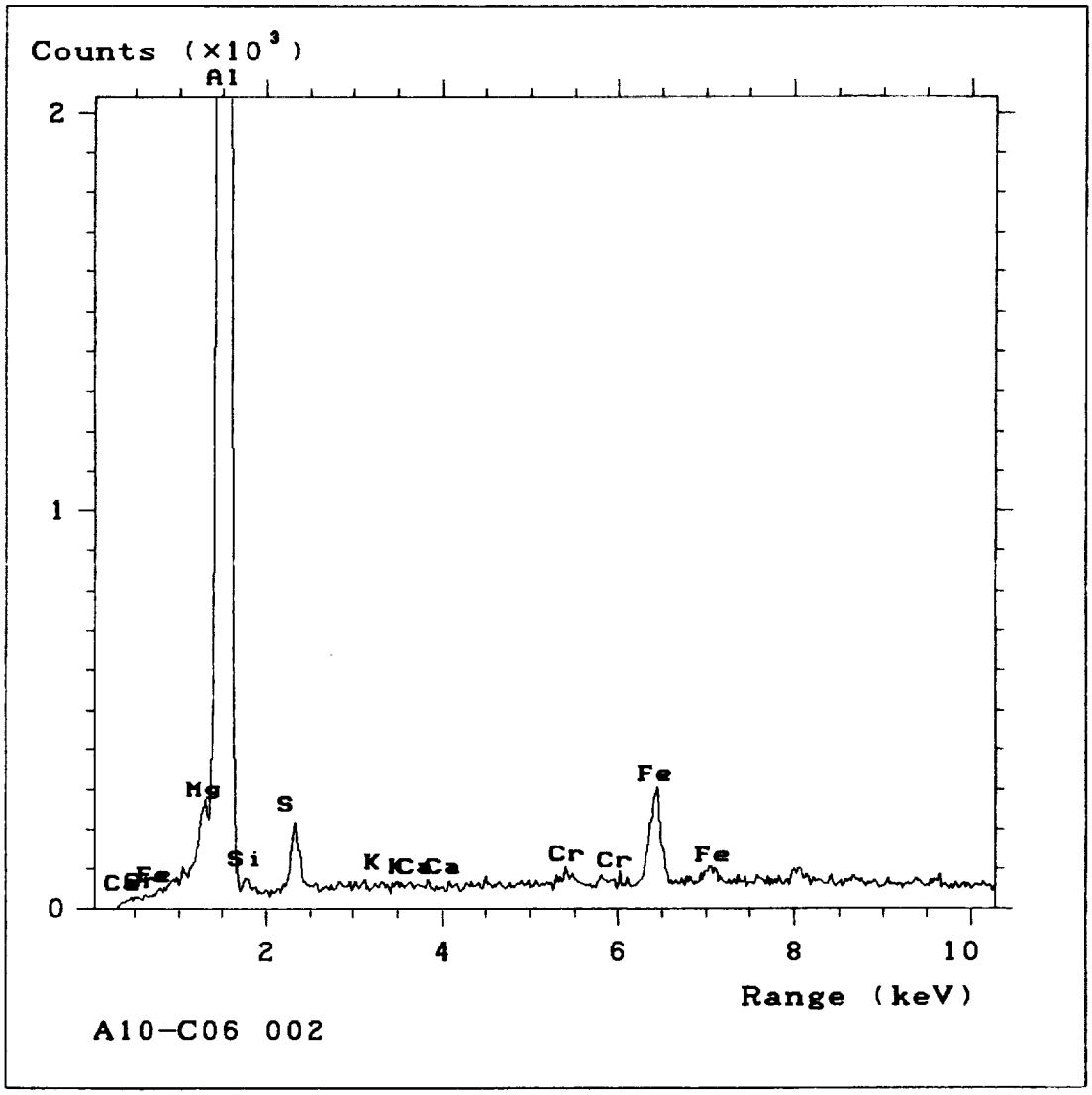
CLAMP NUMBER A10 CO6

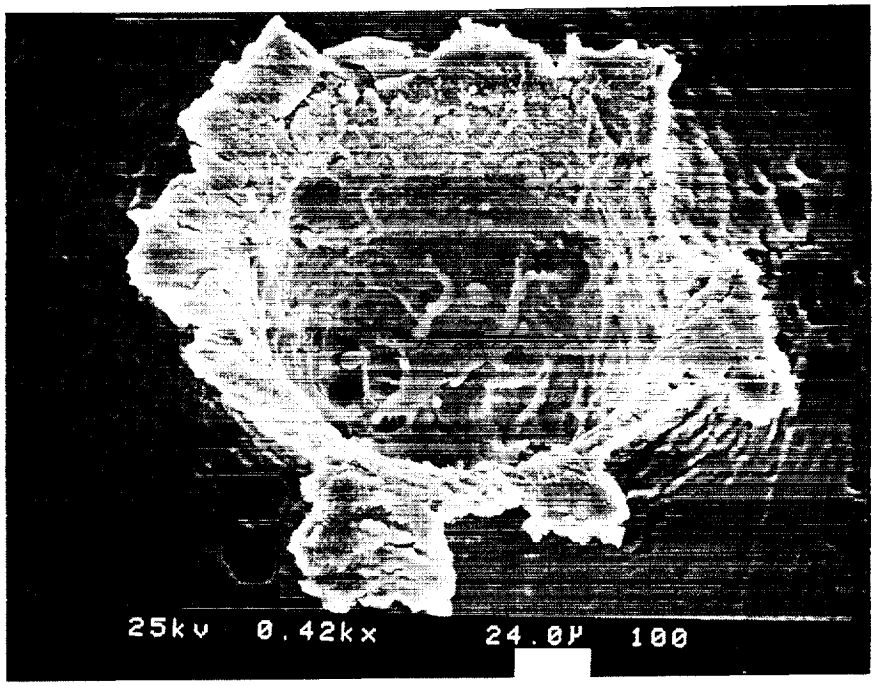
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	2800	Mg
002	200	Si, Mg, Fe
003	100	Unknown
004	120	Trace
005	150	Unknown
006	170	Unknown
007	80	Unknown
008	470	Unknown
009	200	Unknown

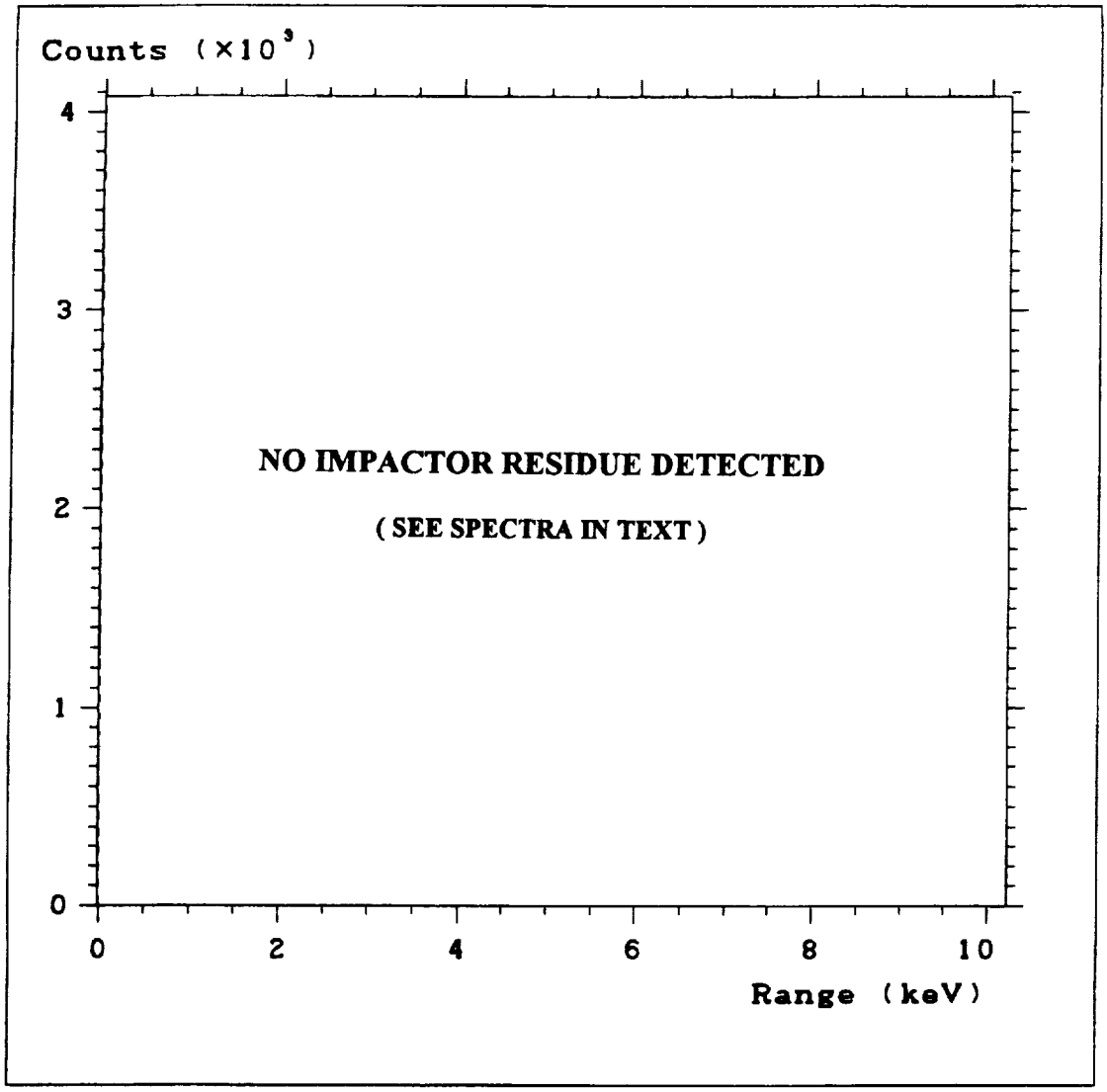


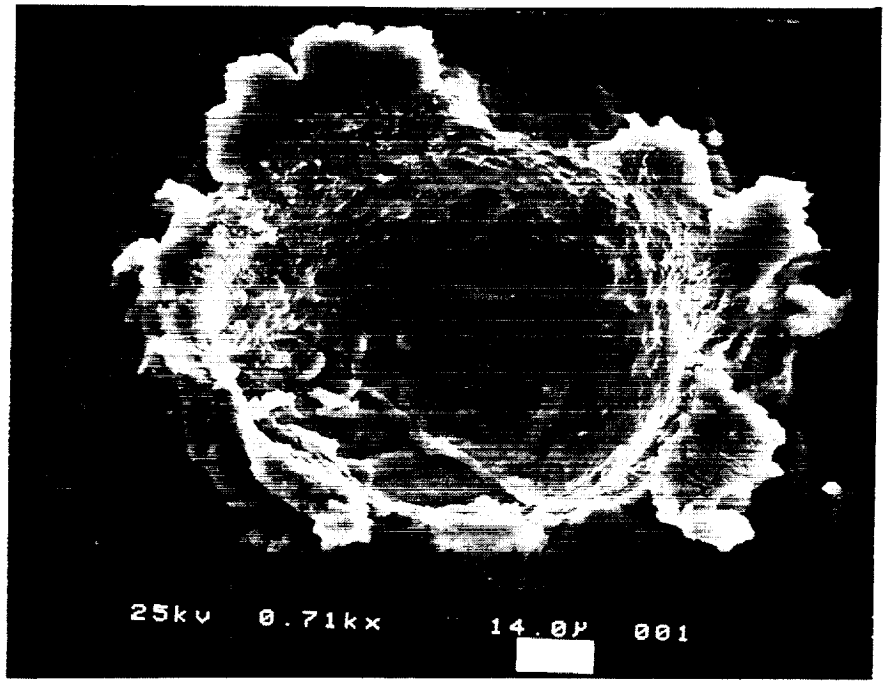

Counts (×10³)
4
3
2
1
0
Al
Mg
Si
0
2
4
6
8
10
Range (keV)
A10-CO6 001

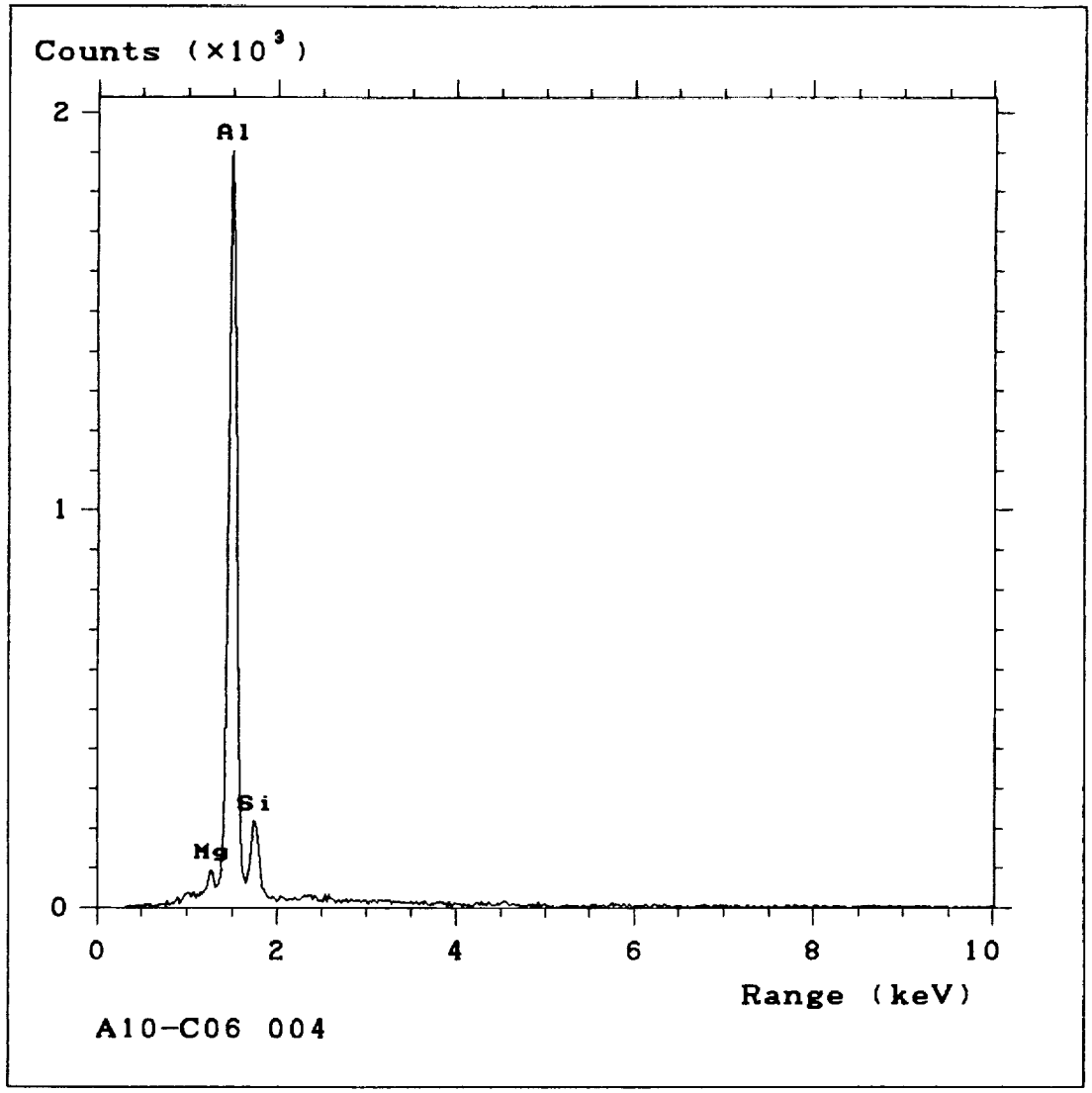

25kv .025kx 400µ 095

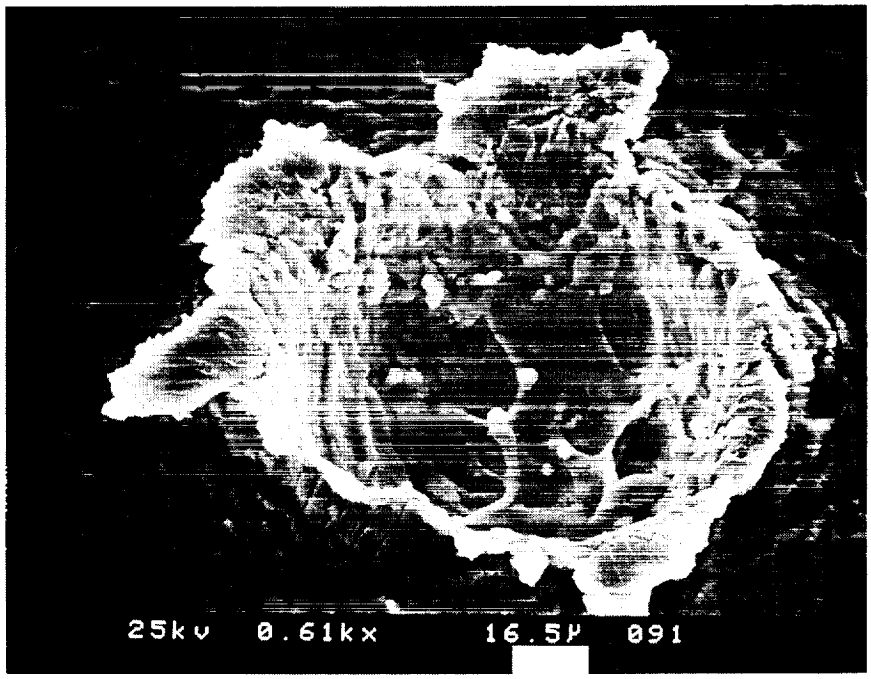

Counts (x10³)
Al
2
1
0
Mg
S
Si
K
Ca
Cr
Cr
Fe
Fe
2
4
6
8
10
Range (keV)
A10-C06 002

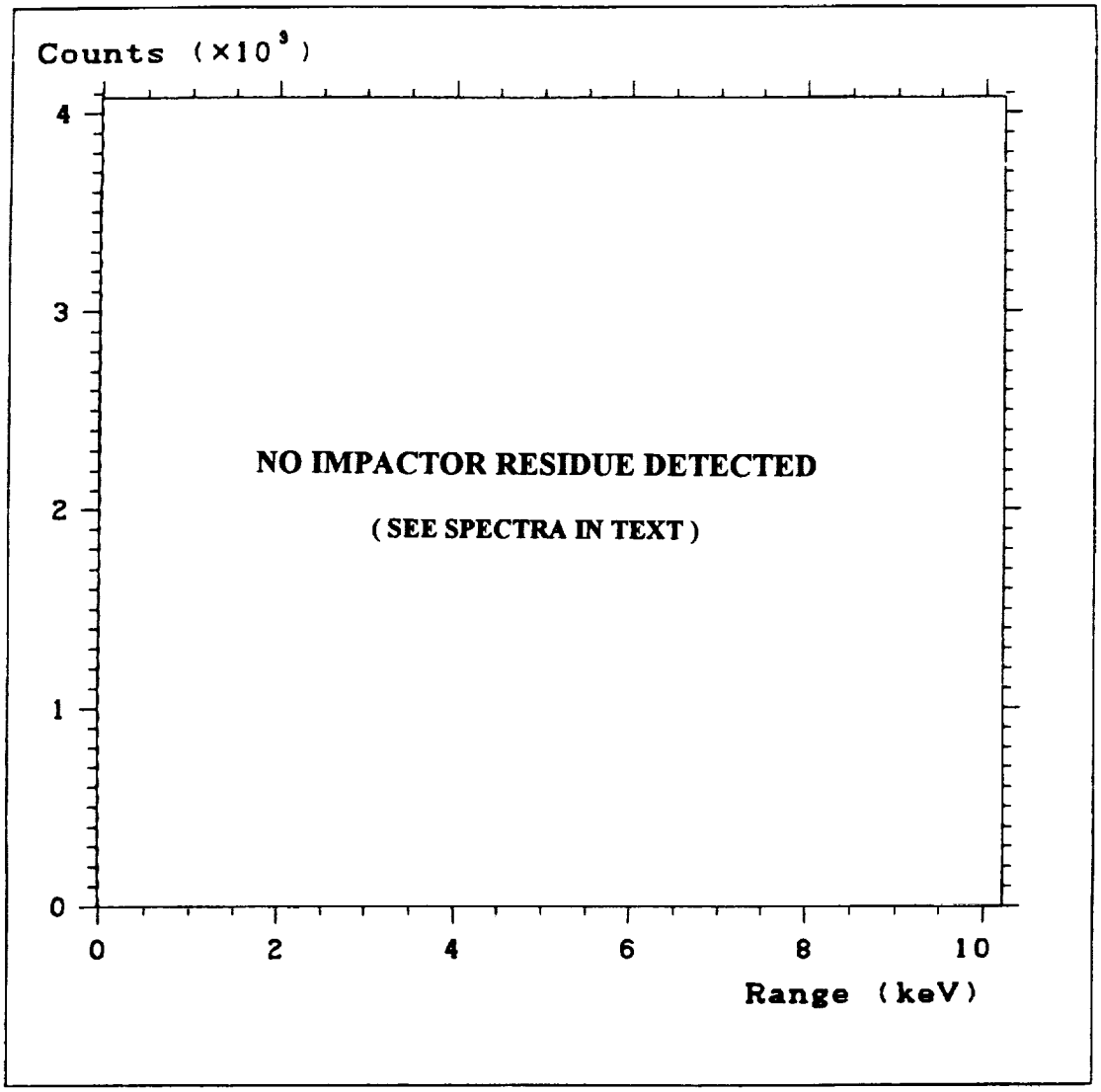

25kv 0.42kx 24.0µ 100

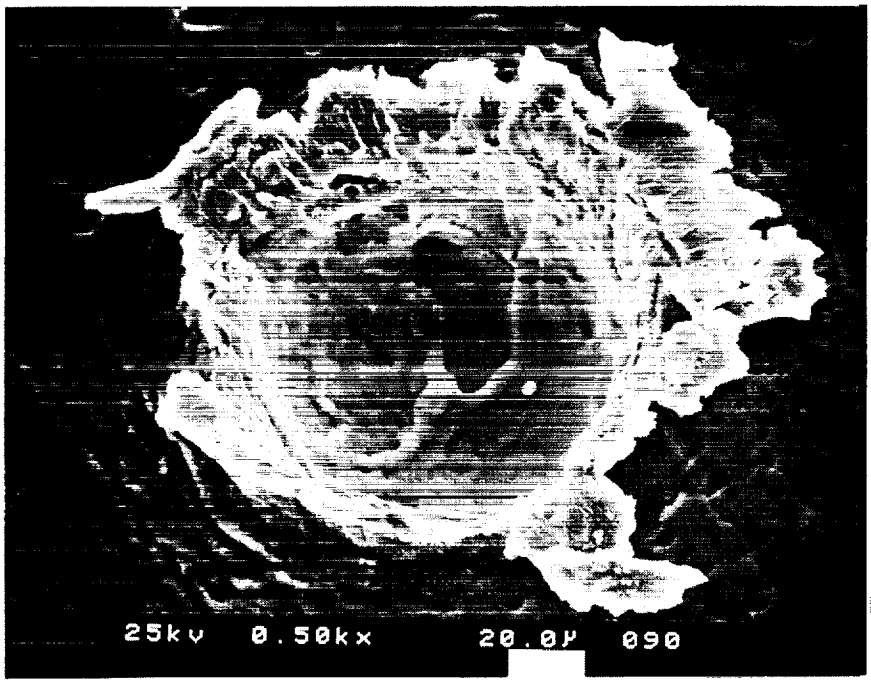

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

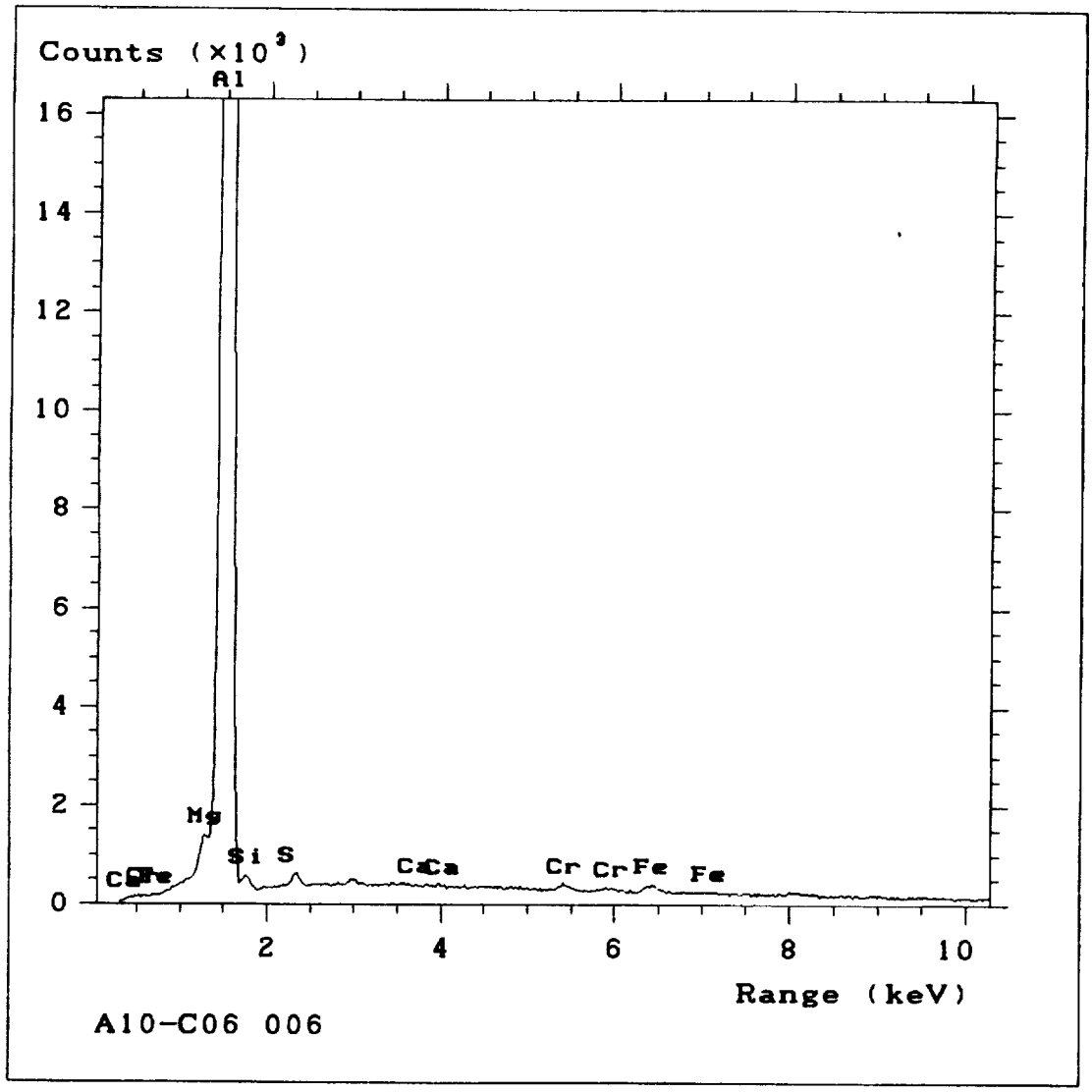

25kv 0.71kx 14.0µ 001

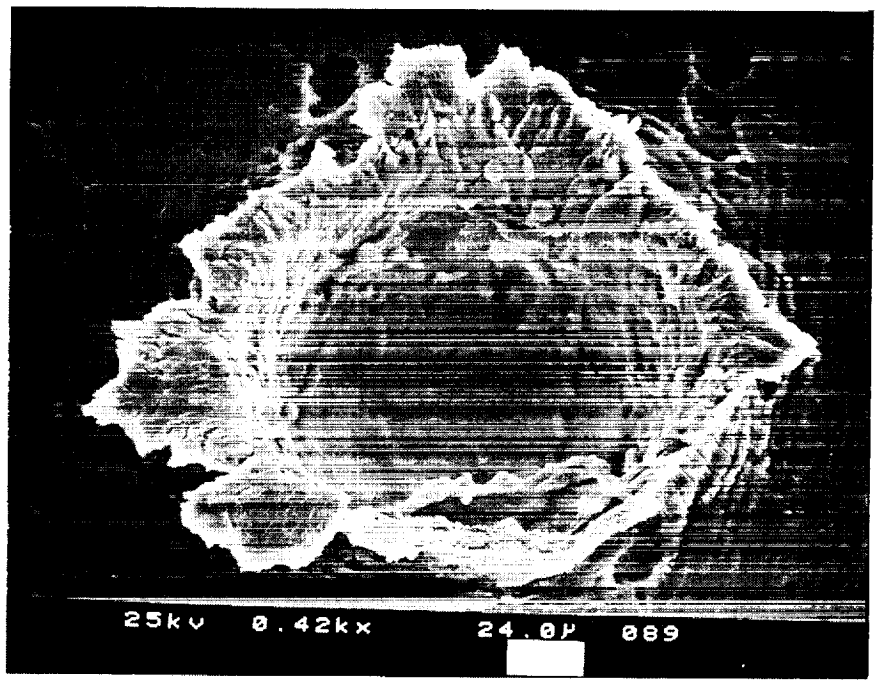

Counts (×10³)
2
1
0
Al
Si
Mg
0
2
4
6
8
10
Range (keV)
A10-C06 004

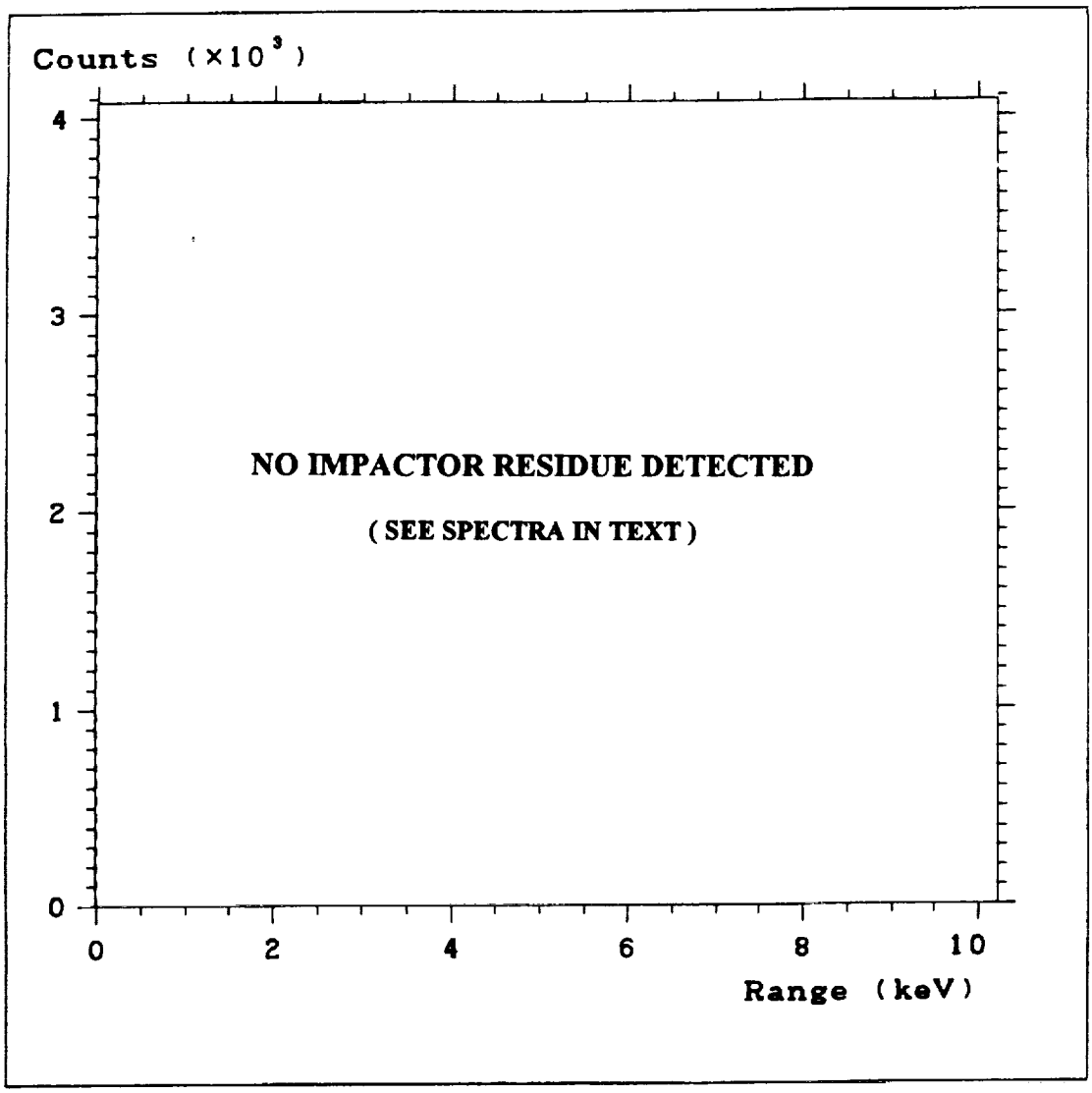

25kv 0.61kx 16.5μ 091

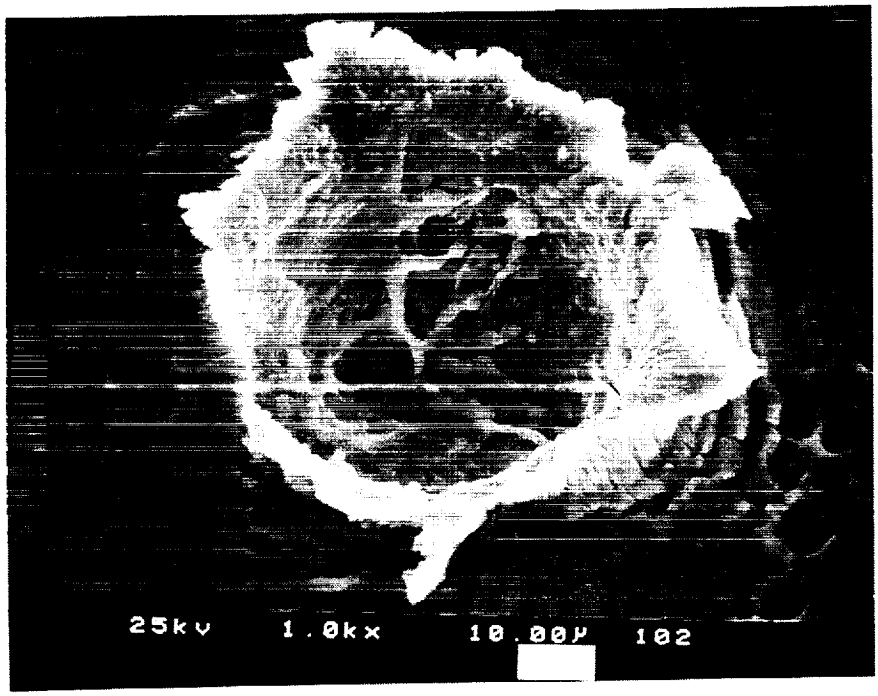

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

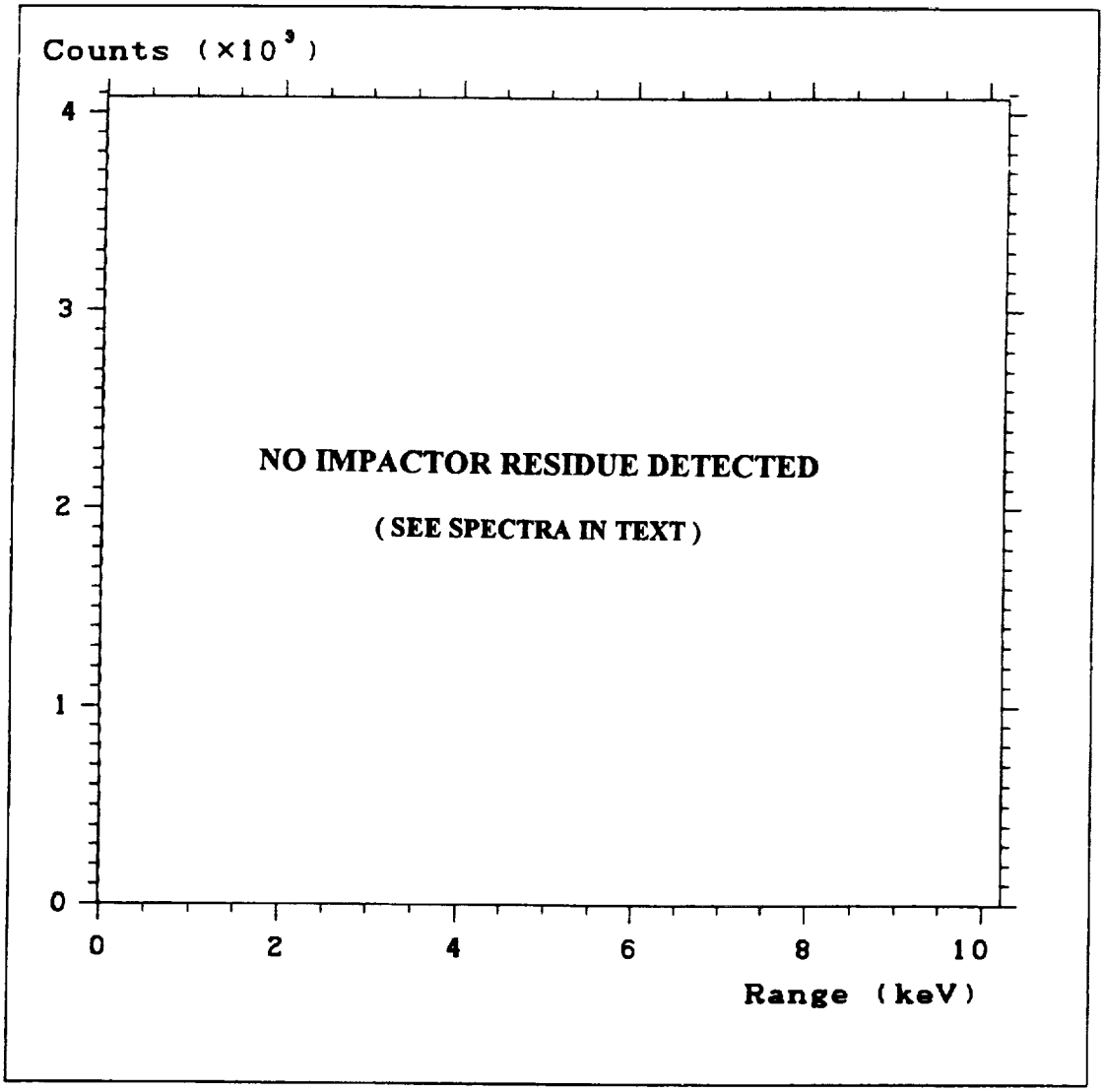

25kv 0.50kx 20.0µ 090

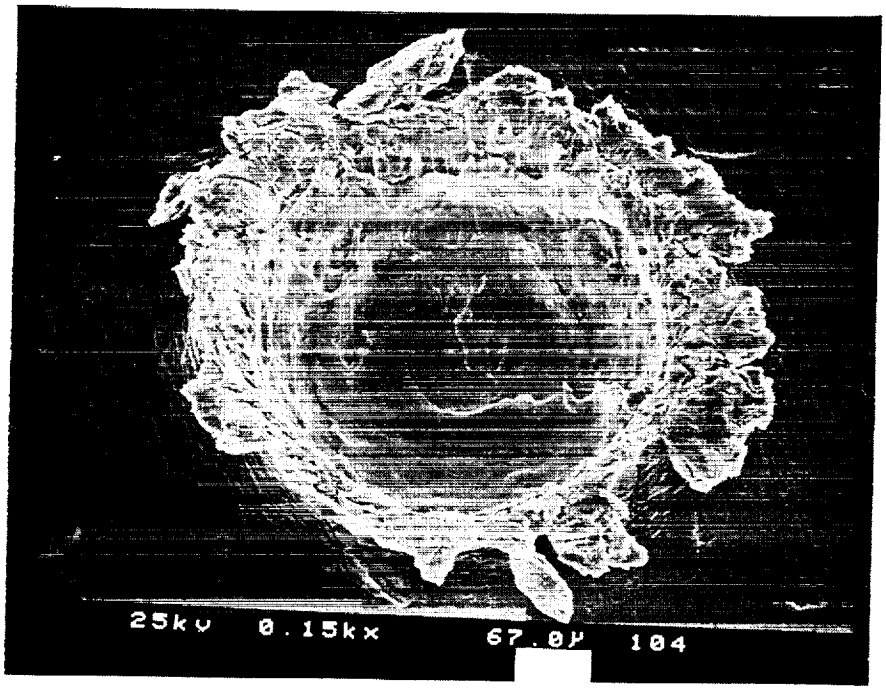

Counts (×10³)
Al
16
14
12
10
8
6
4
2
0
Mg
Si S
Ca Ca
Cr Cr Fe Fe
2
4
6
8
10
Range (keV)
A10-C06 006

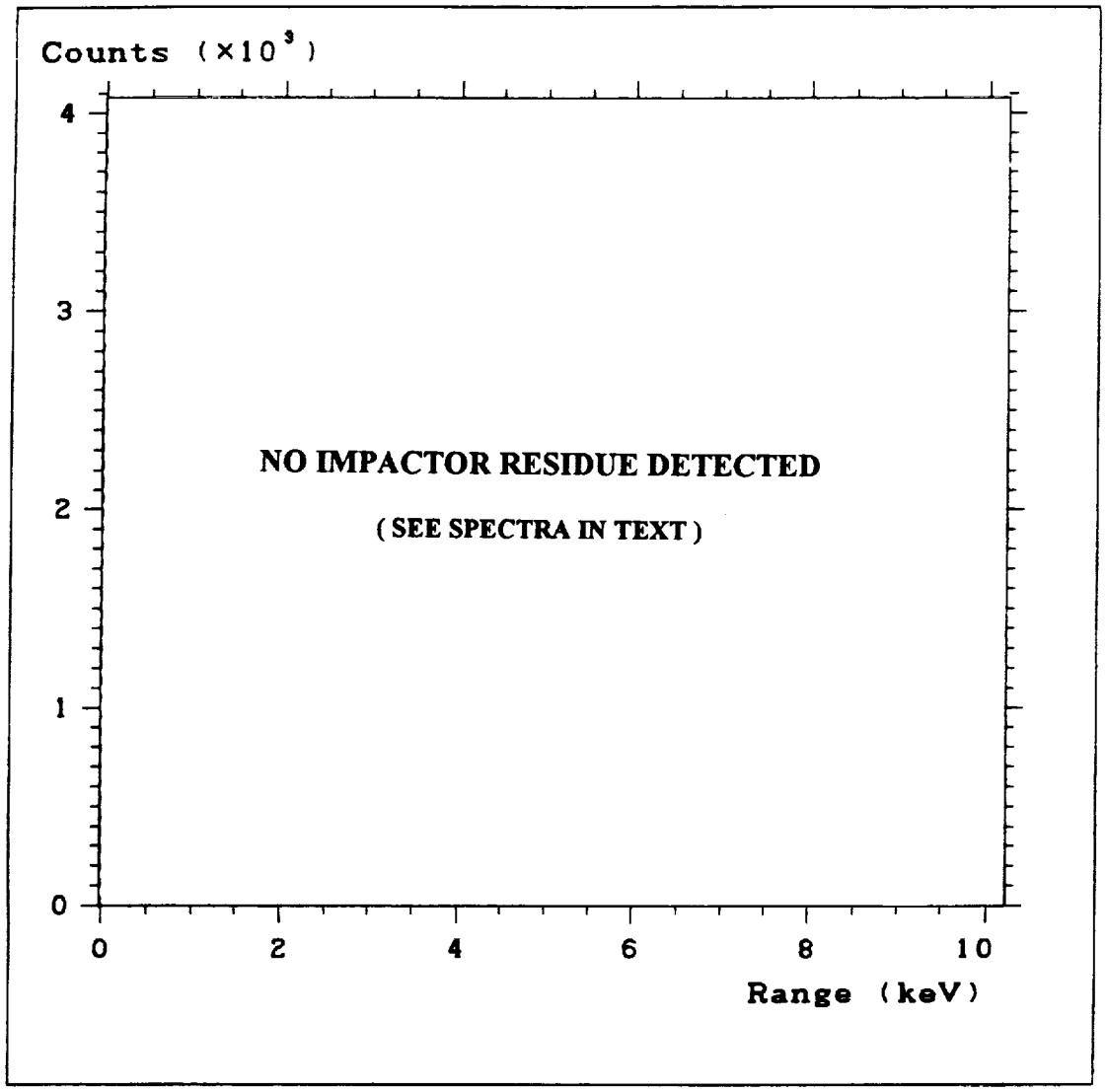

25kv 0.42kx 24.0µ 089

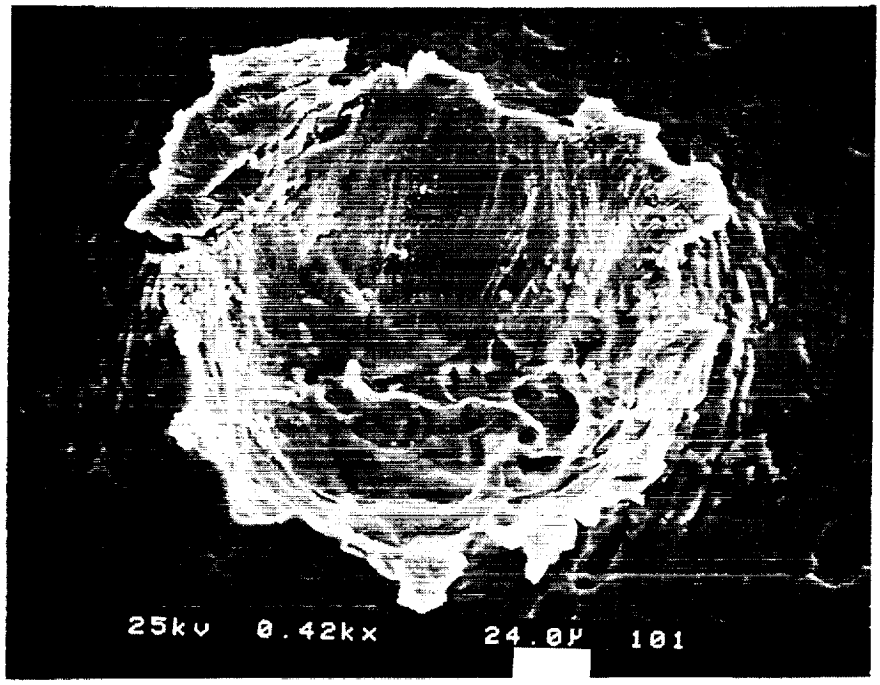

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 1.0kx 10.00µ 102


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

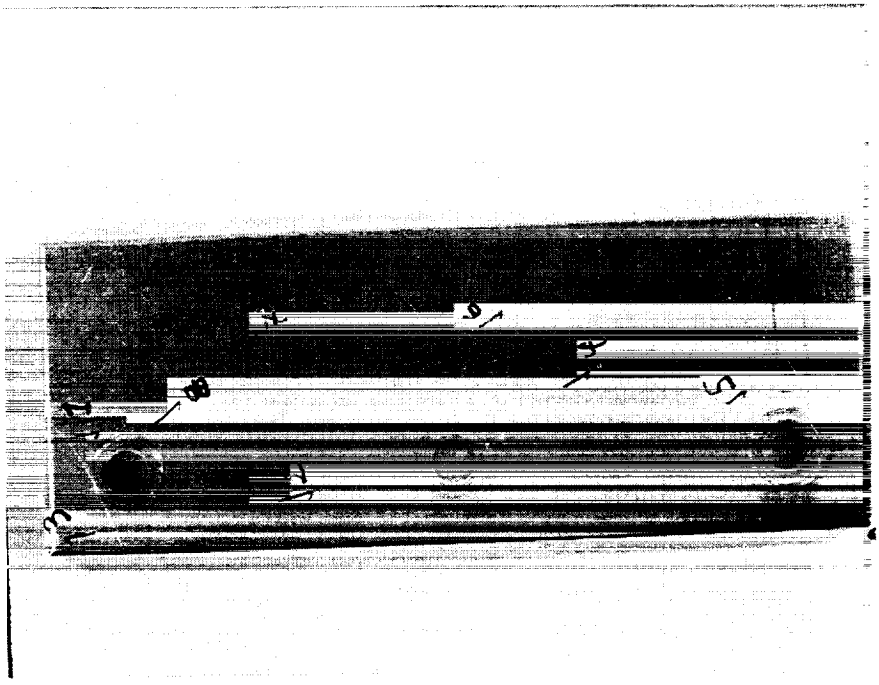

25kV 0.15kx 67.0μ 104

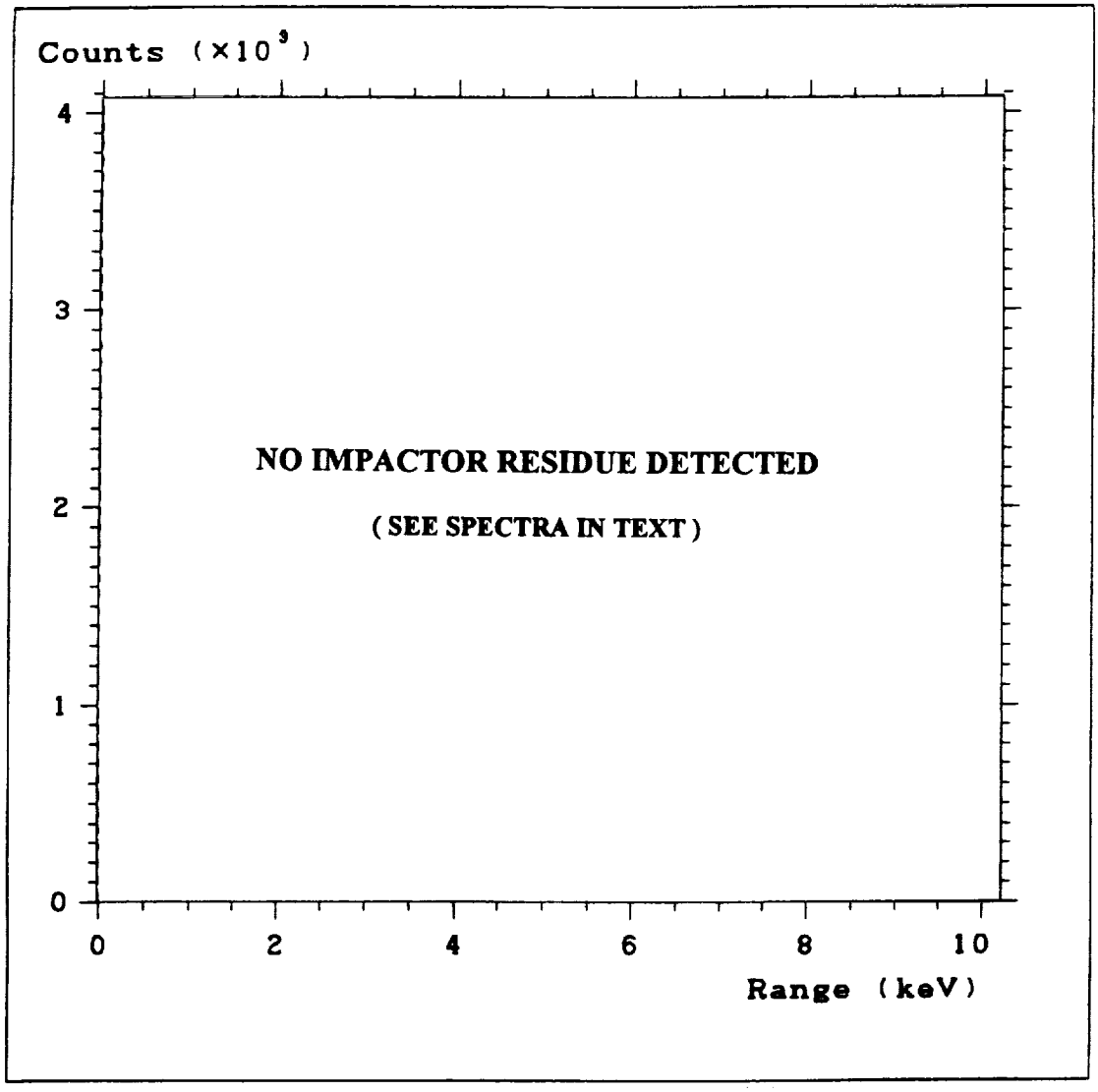

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

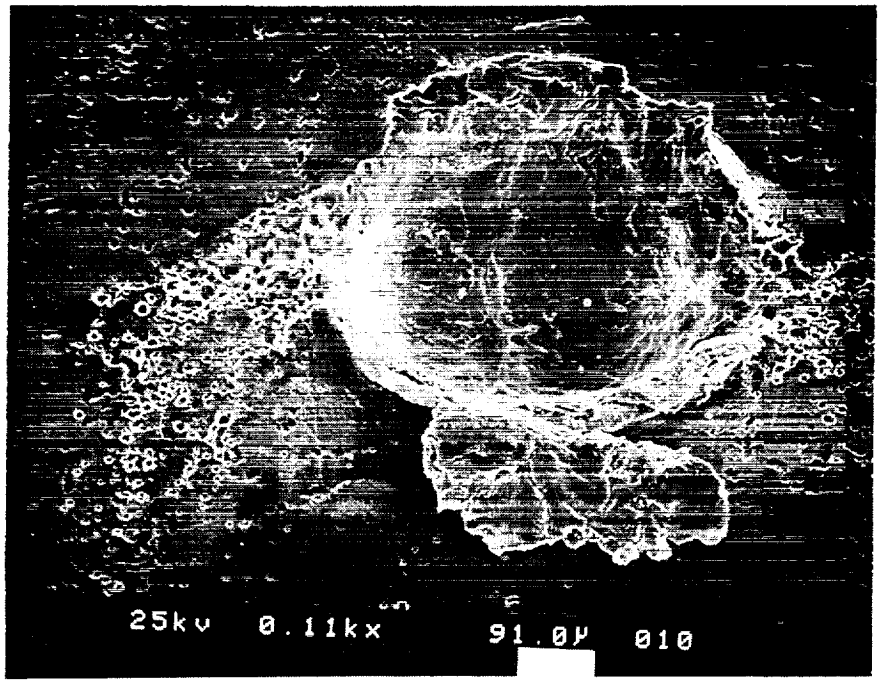

25kv 0.42kx 24.0µ 101

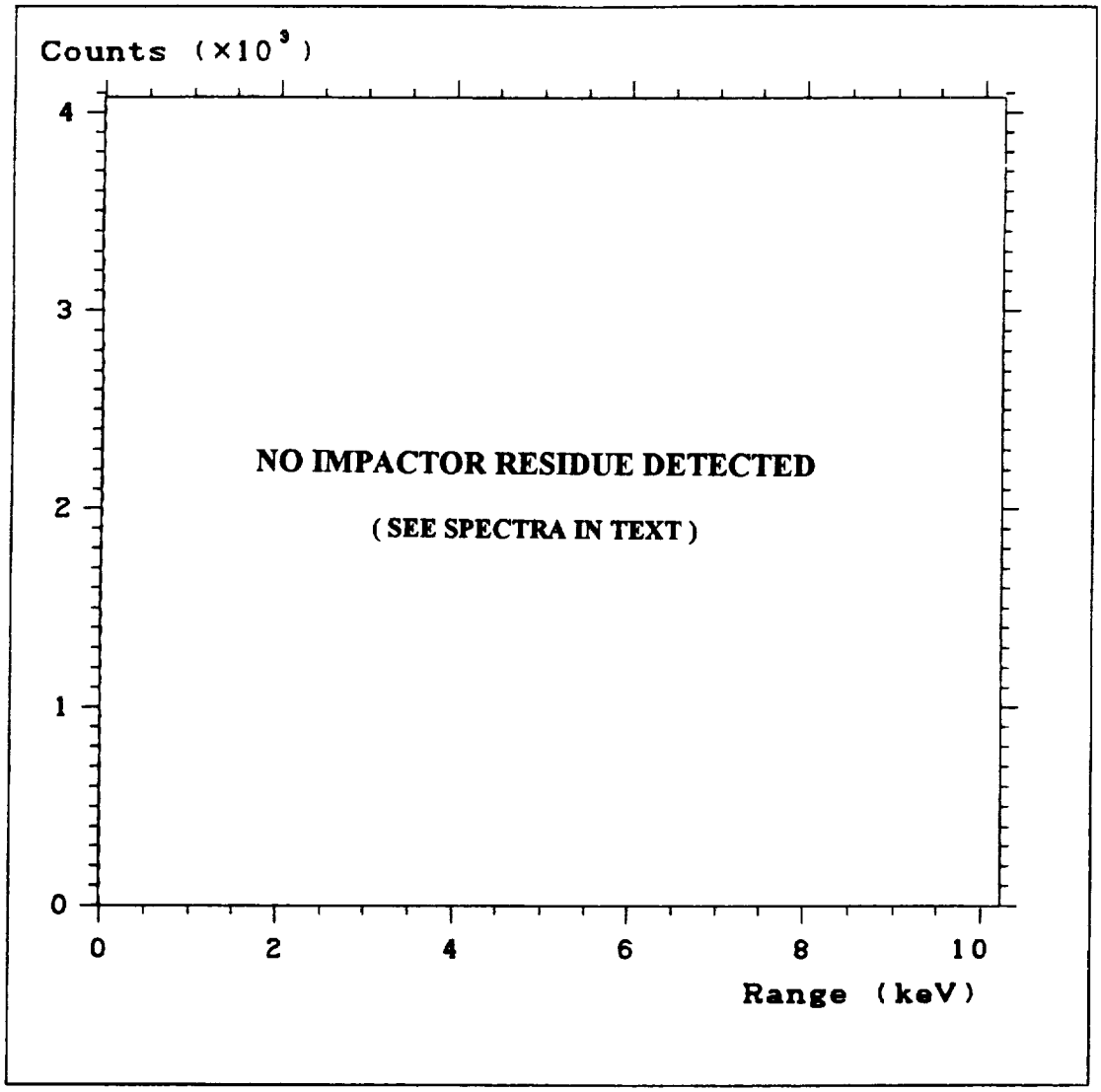
CLAMP NUMBER A10 CO8

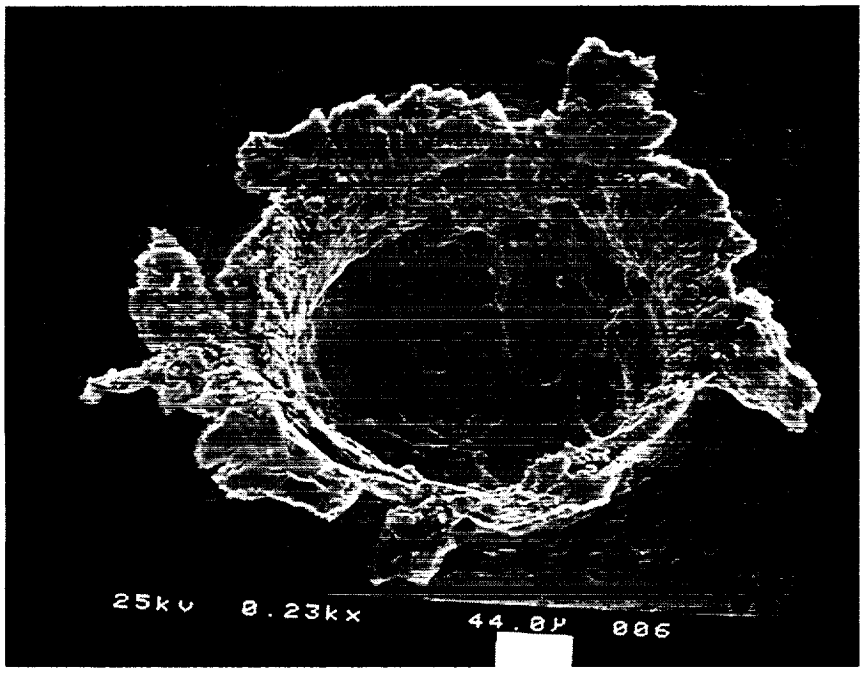
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	500	Unknown
002	260	Unknown
003	140	Unknown
004	500	Unknown
005	100	Unknown
006	120	Unknown
007	140	Unknown
008	70	Unknown

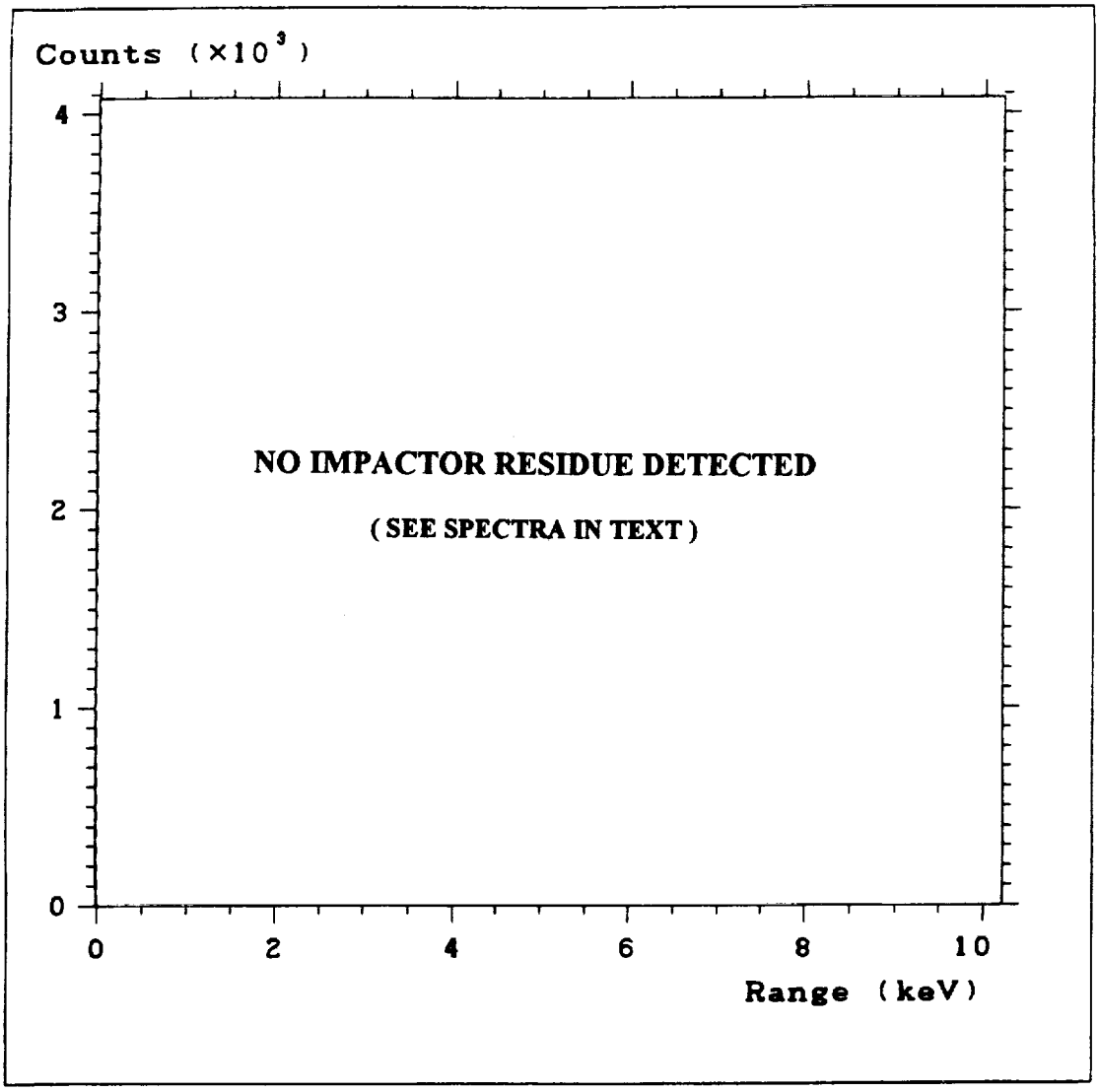


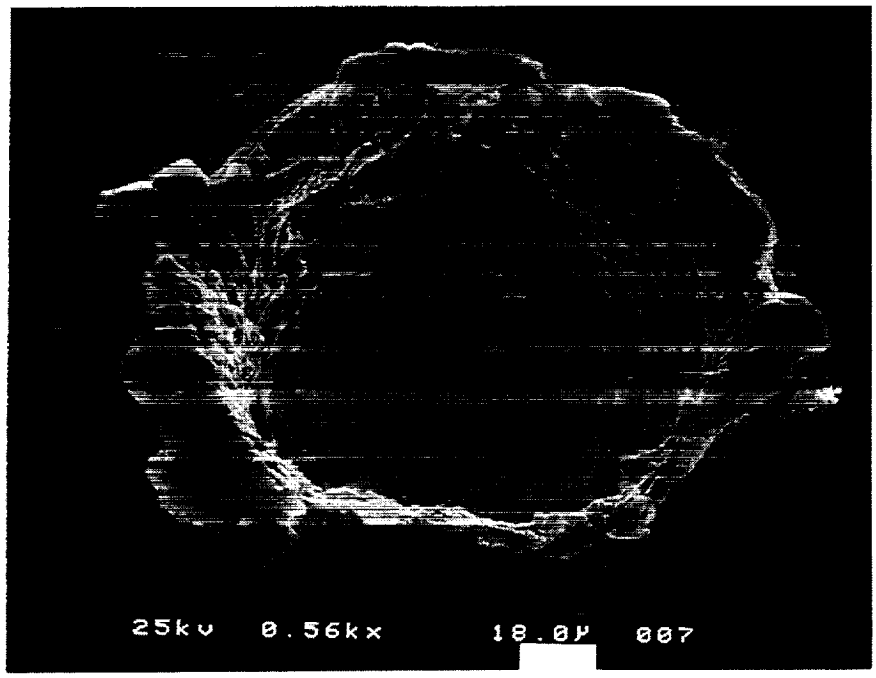

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

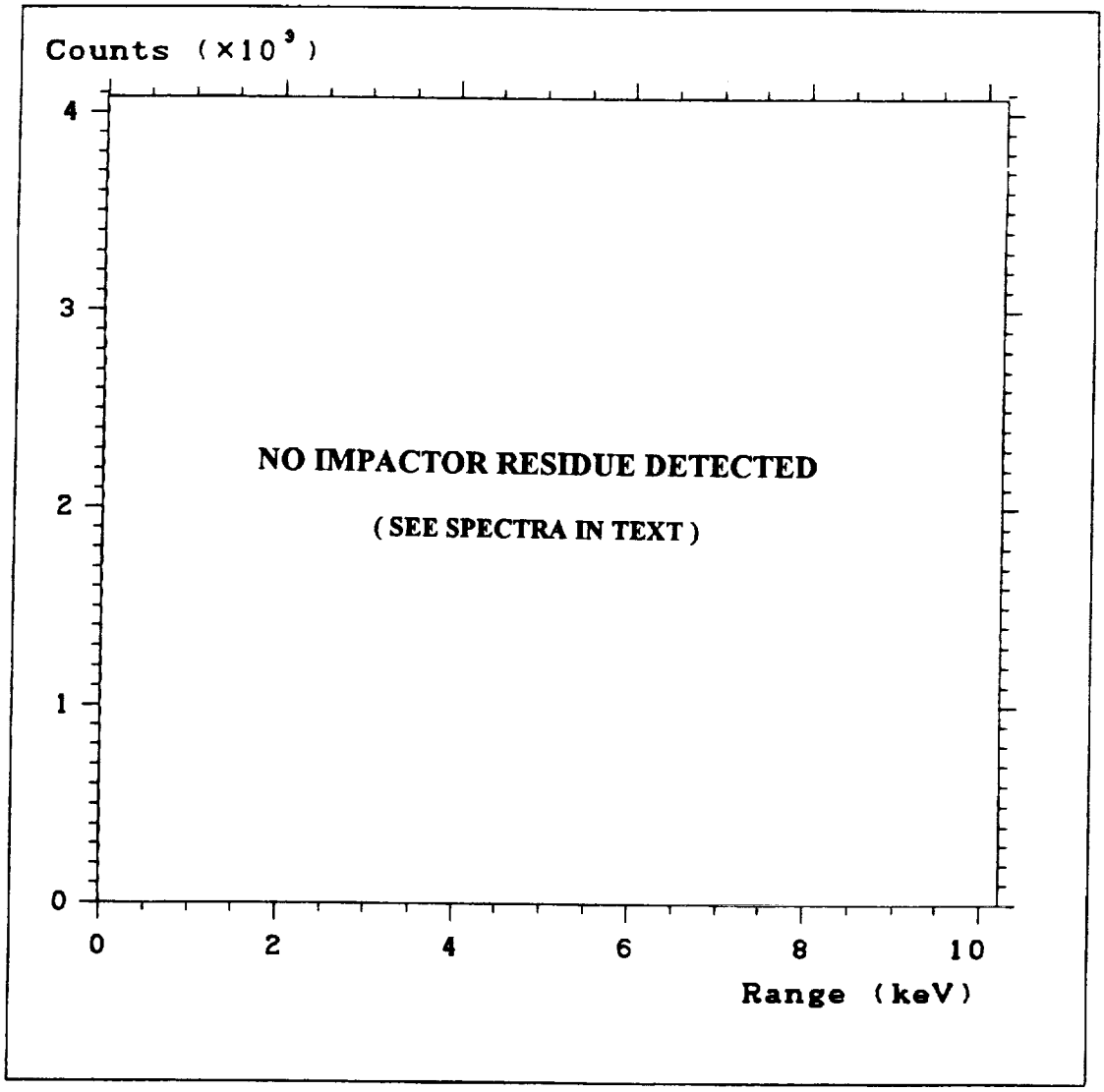

25kv 0.11kx 91.0μ 010

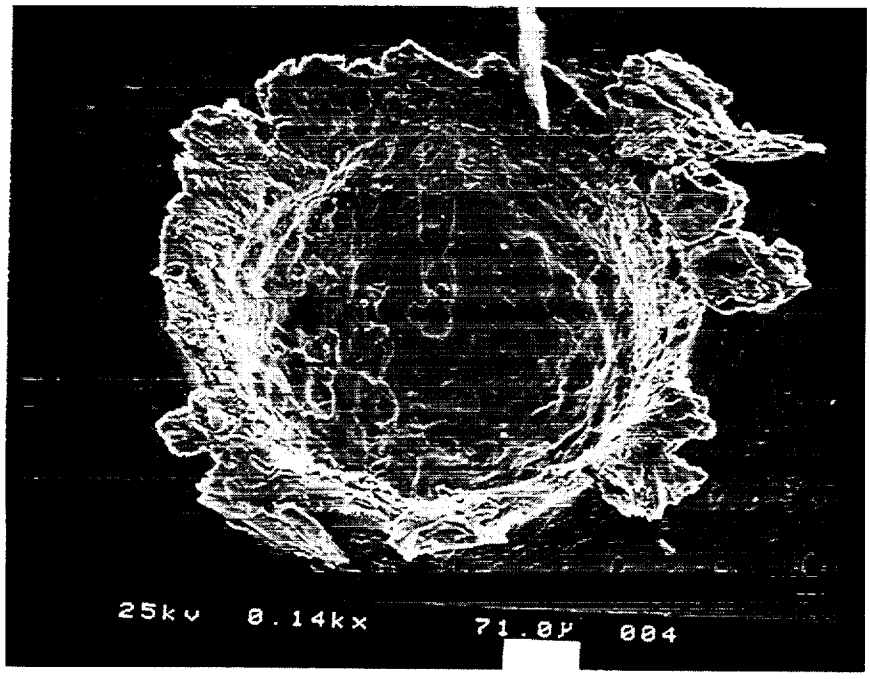

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

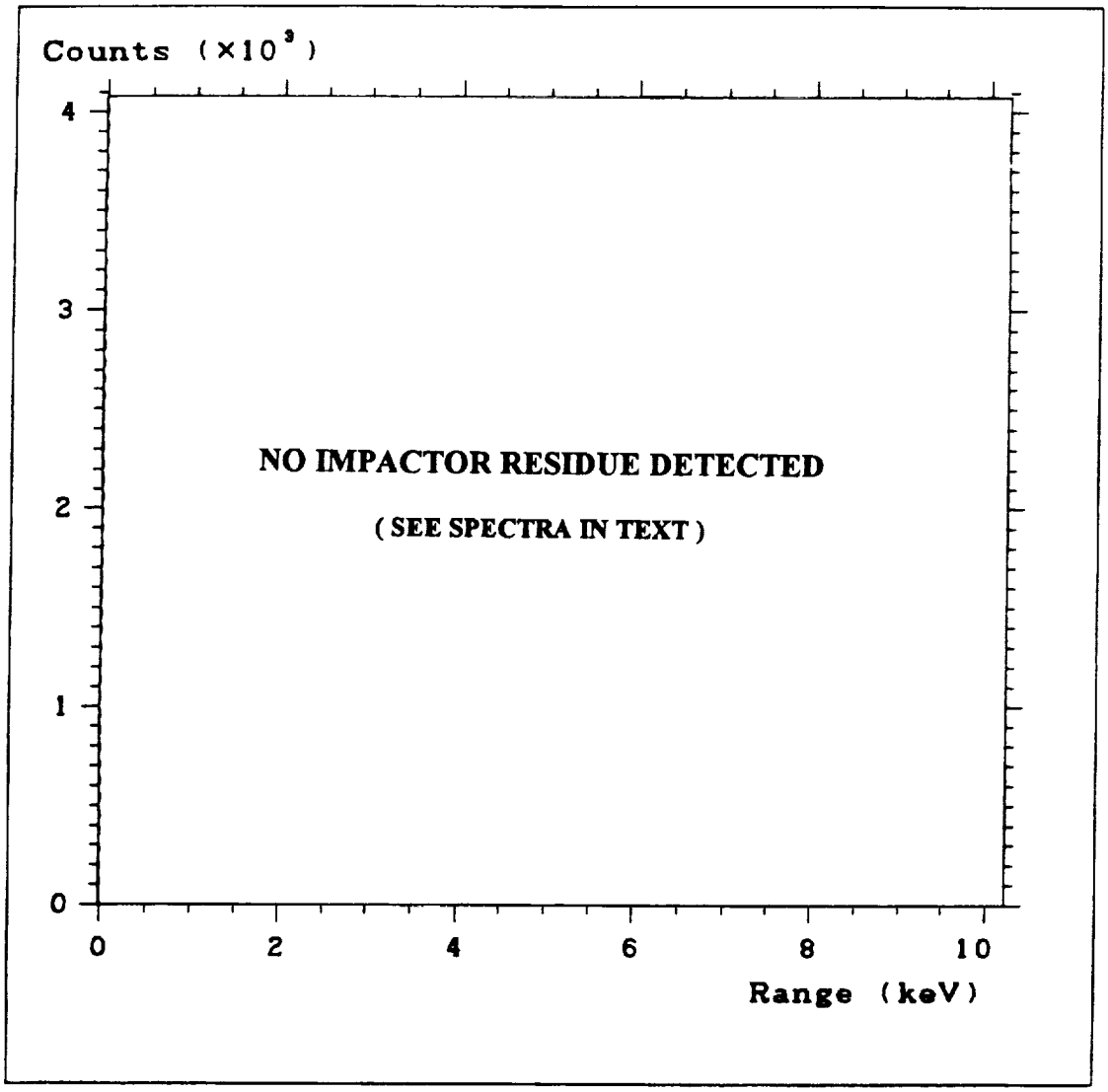

25kv 0.23kx 44.0µ 006

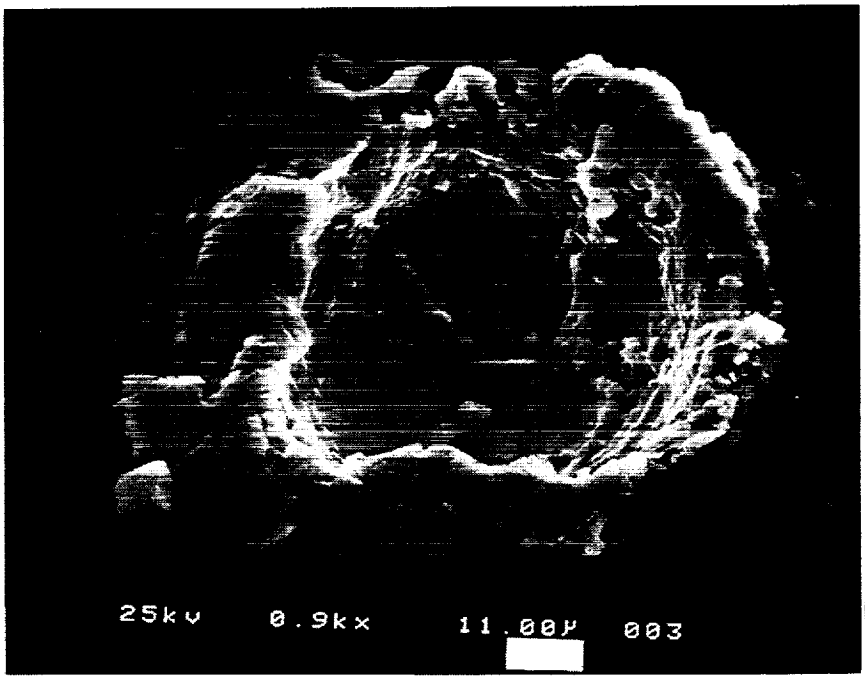

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

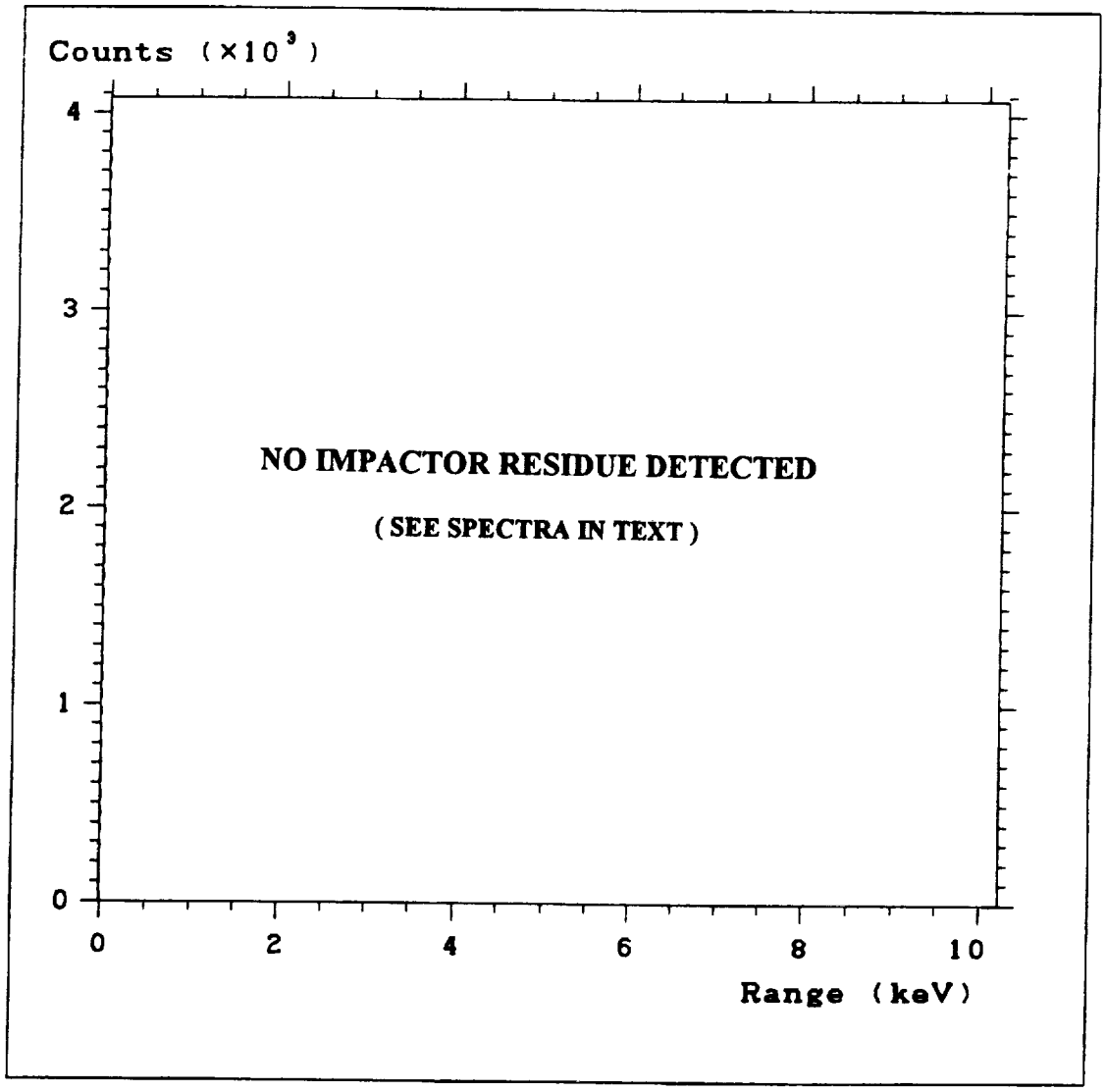

25kv 0.56kx 18.0μ 007

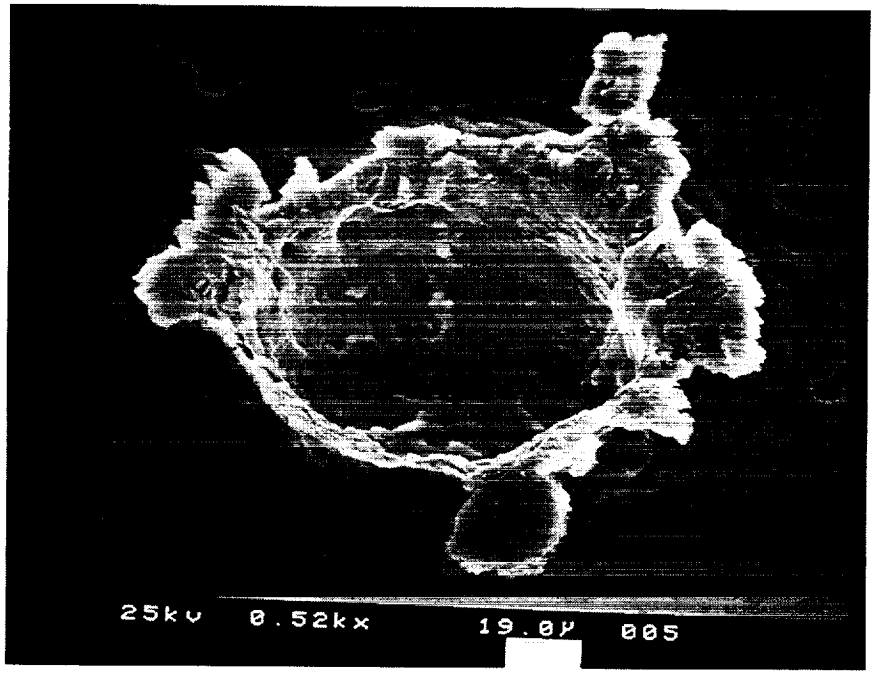

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

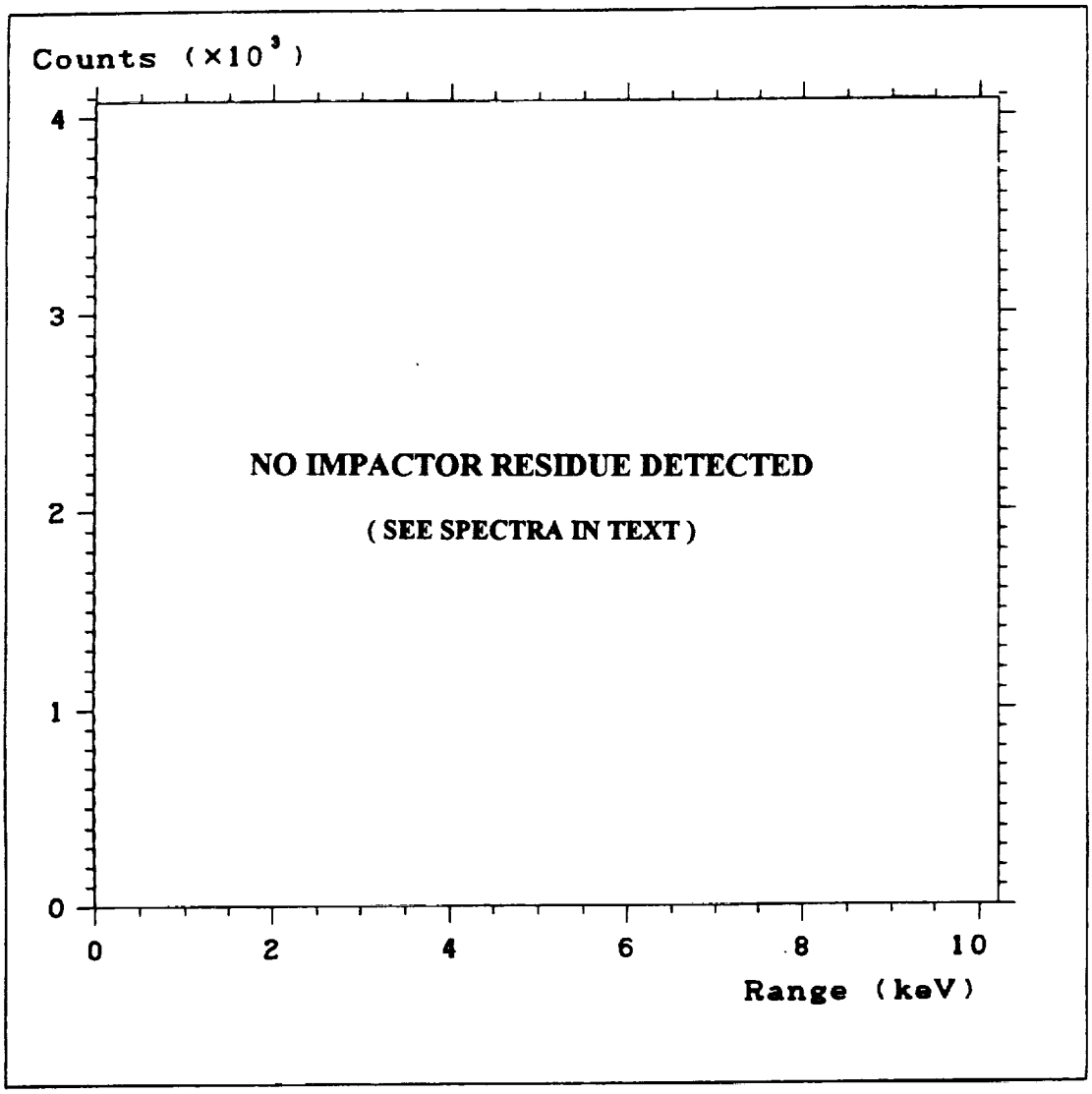

25kv 0.14kx 71.0µ 004

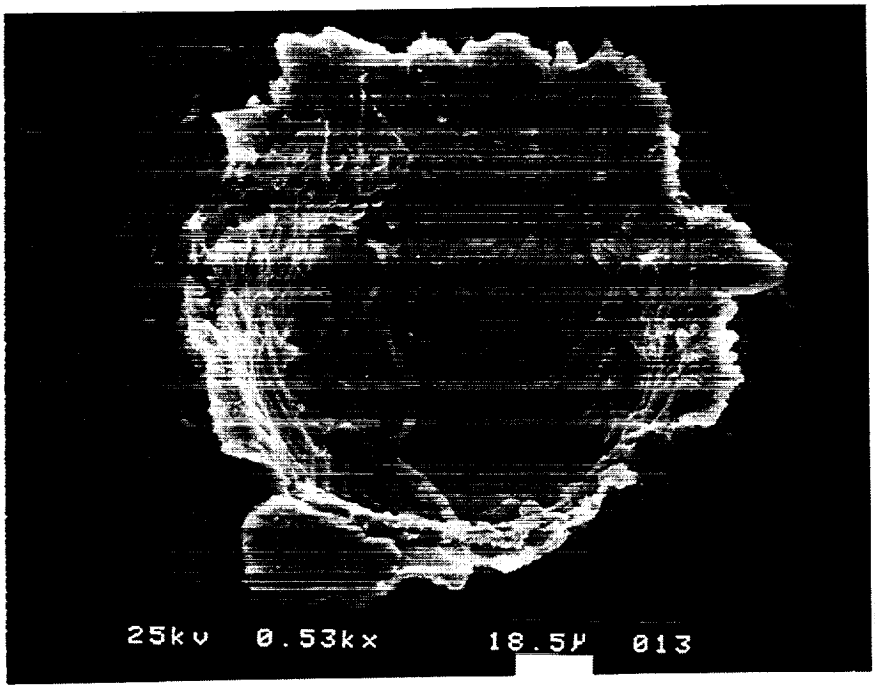

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

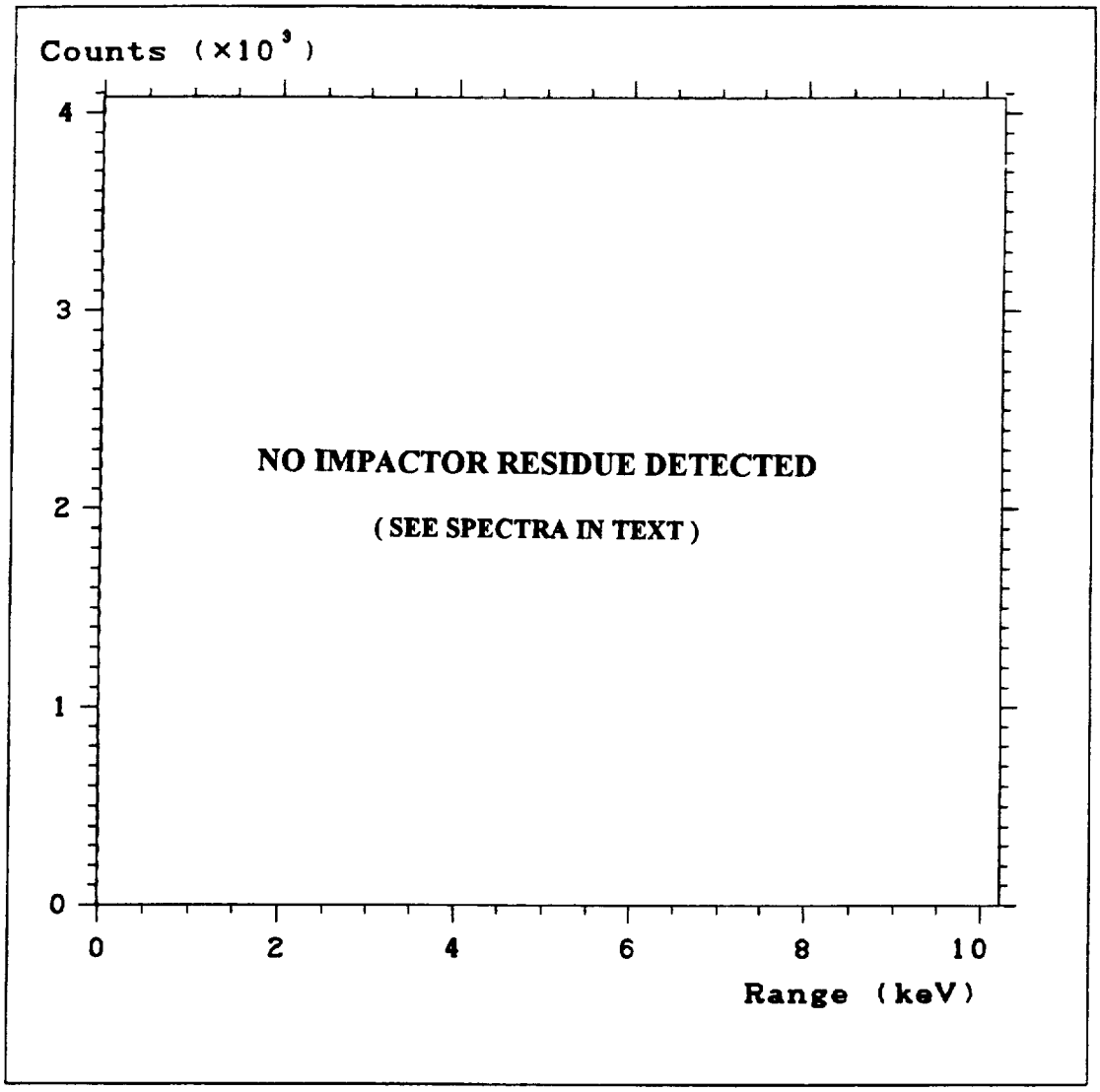

25kv 0.9kx 11.00µ 003

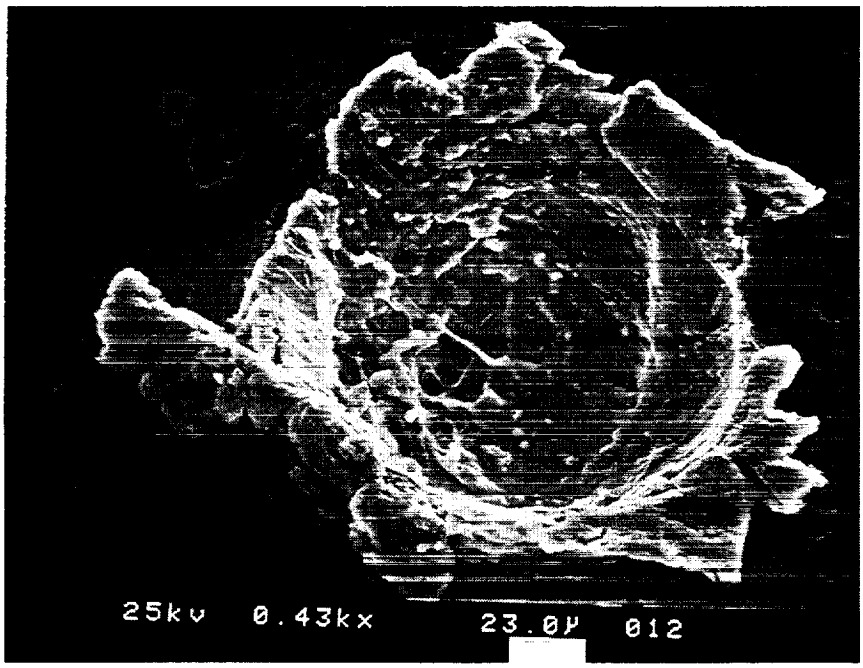

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


25kv 0.52kx 19.0µ 005


Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

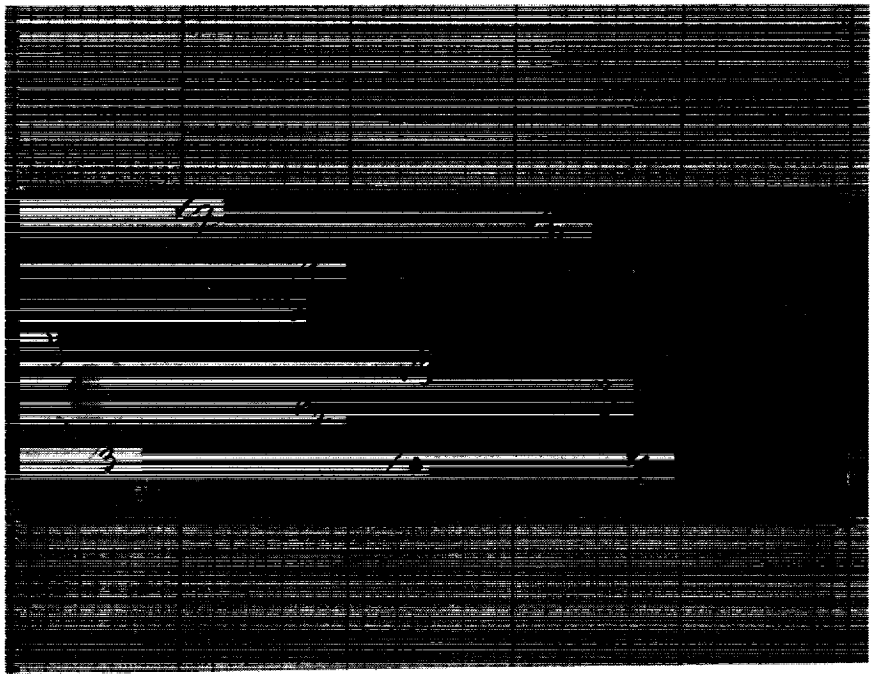

25kv 0.53kx 18.5µ 013

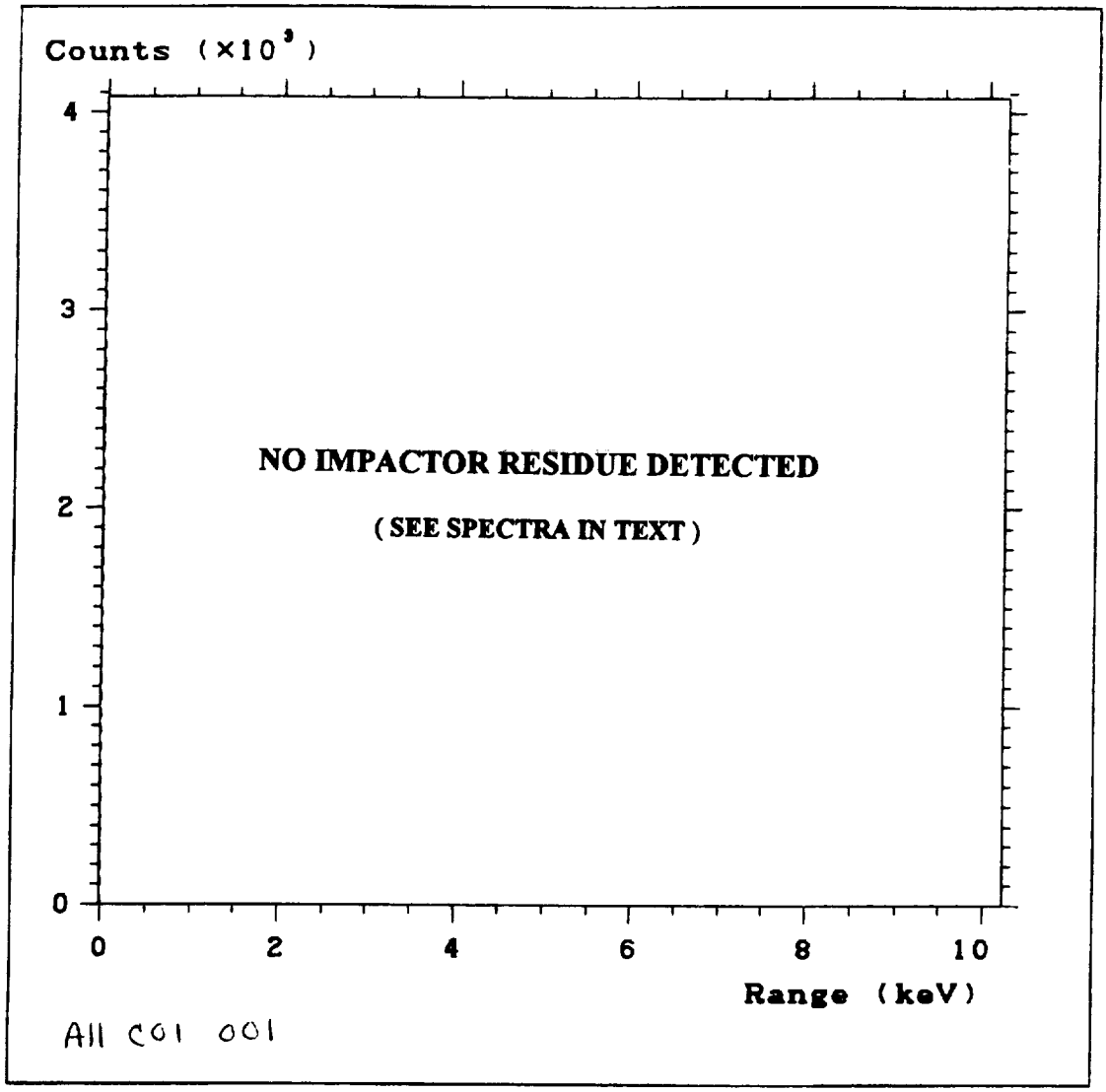

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

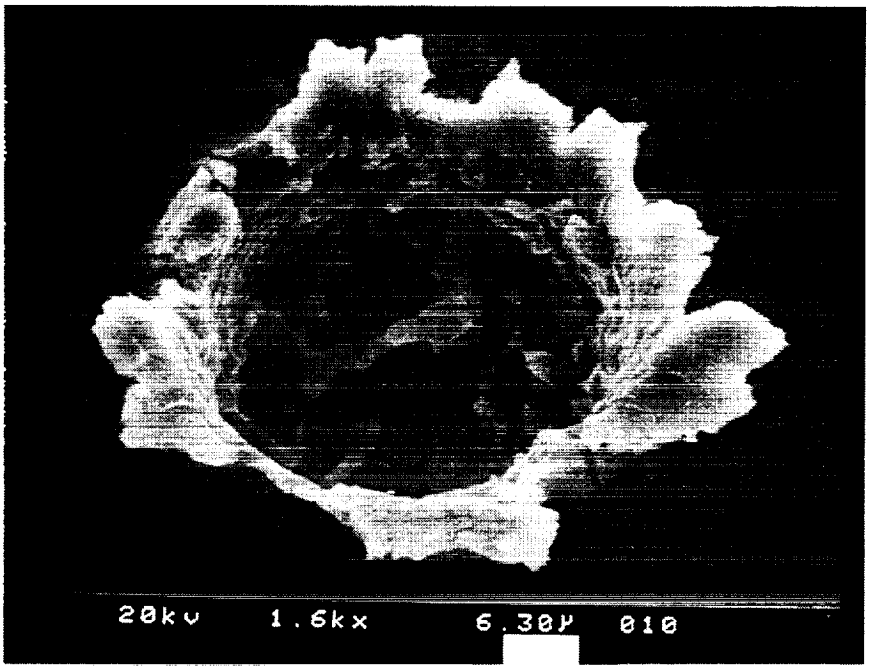

25kv 0.43kx 23.0µ 012

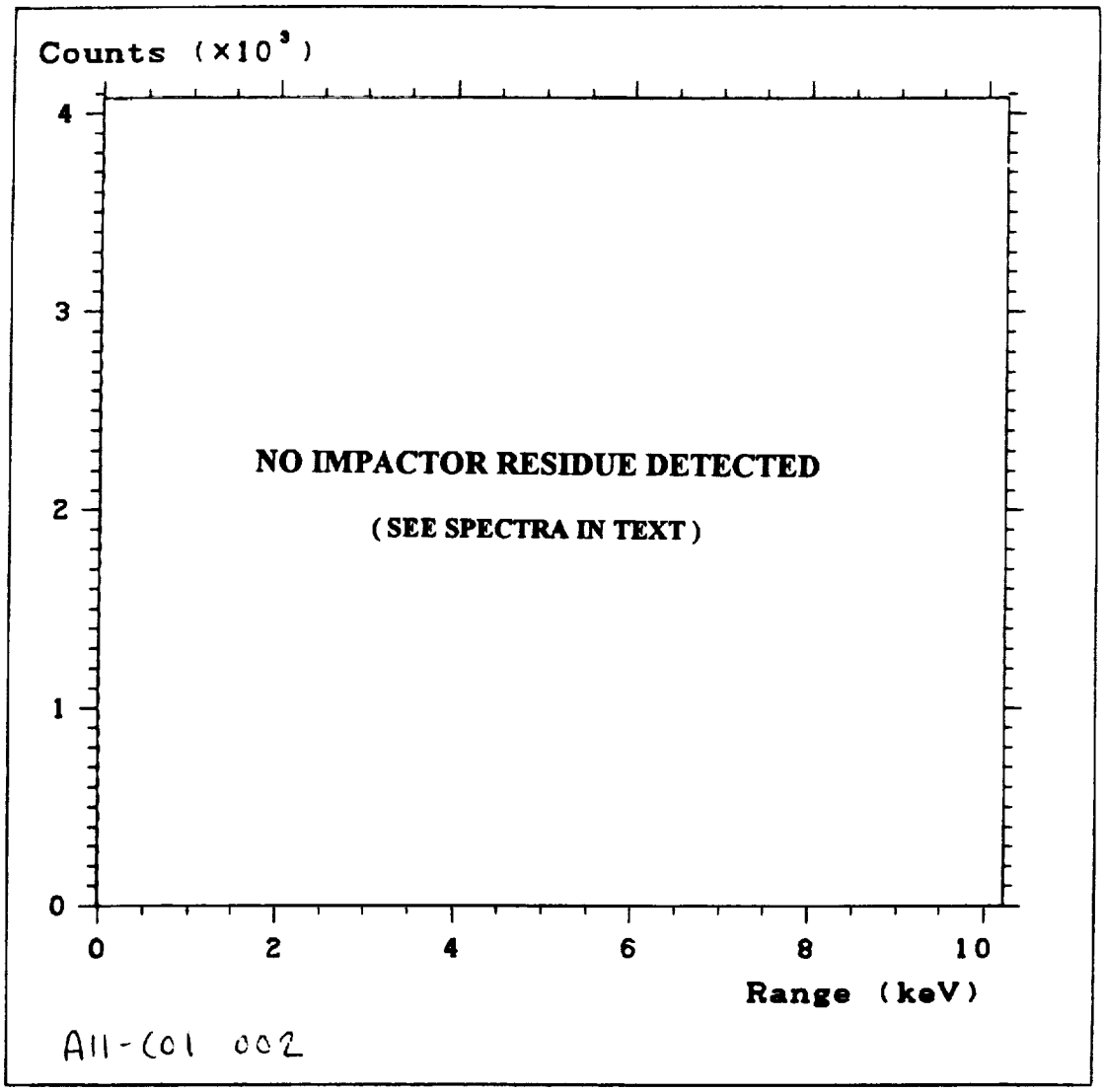
CLAMP NUMBER A11 CO1

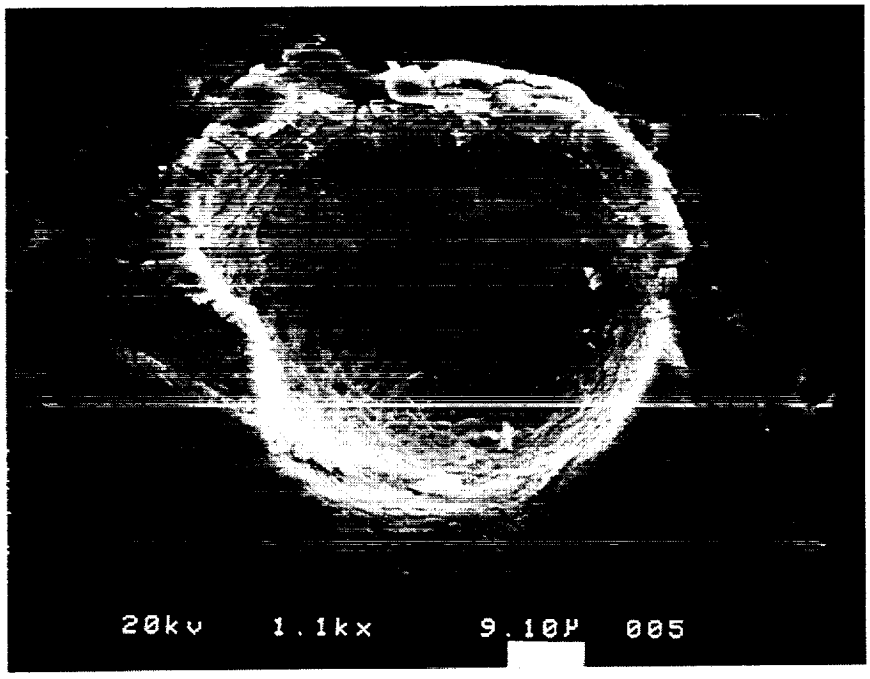
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	60	Unknown
002	50	Flaw
003	60	Unknown
004	130	Bolt Spray
005	180	Unknown
006	140	Unknown
007	60	Unknown
008	90	Unknown

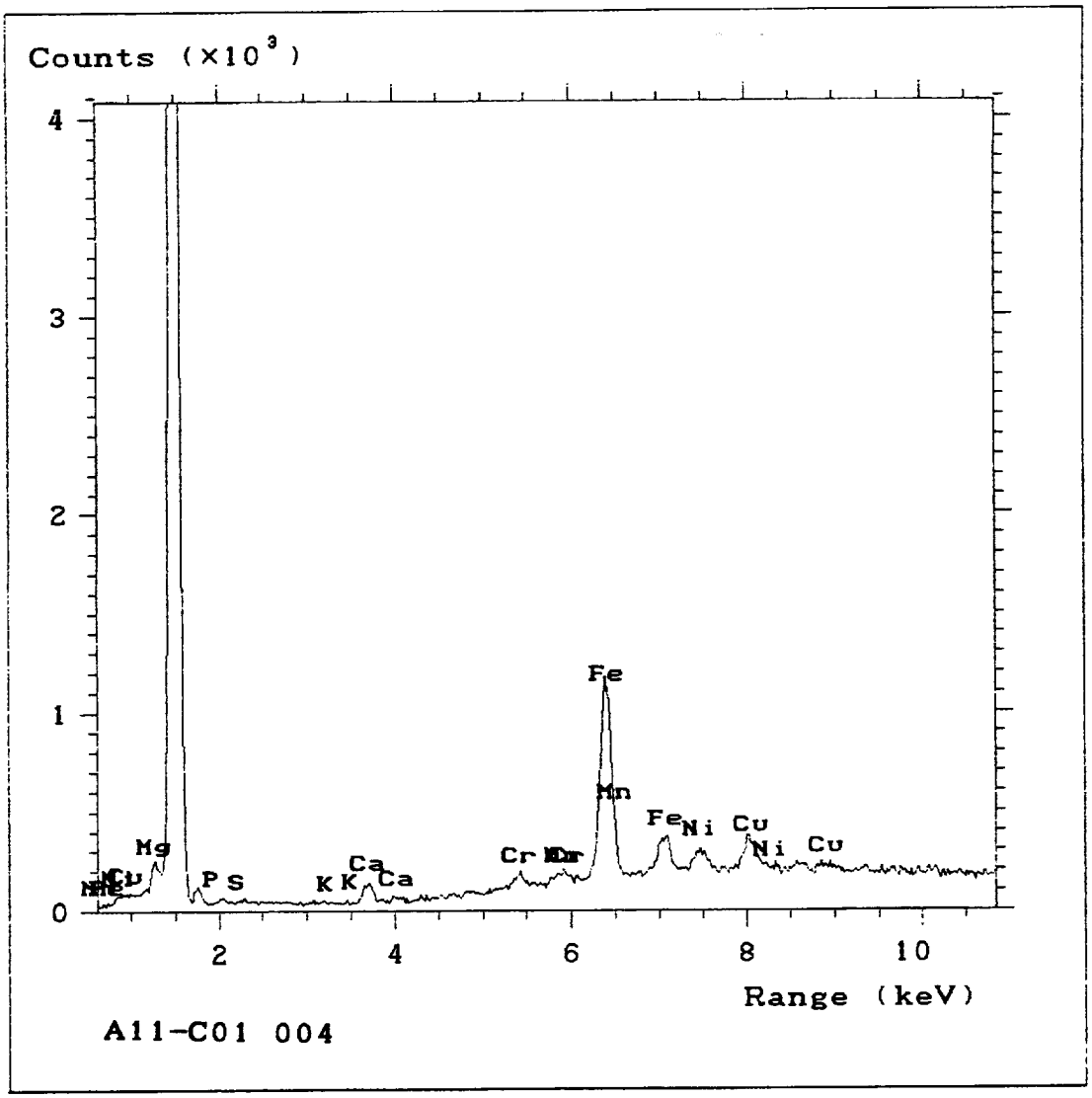


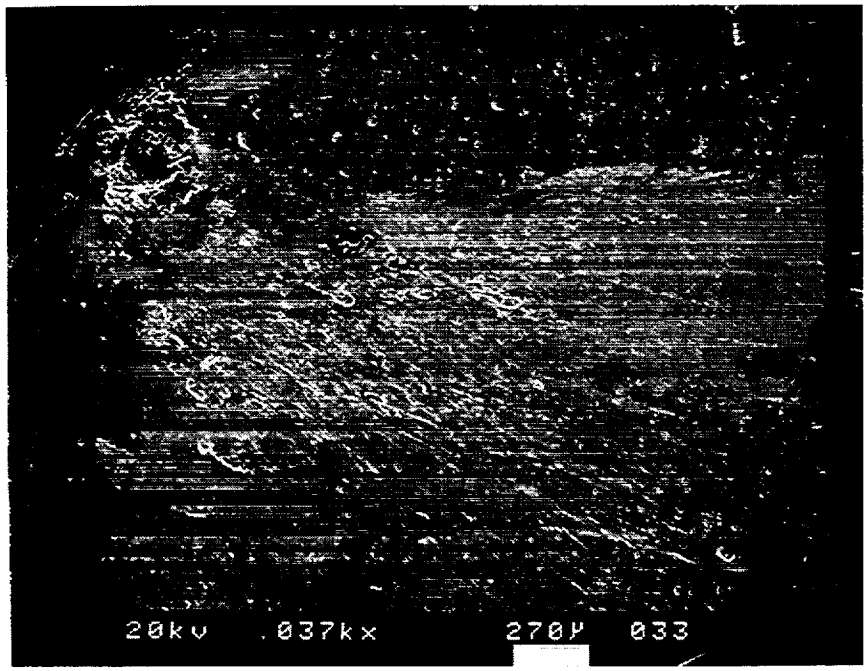

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
All C01 001

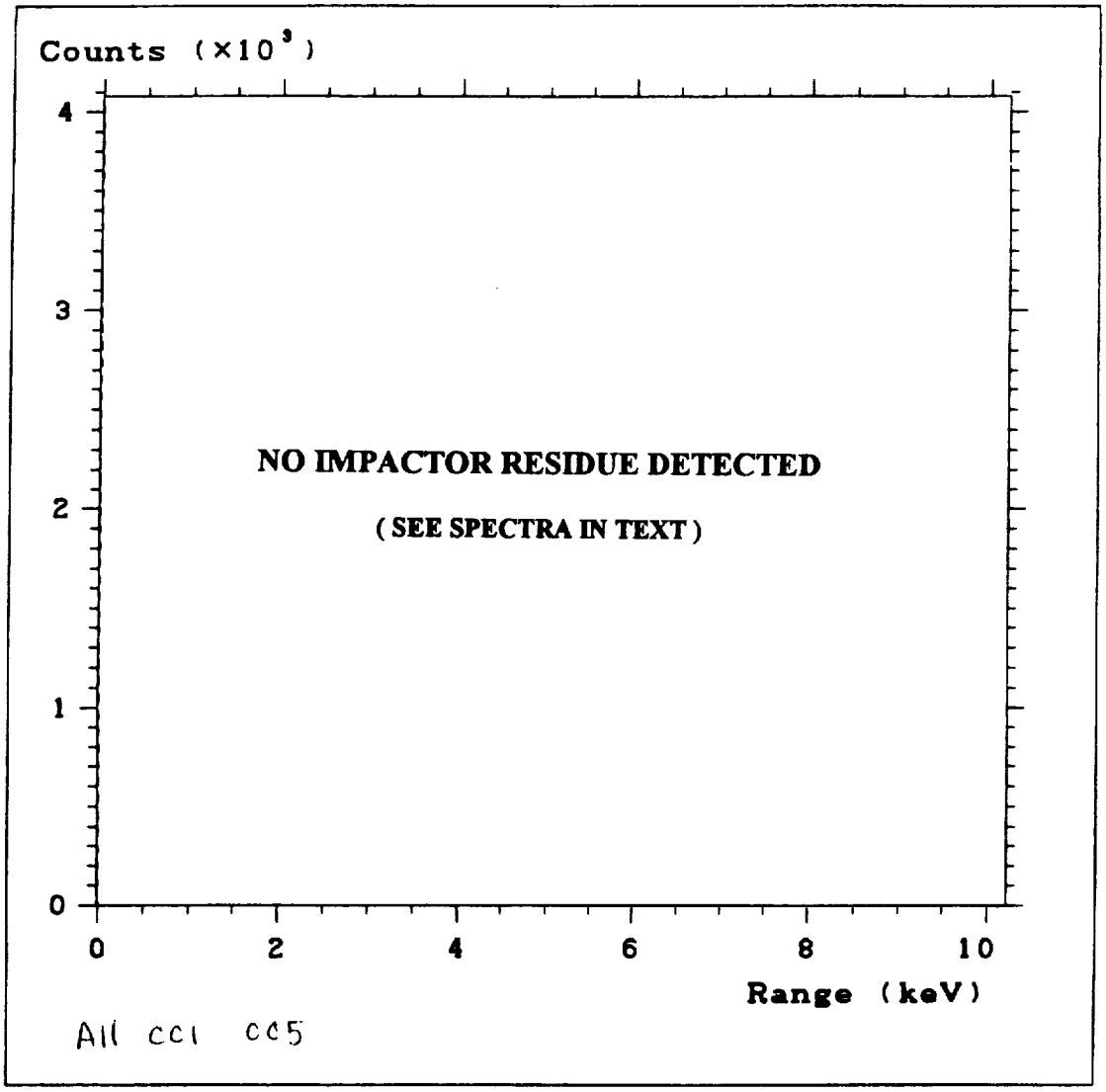

20kv 1.6kx 6.30µ 010

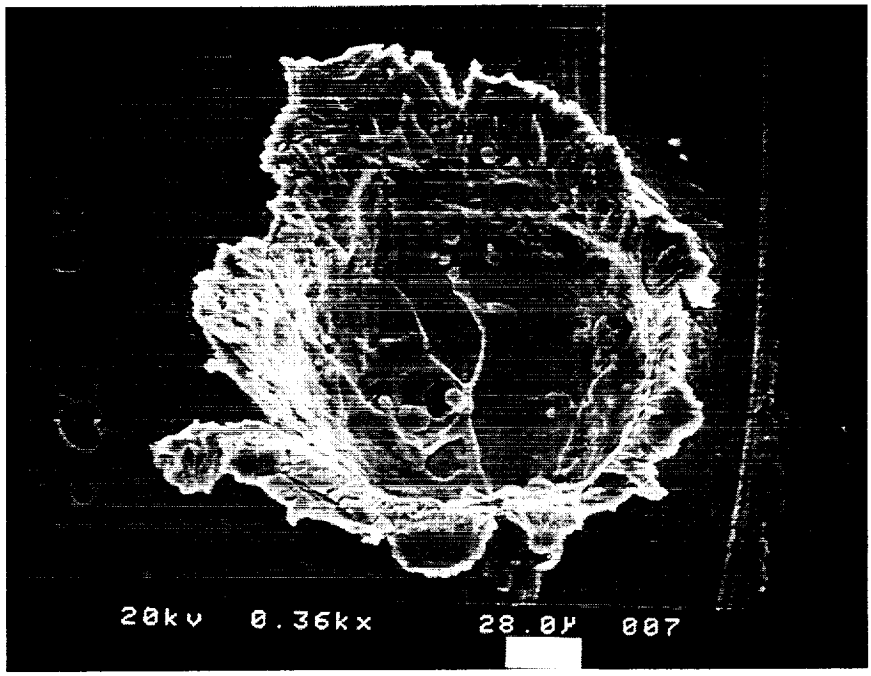

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)
A11-C01 002

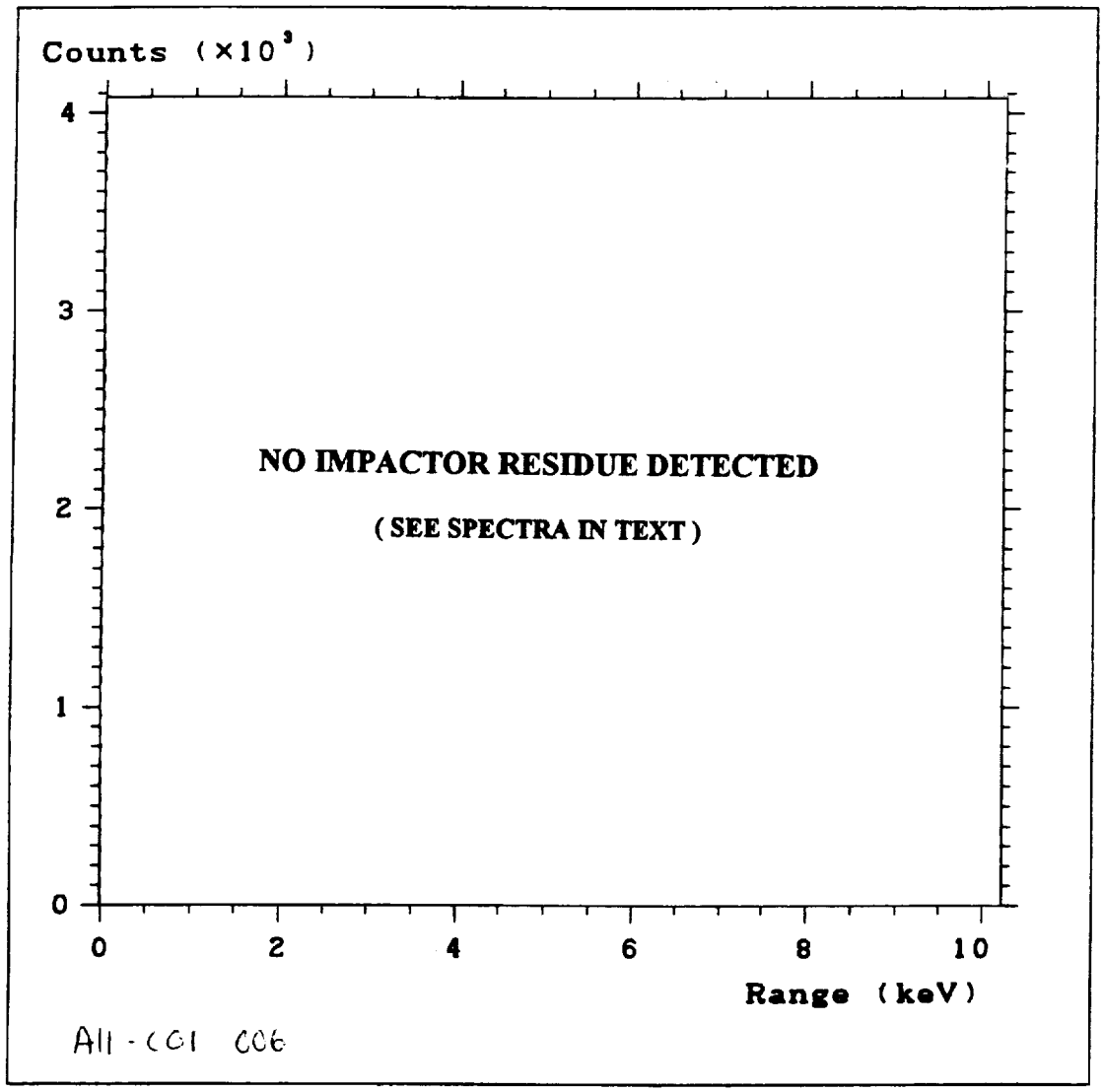

20kv 1.1kx 9.10P 005

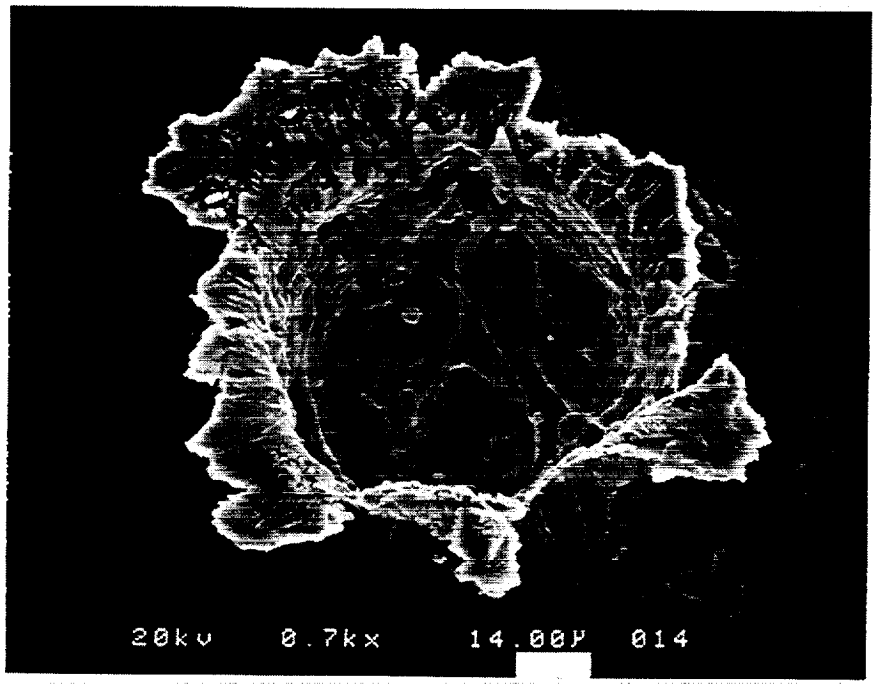

Counts (×10³)
4
3
2
1
0
Mg
Cu
P S
K K
Ca
Ca
Cr
Fe
Mn
Fe
Ni
Cu
Ni
Cu
2
4
6
8
10
Range (keV)
A11-C01 004

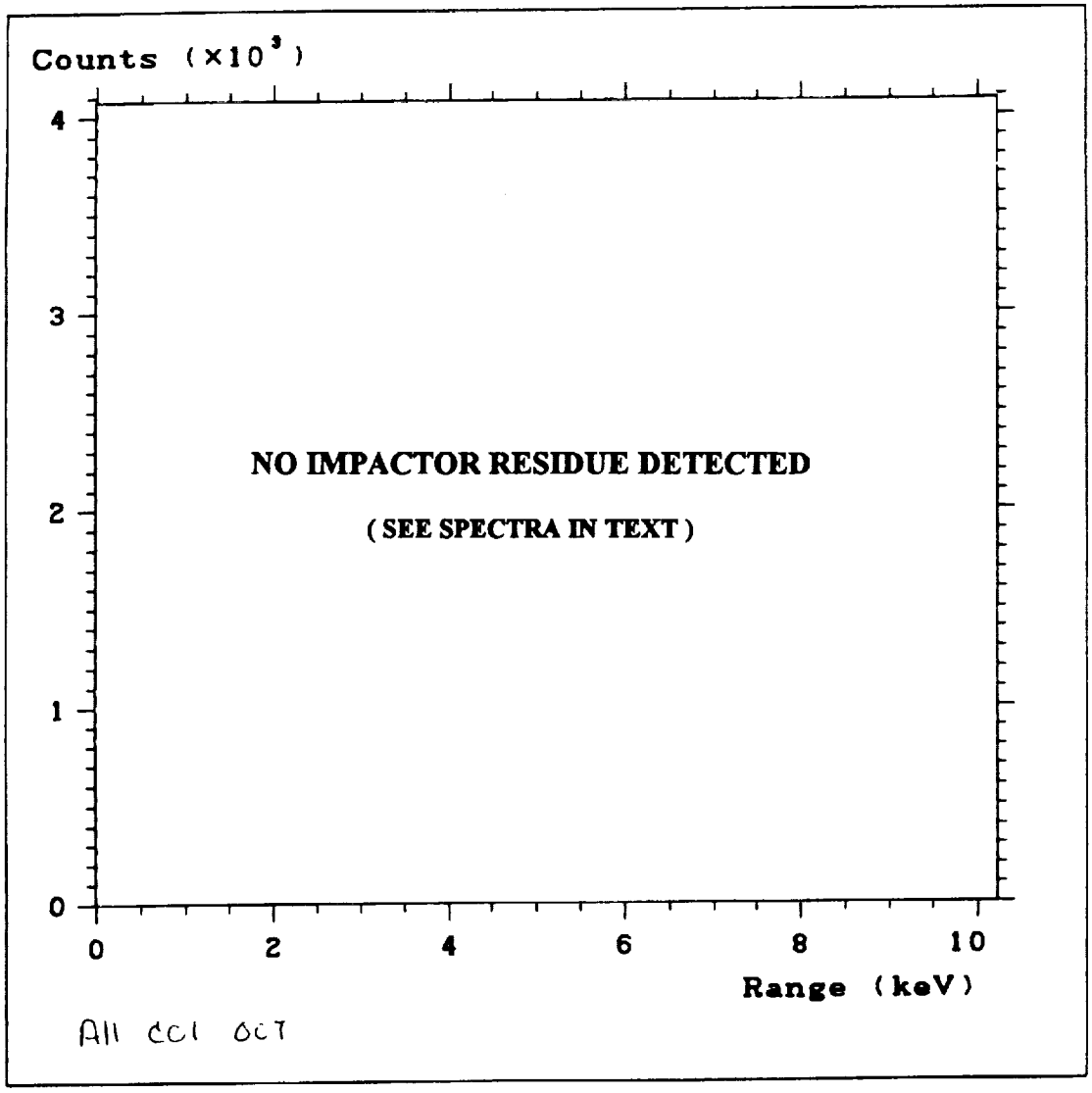

20kv .037kx 270µ 033

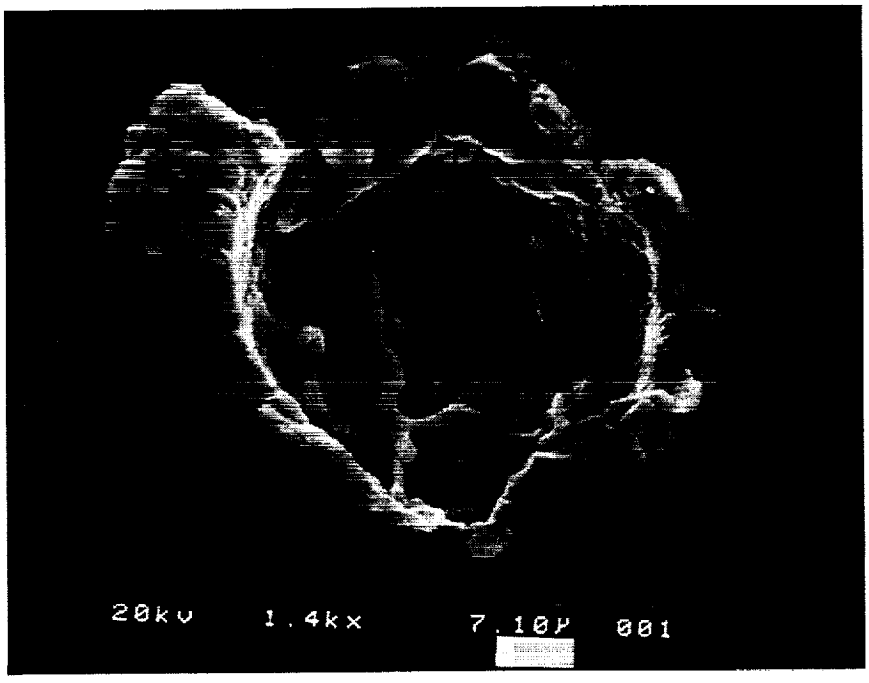

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)
All cc1 cc5

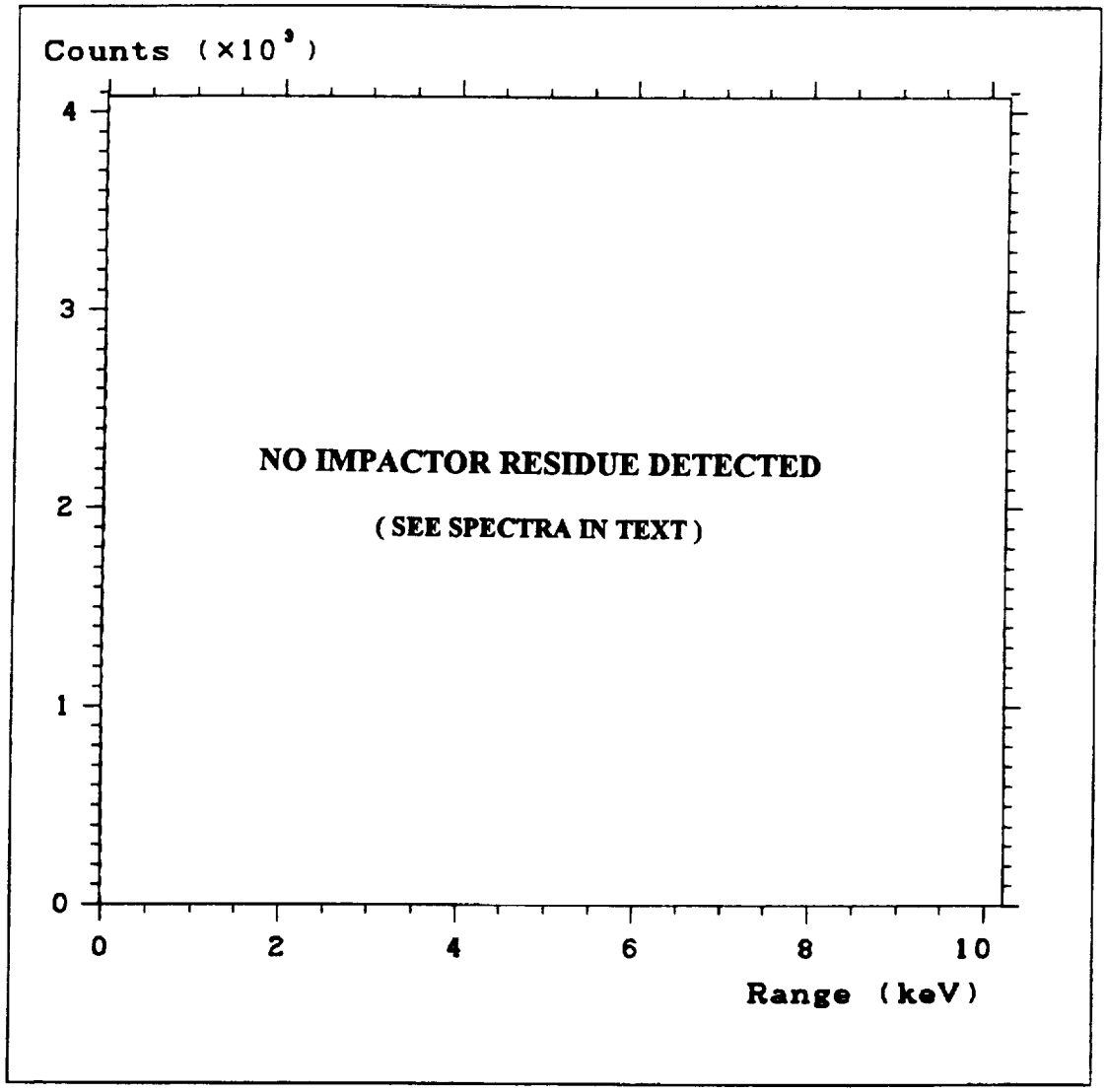

20kv 0.36kx 28.0µ 007

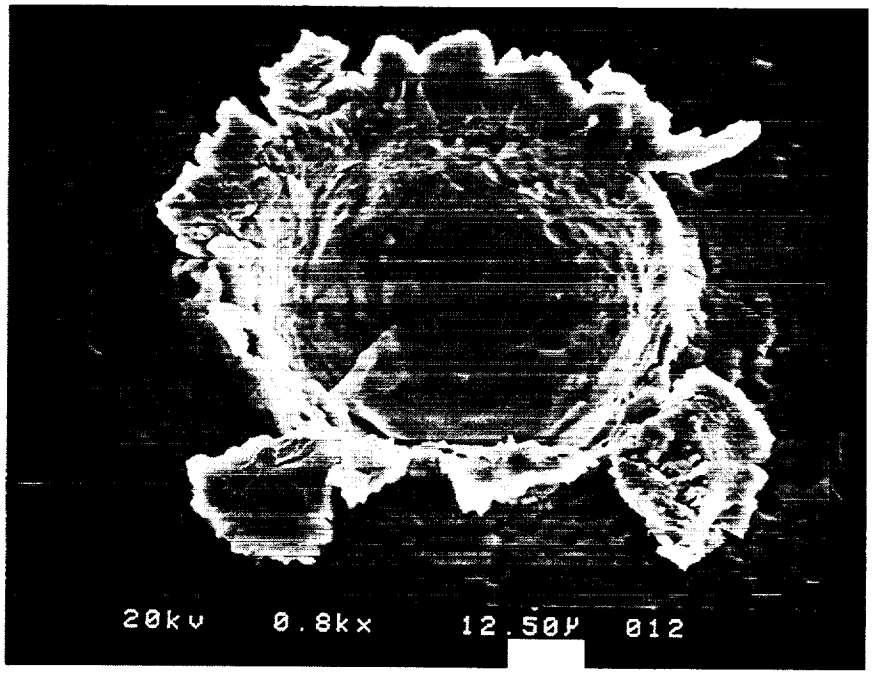

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)
All - CC1 CC6


20kv 0.7kx 14.00µ 014


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)
All CCI OCT

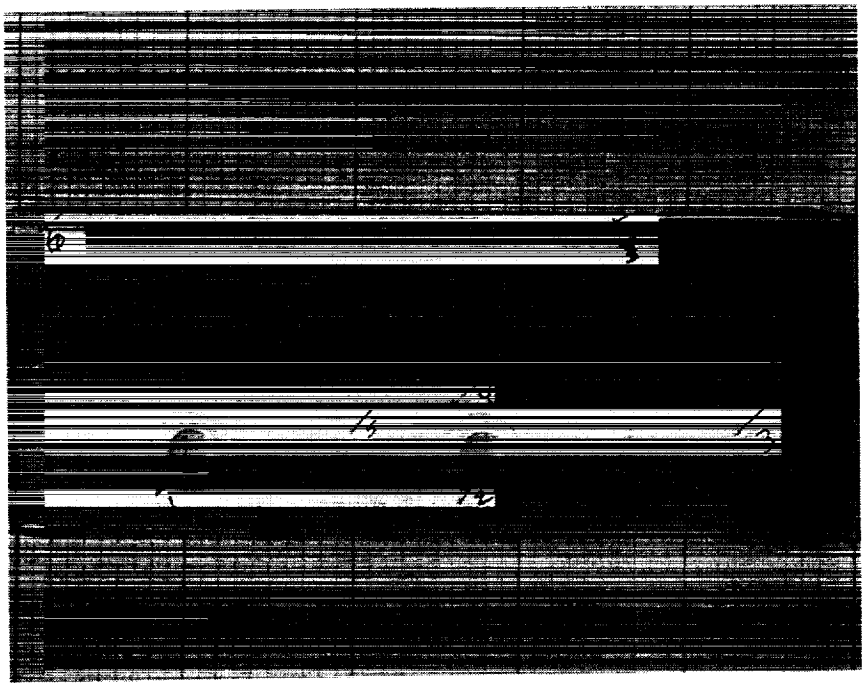

20kv 1.4kx 7.10µ 001

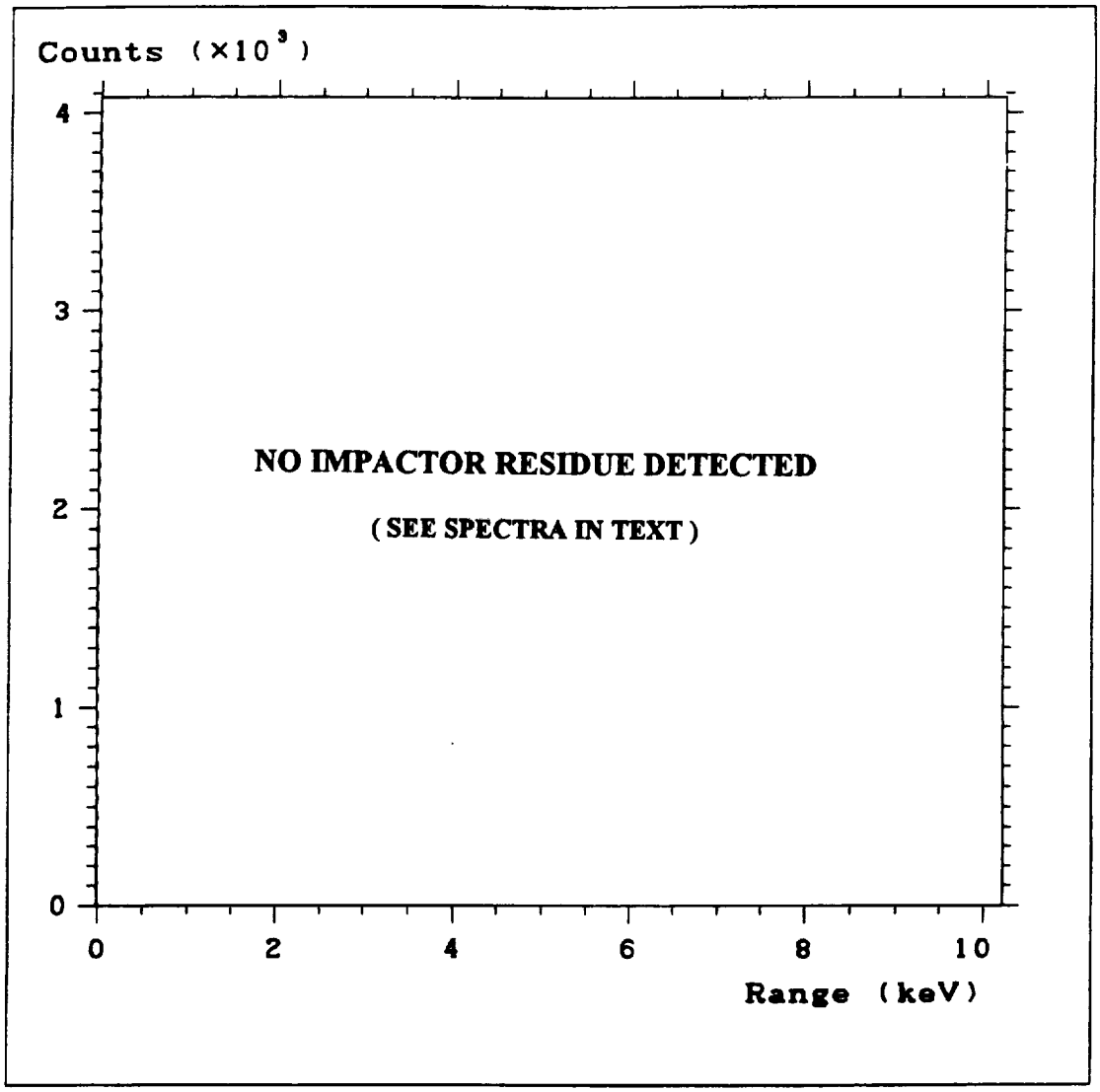

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

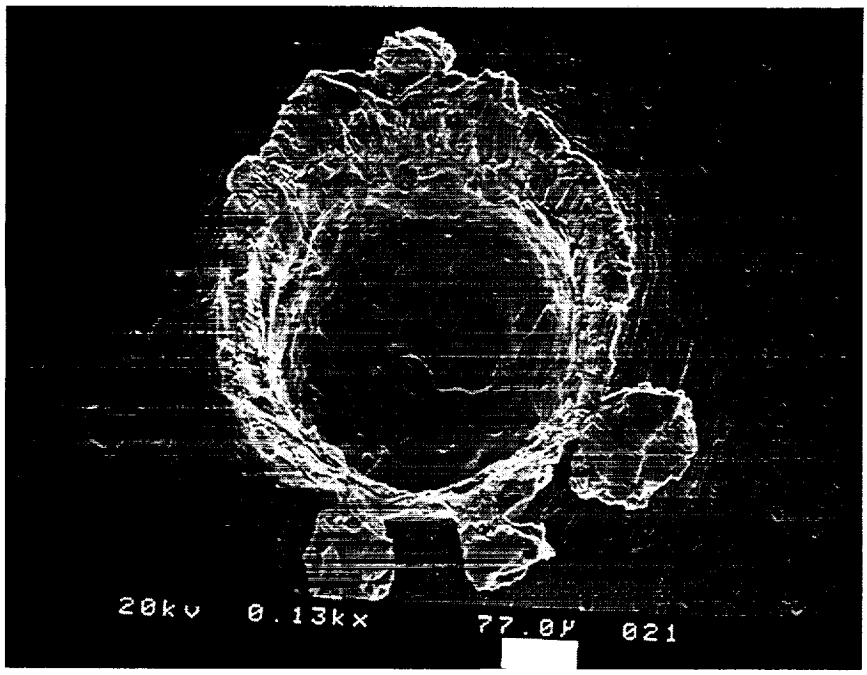

20kv 0.8kx 12.50µ 012

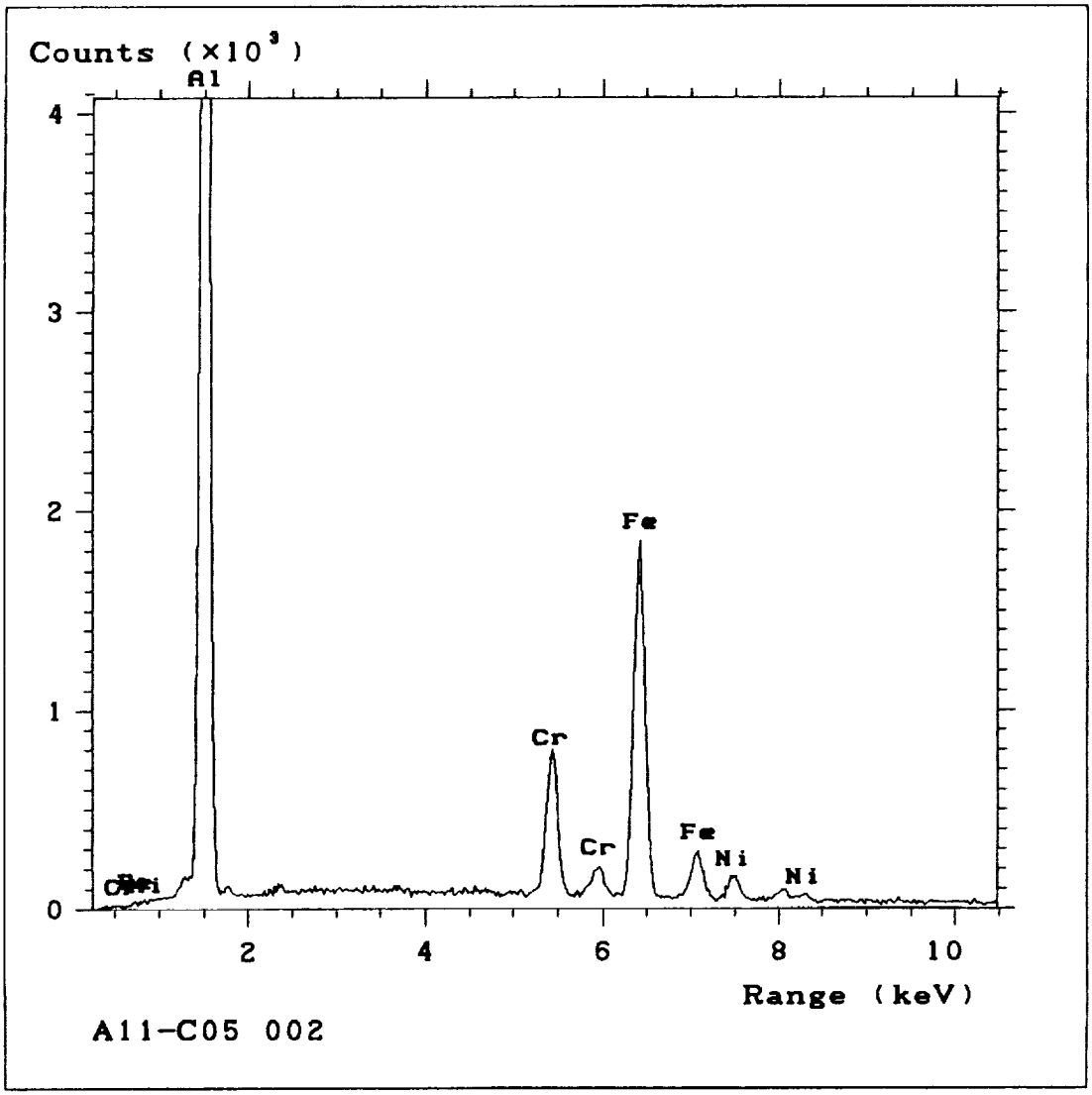
CLAMP NUMBER A11 CO5

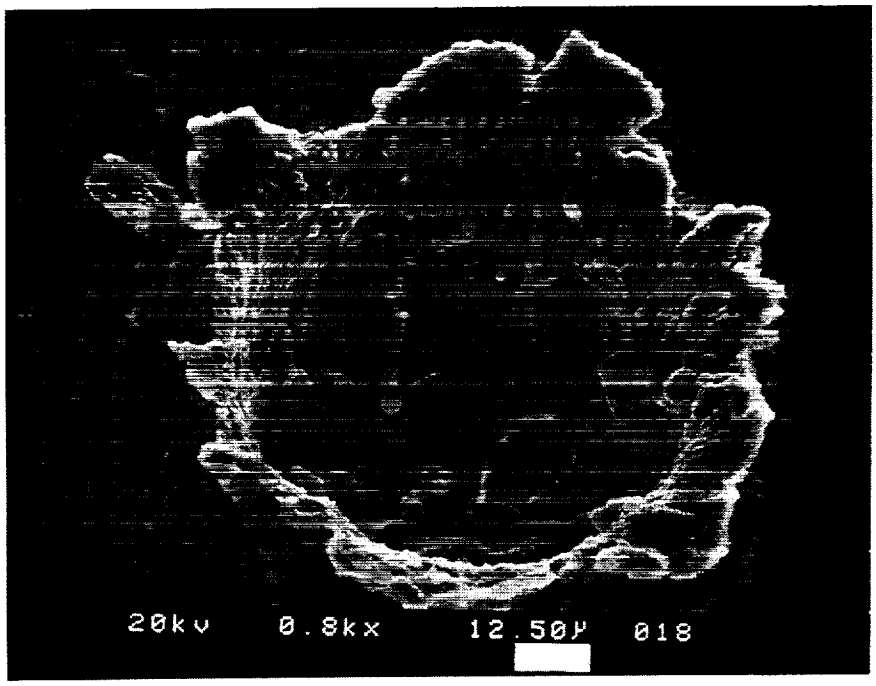
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	400	Unknown
002	120	Fe, Ni, Cr
003	100	Unknown
004	250	Trace
005	150	Unknown
006	120	Mg, Si, Ca, Fe

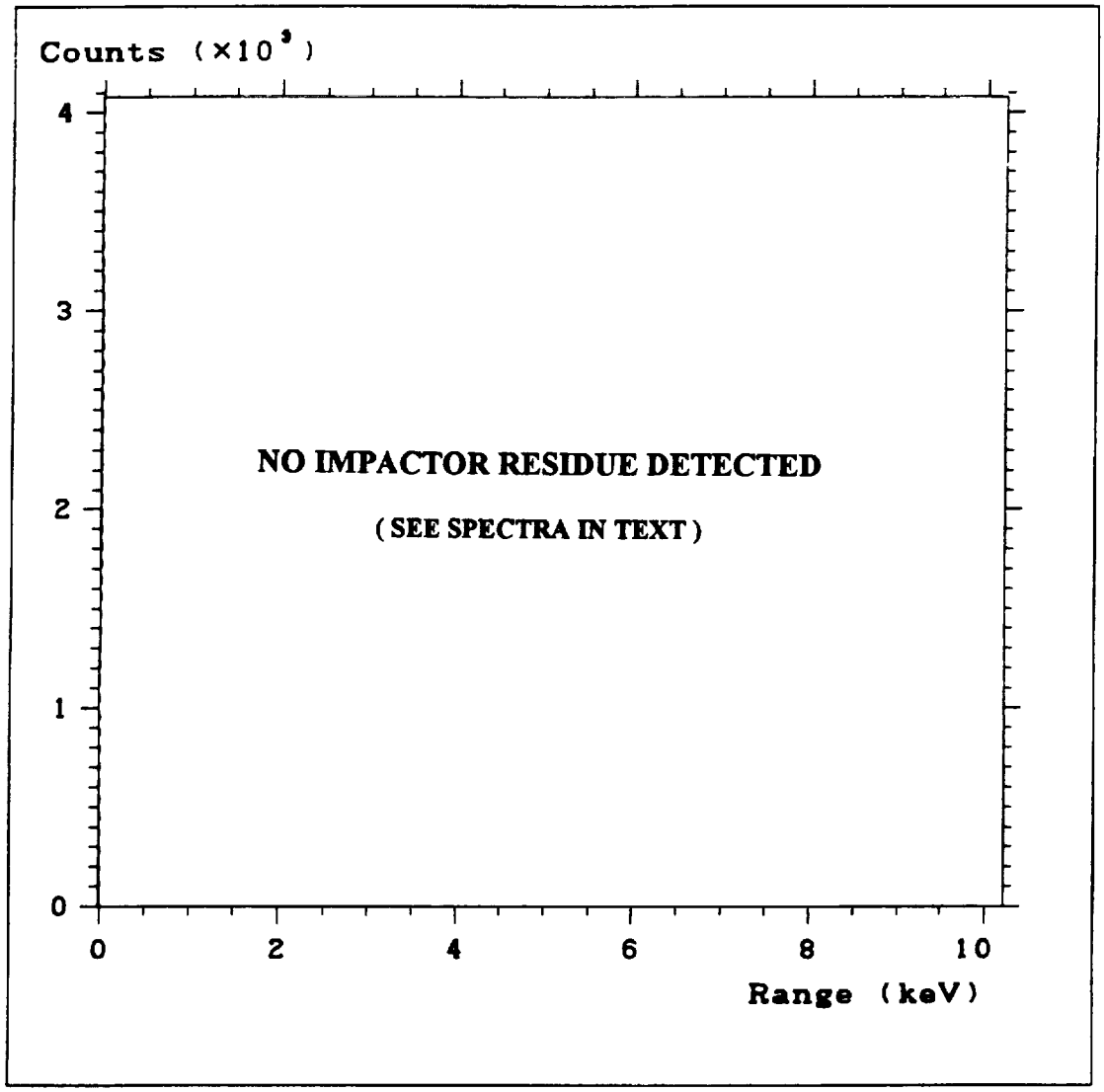


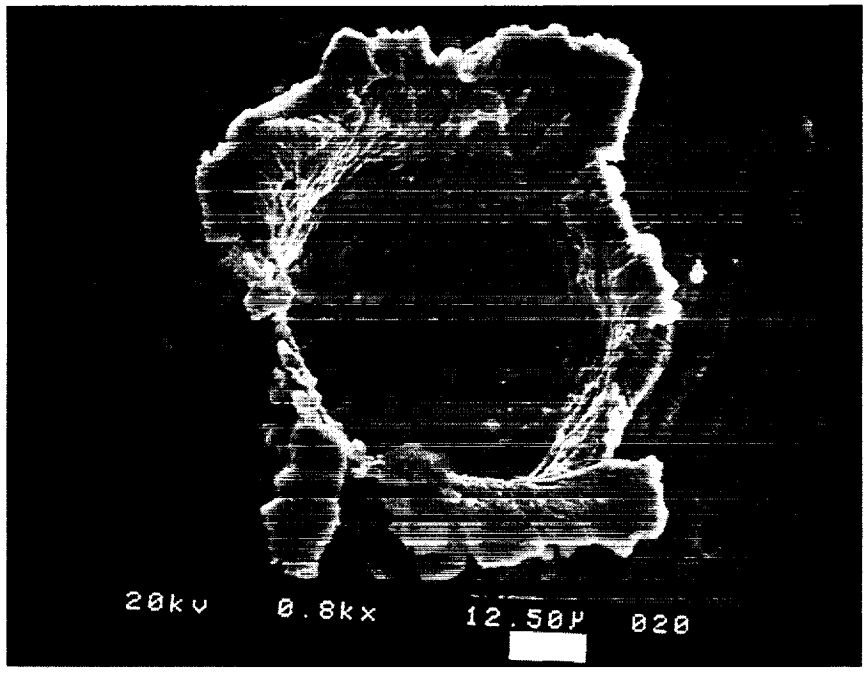

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

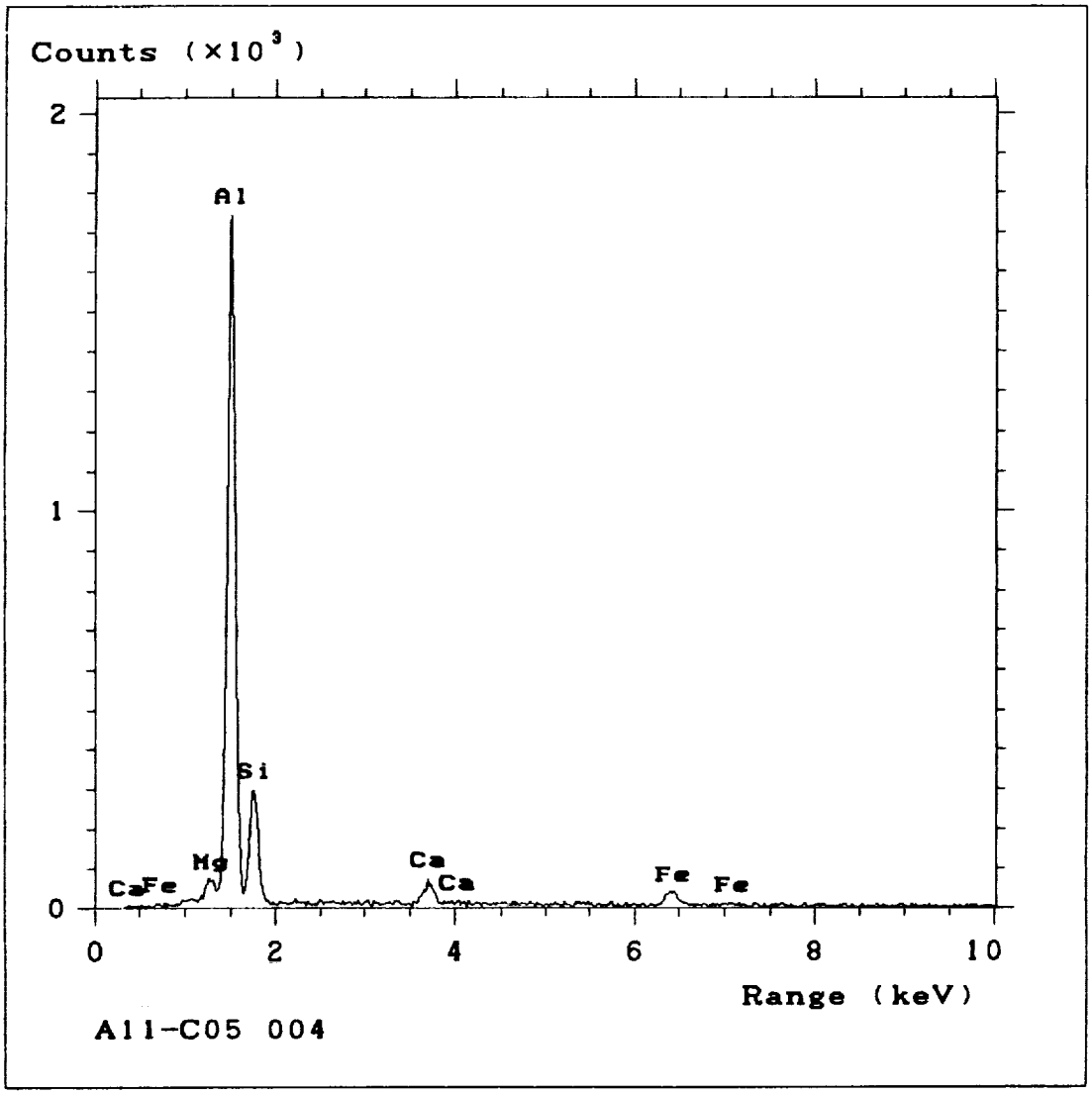

20kv 0.13kx 77.0µ 021

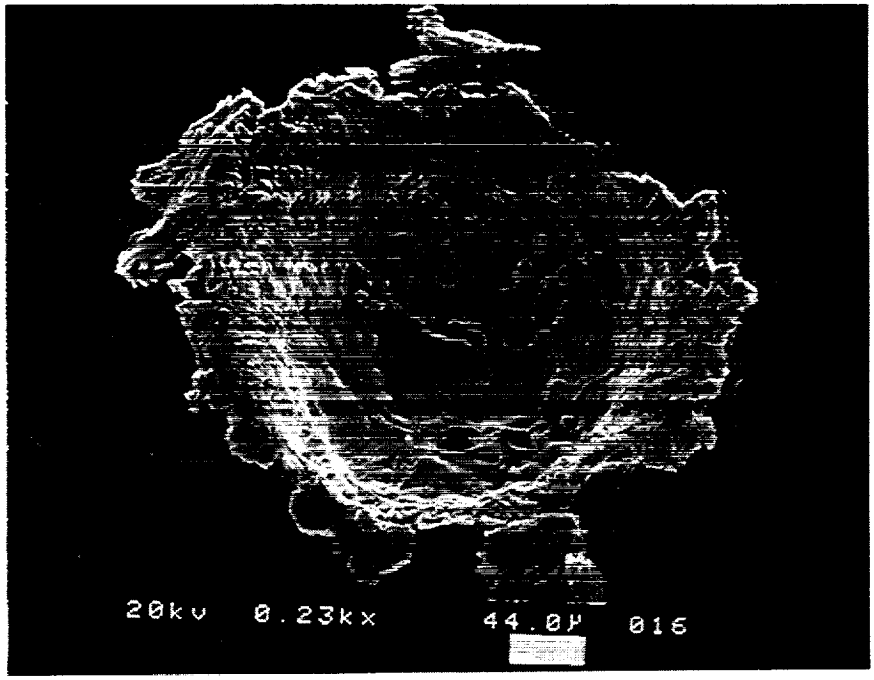

Counts (×10³)
Al
Cr
Cr
Fe
Fe
Ni
Ni
0
1
2
3
4
2
4
6
8
10
Range (keV)
A11-C05 002

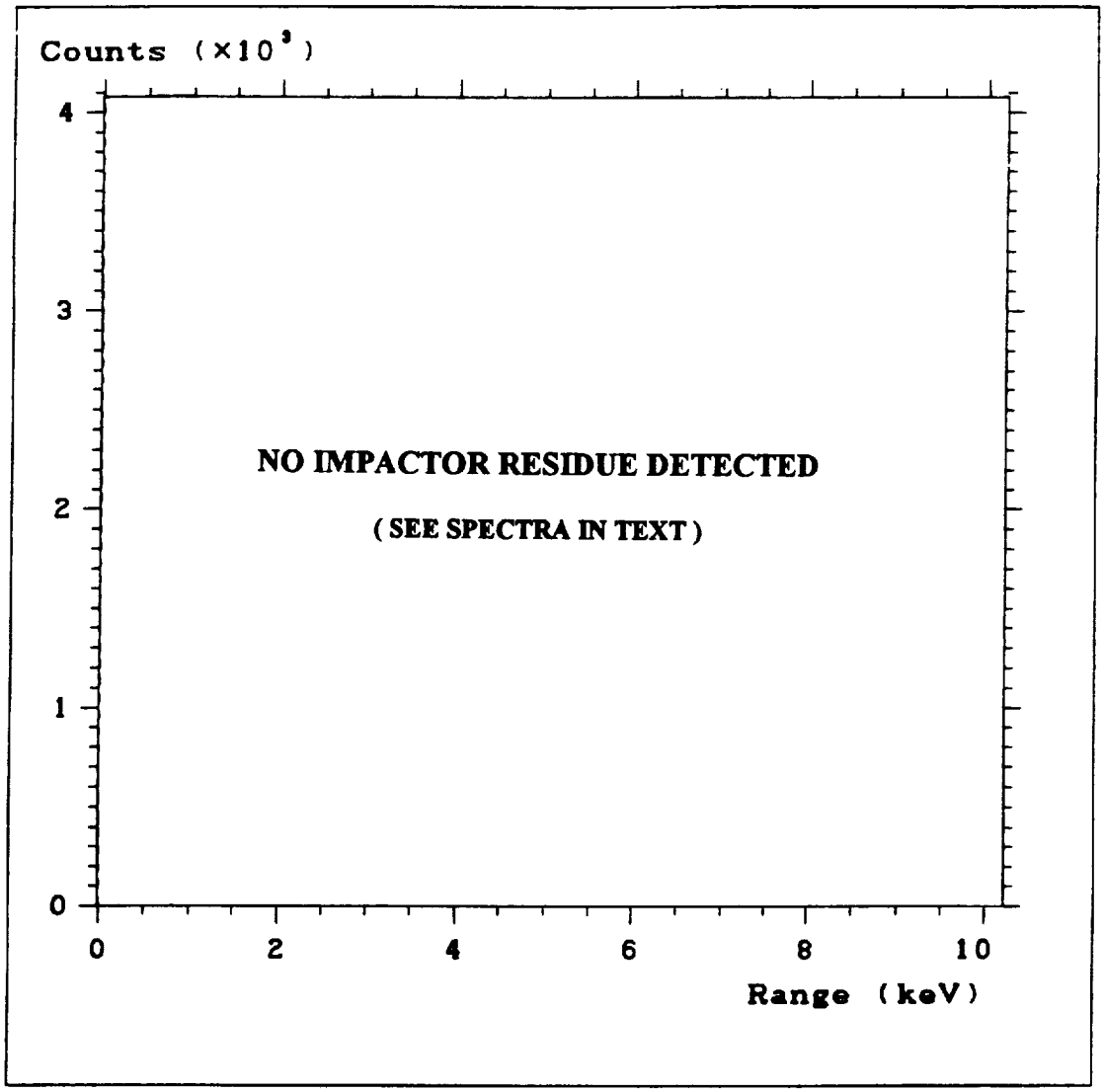

20kv 0.8kx 12.50µ 018

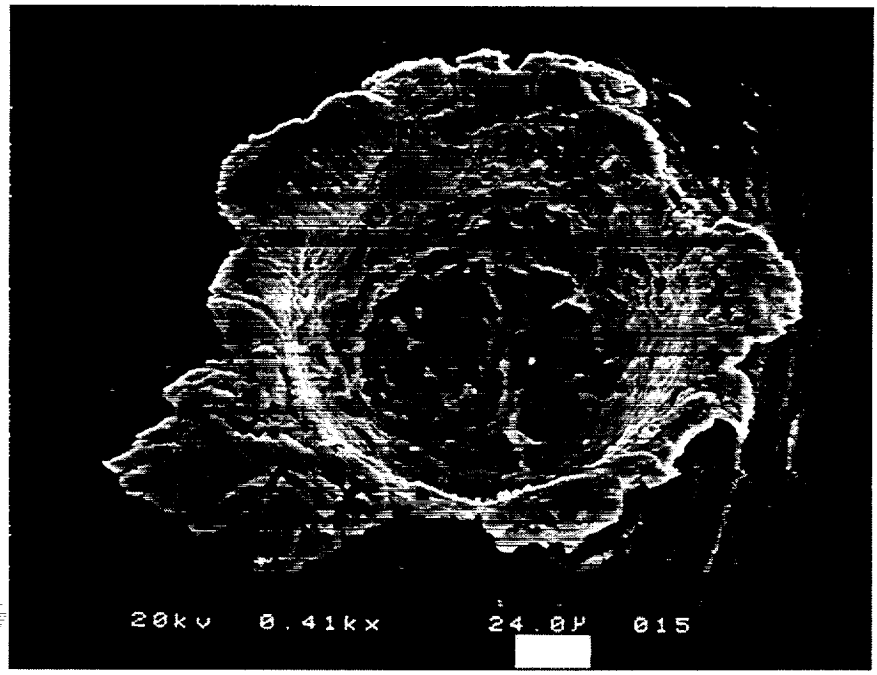

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

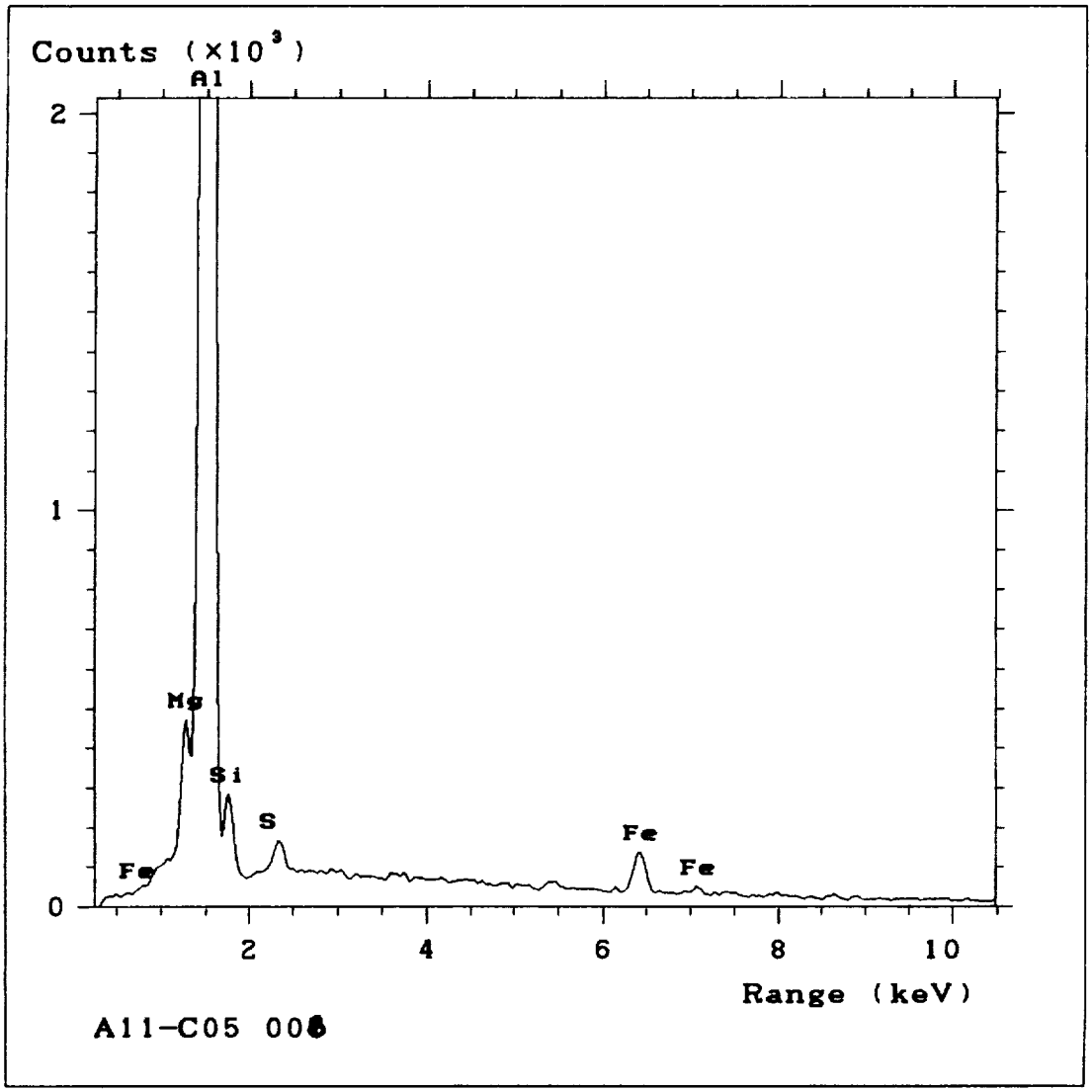

20kv
0.8kx
12.50µ
020

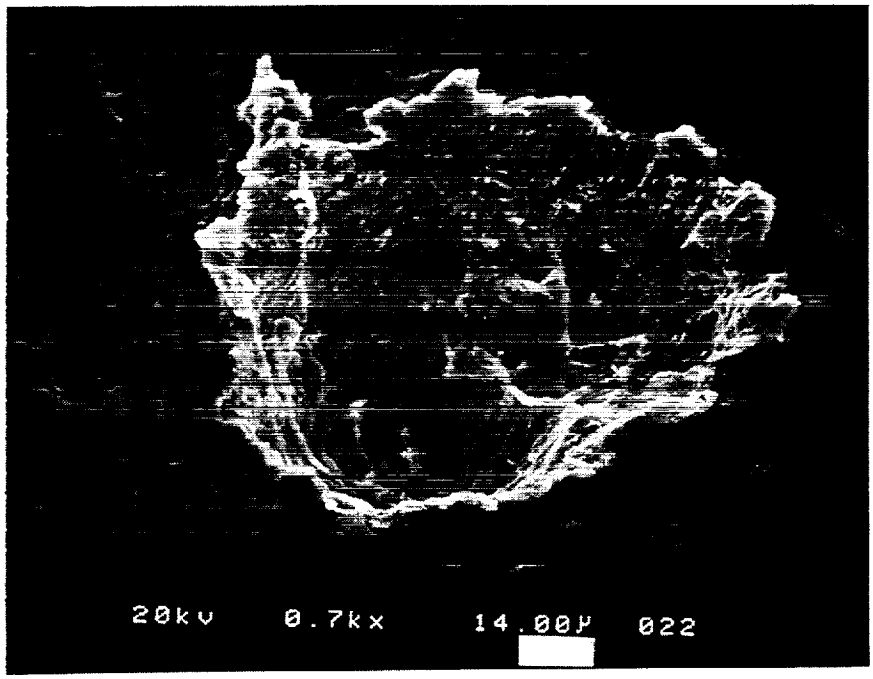

Counts (×10³)
2
1
0
Al
Si
Mg
Ca
Fe
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A11-C05 004


20kv 0.23kx 44.0µ 016


Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

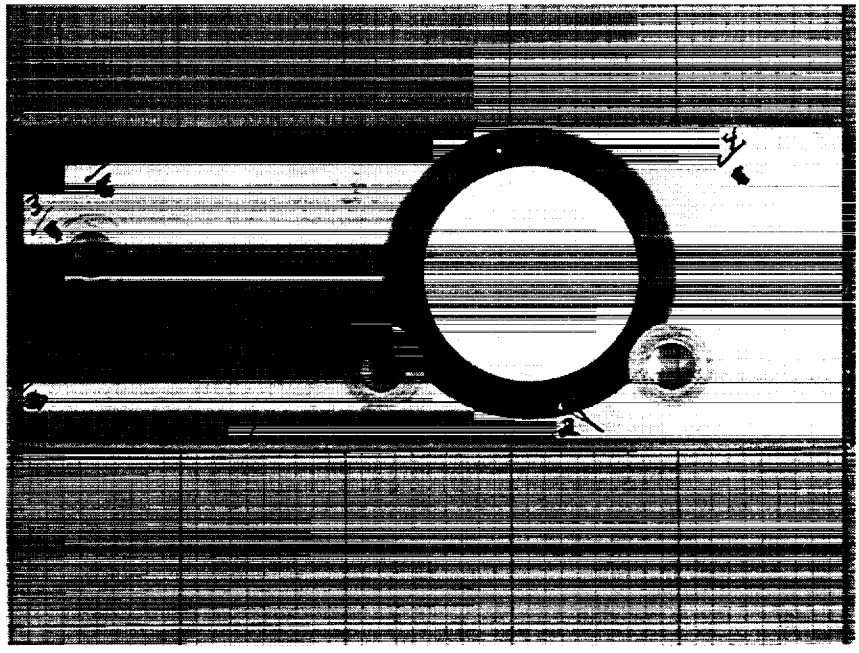

20kv 0.41kx 24.0µ 015

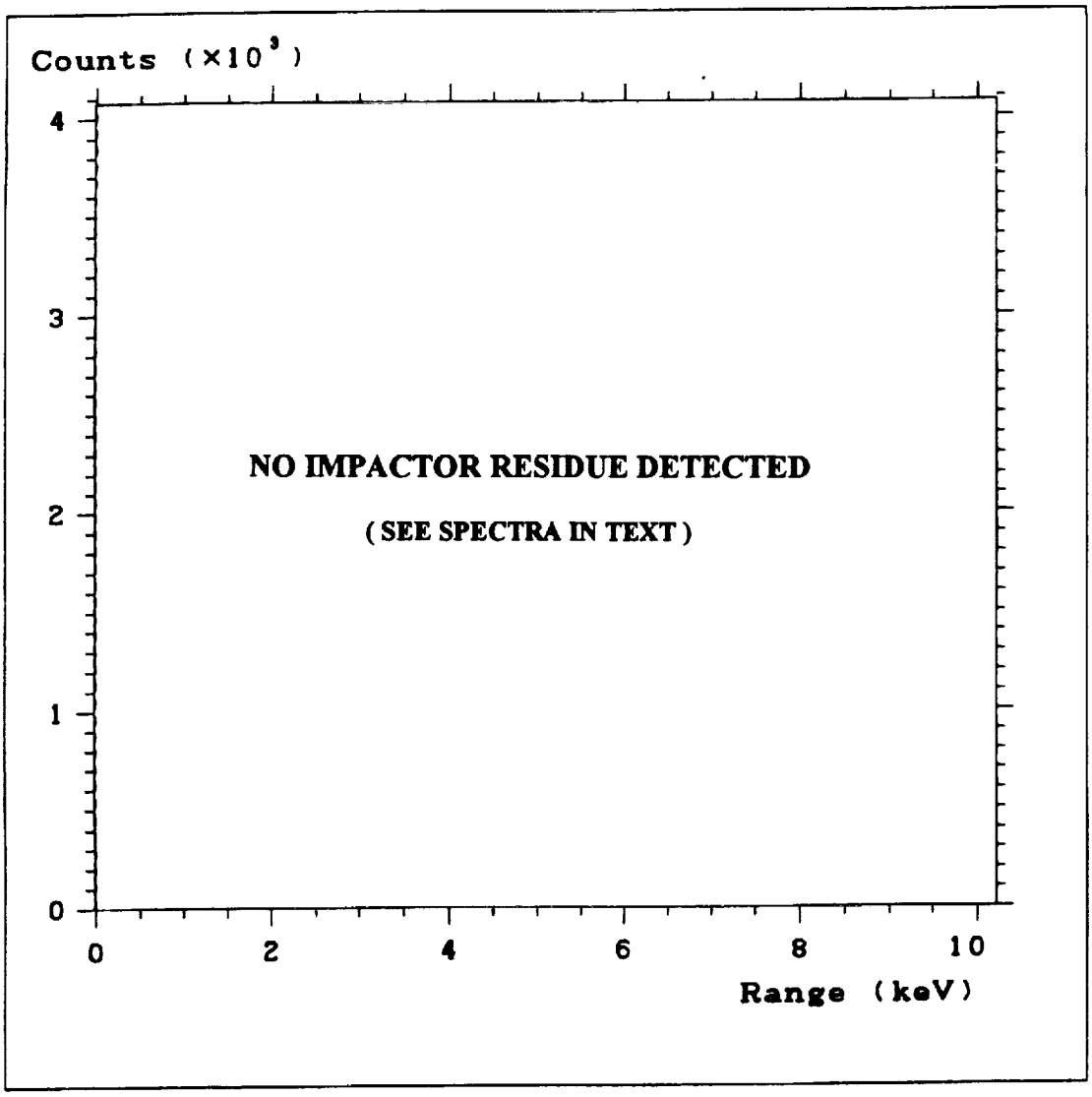

Counts (×10³)
Al
2
1
0
Mg
Si
S
Fe
Fe
Fe
2
4
6
8
10
Range (keV)
A11-C05 008

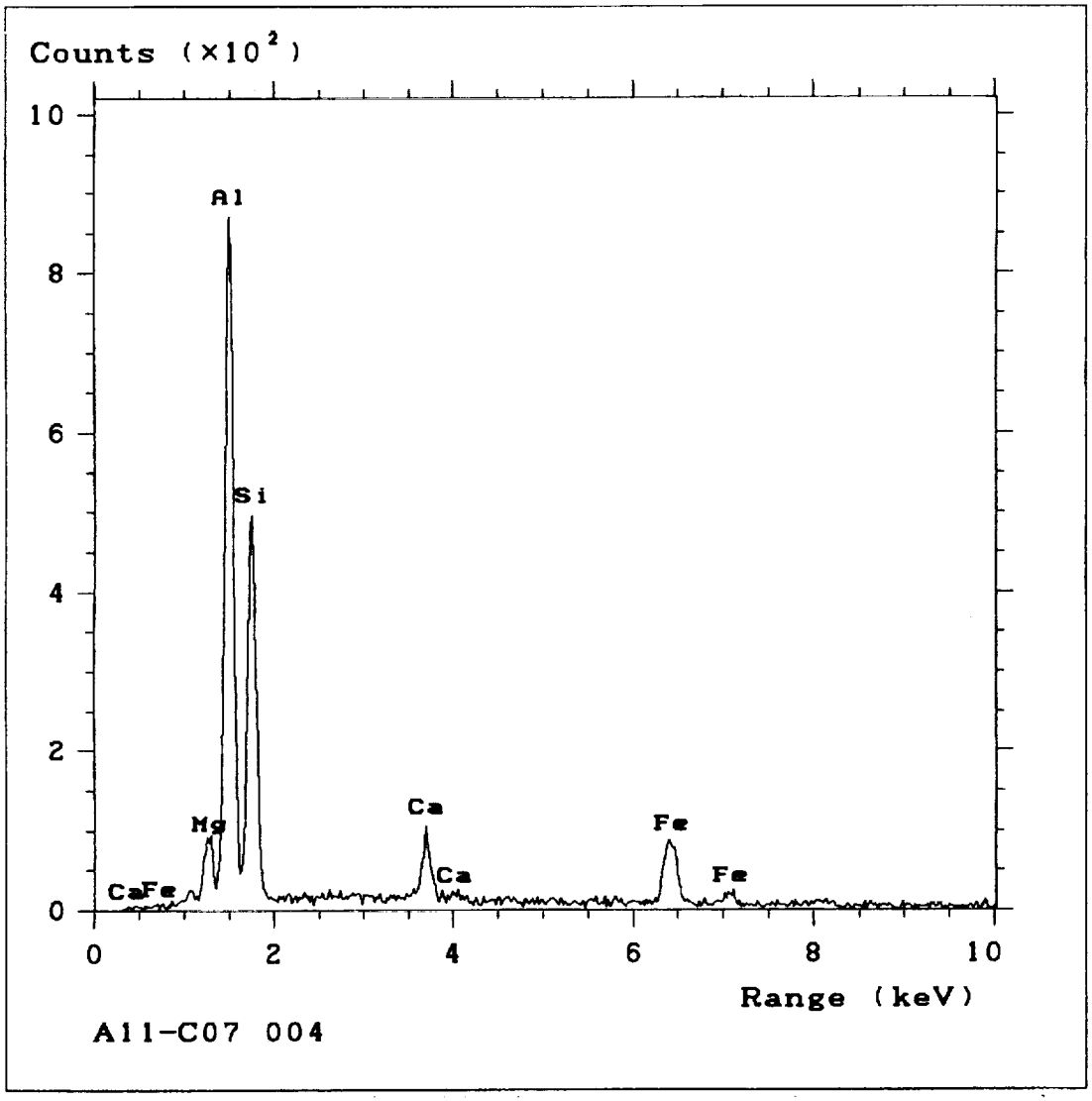

20kv 0.7kx 14.00µ 022

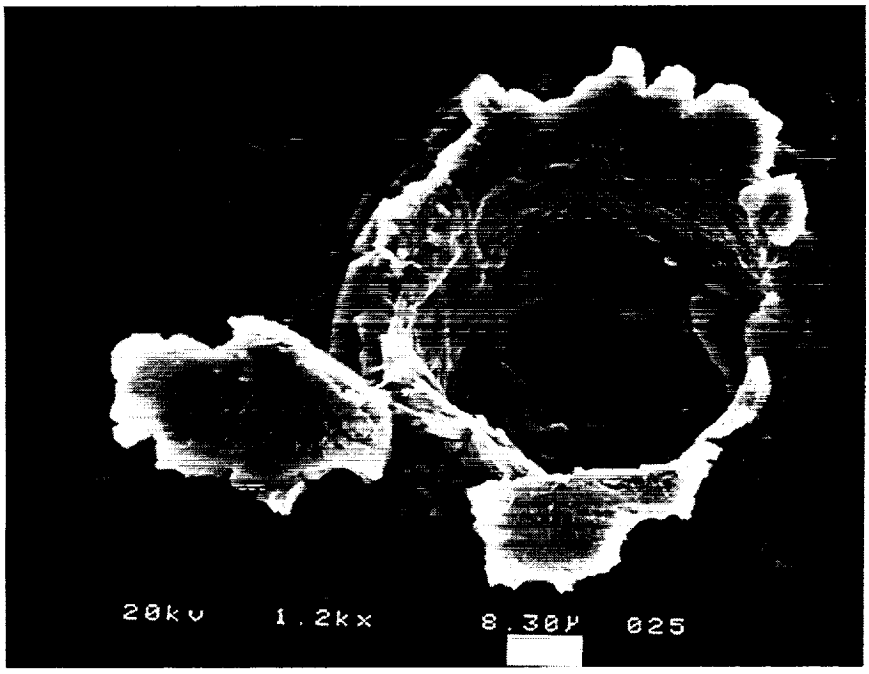
CLAMP NUMBER A11 CO7

IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	550	Paint Patch
002	100	Paint Patch
003	150	Unknown
004	60	Si, Mg, Ca, Fe



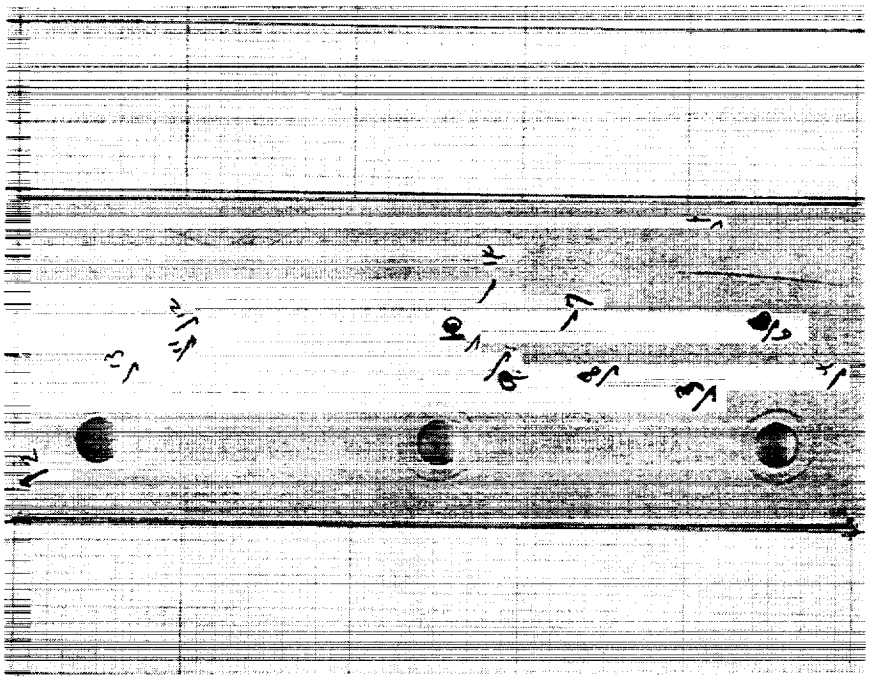

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

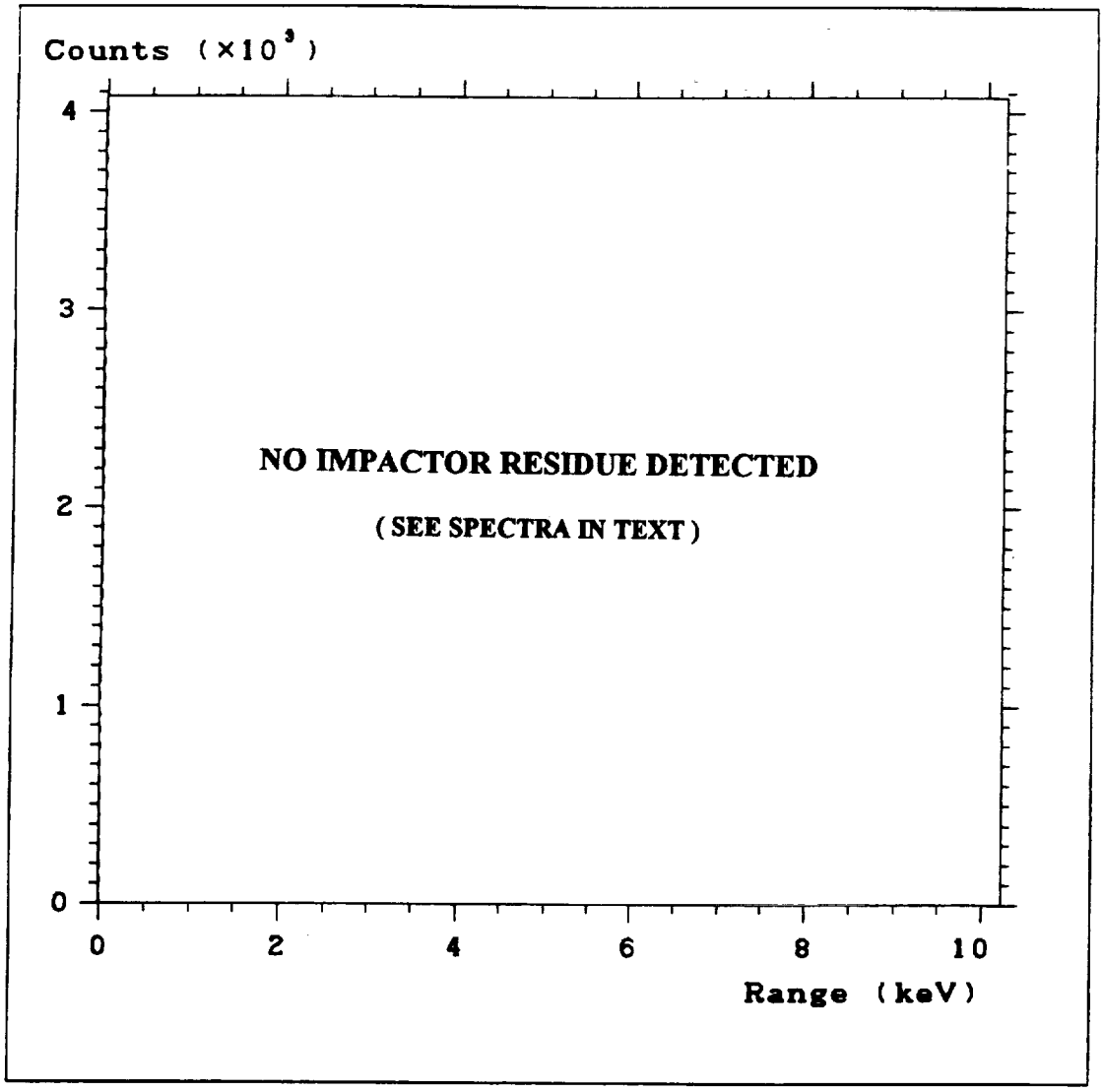

Counts (×10²)
10
8
6
4
2
0
Al
Si
Mg
Ca
Ca
Fe
Fe
Ca Fe
0
2
4
6
8
10
Range (keV)
A11-C07 004

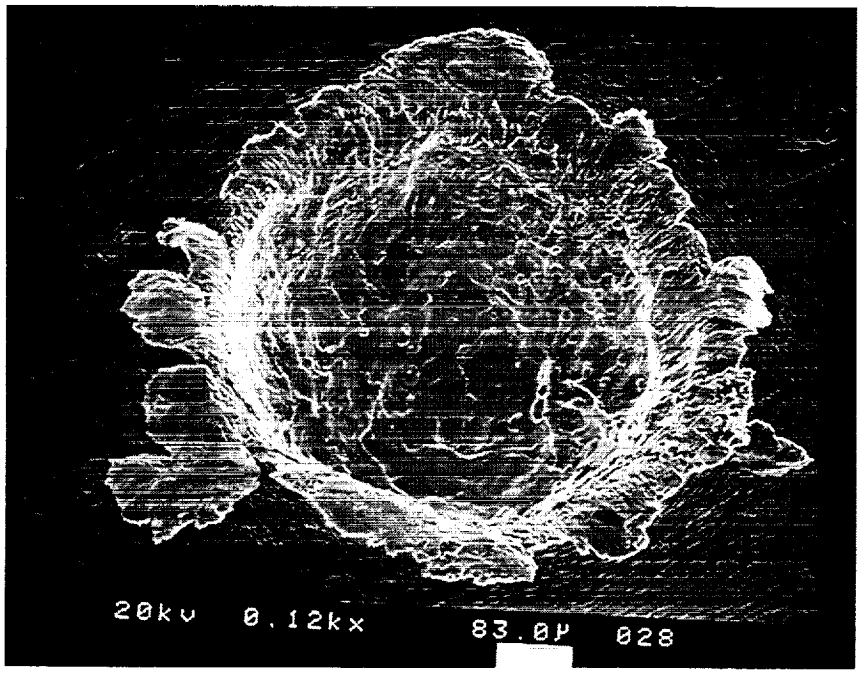

20kv 1.2kx 8.30μ 025

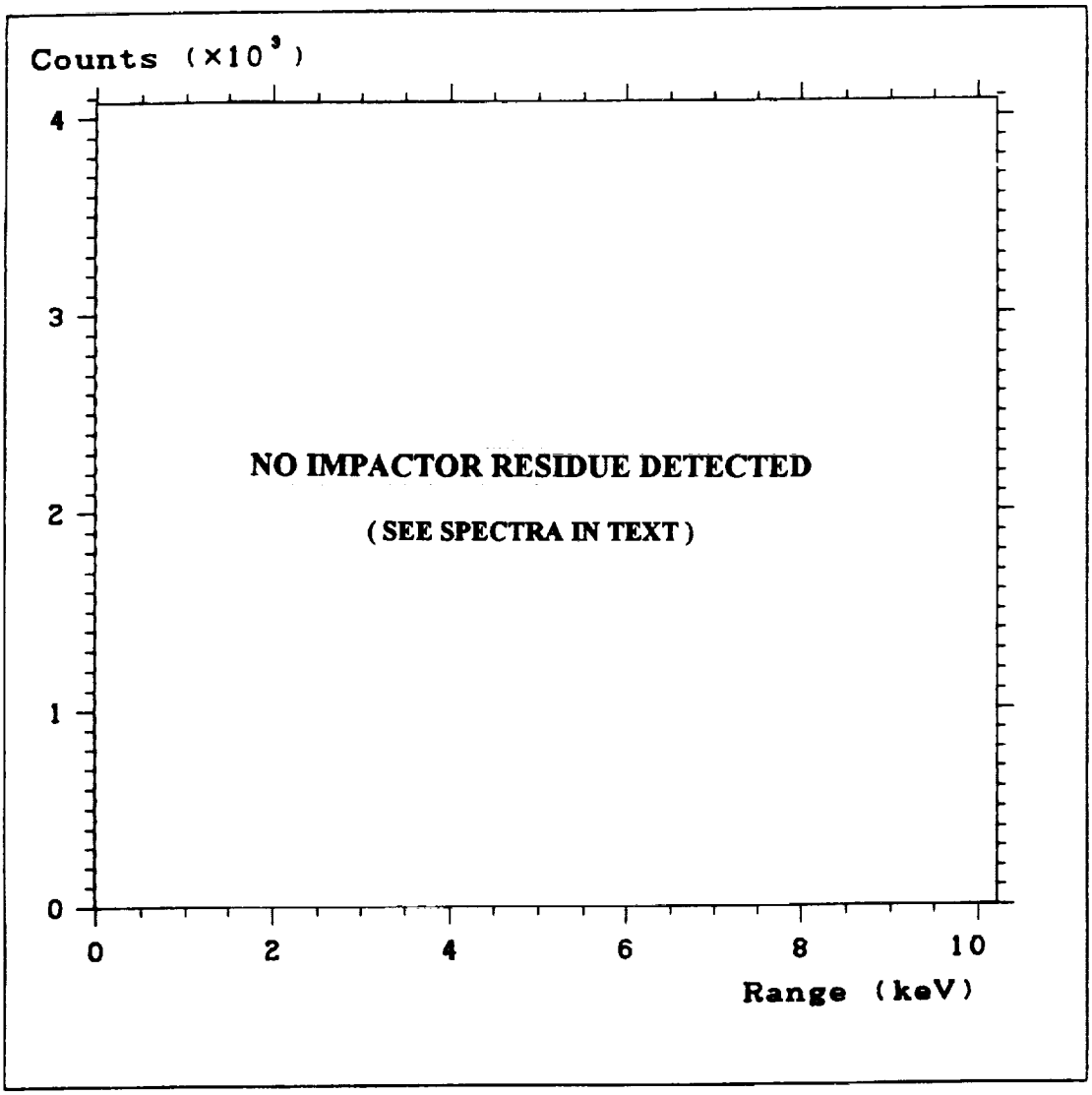
CLAMP NUMBER A11 CO8

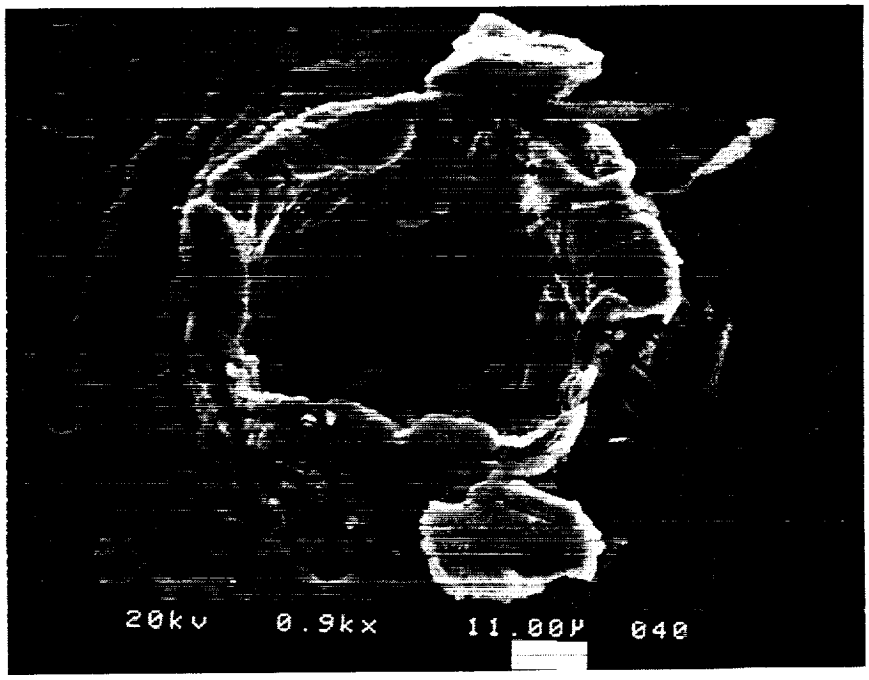
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	600	Unknown
002	60	Unknown
003	200	Unknown
004	500	Unknown
005	N/A	Clamp Flaw
006	40	Ti, Cl, Si, Zn
007	400	Si, Mg, Fe
008	300	Unknown
009	300	Unknown
010	100	Trace
011	60	Zn, Ti, Cl, Si, S
012	200	Unknown
013	80	Unknown
014	140	Trace

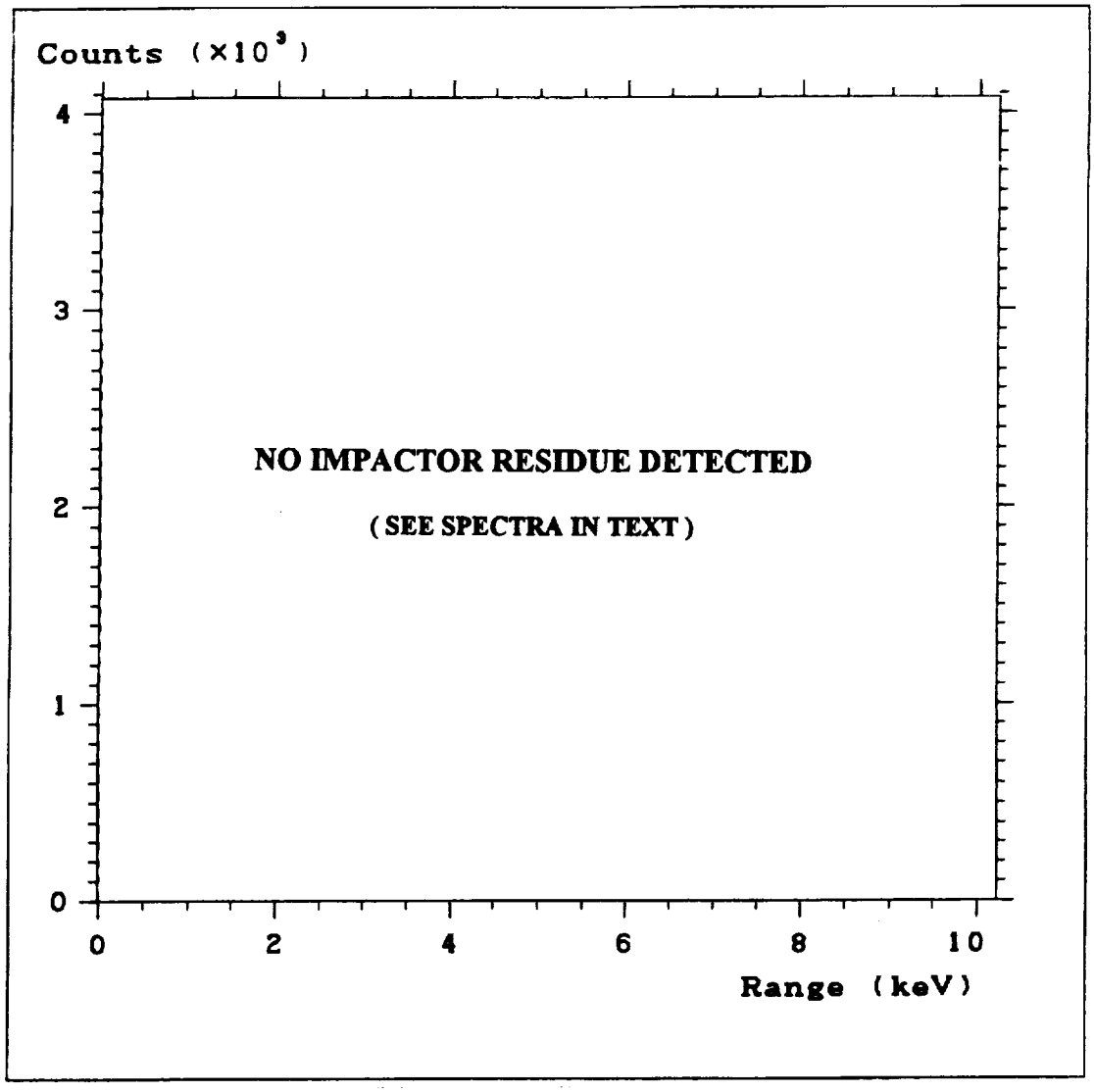


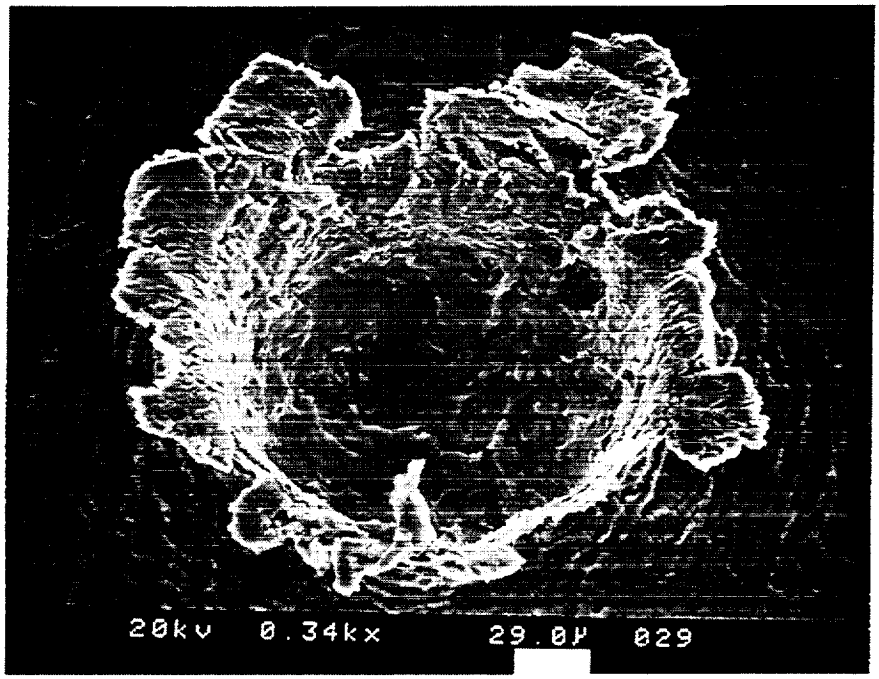

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

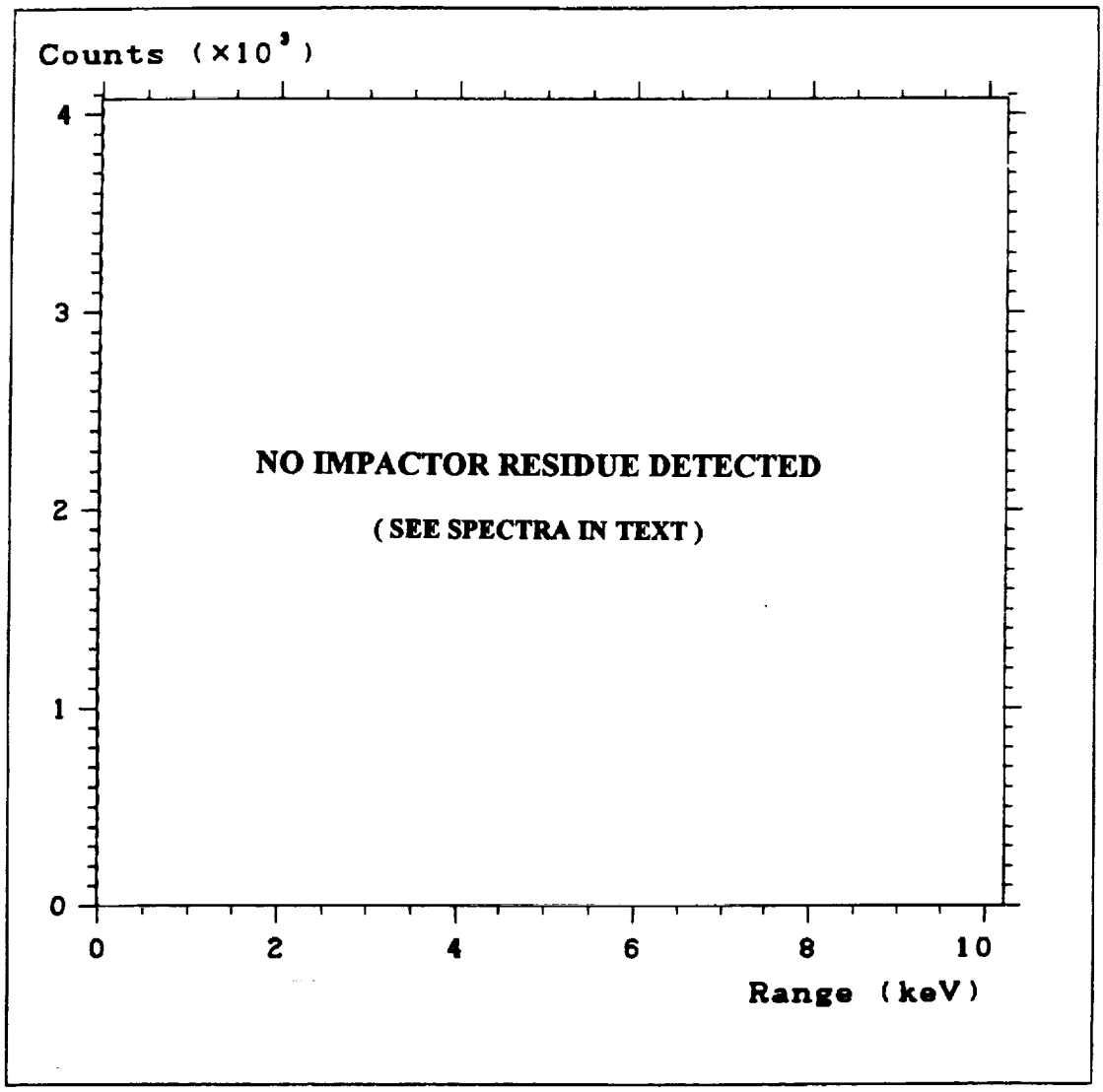

20kv 0.12kx 83.0µ 028

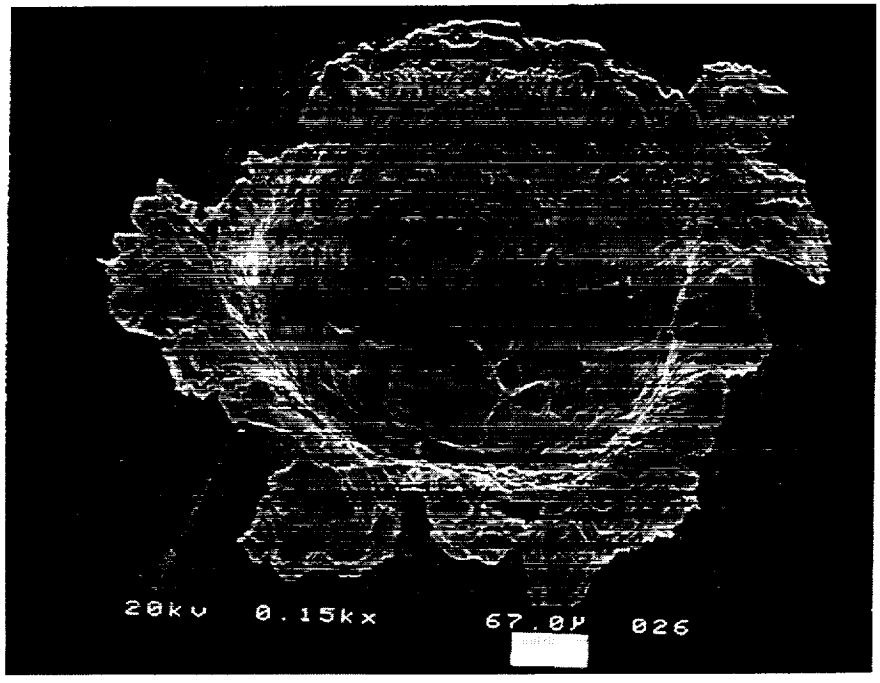

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

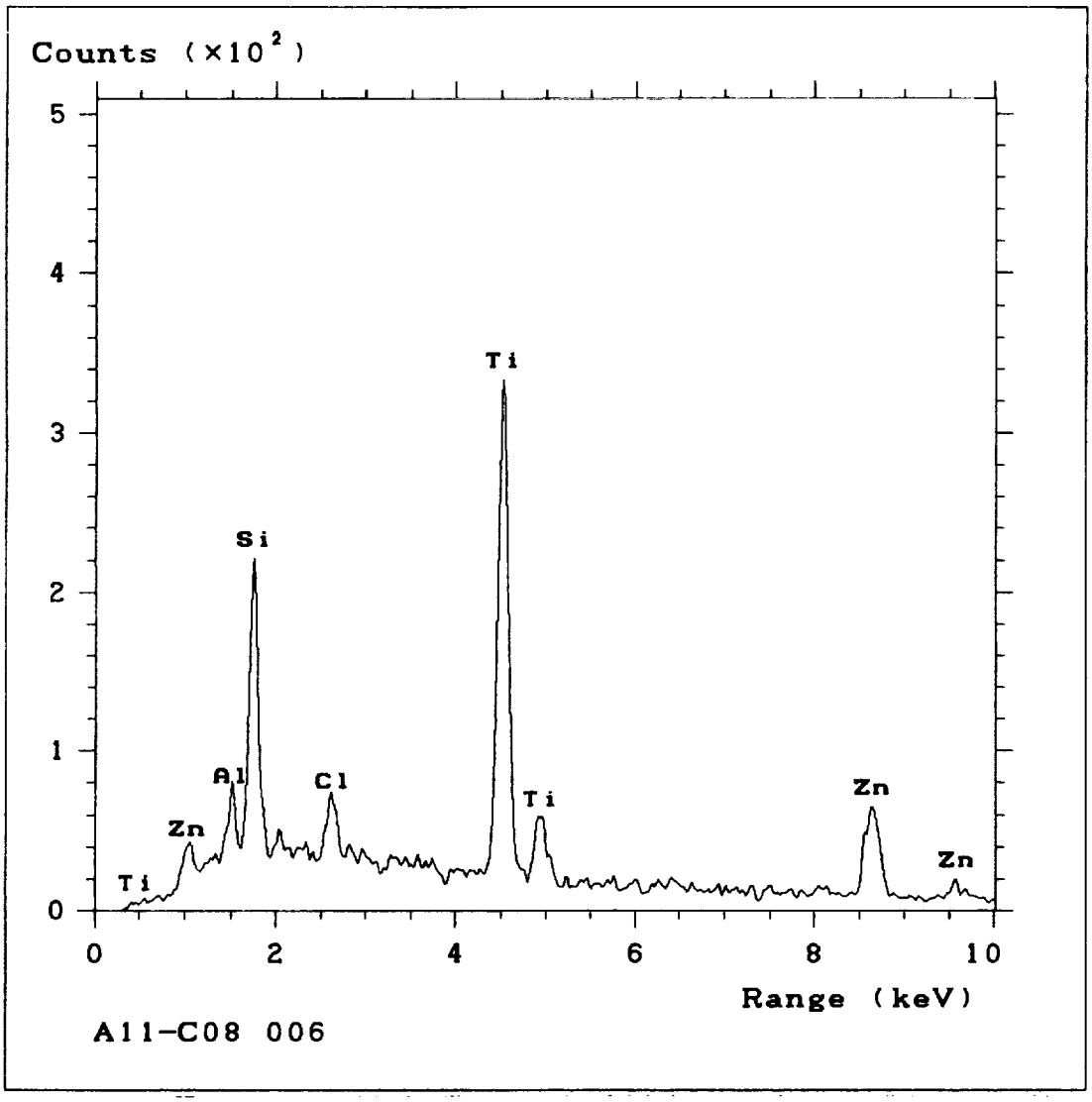

20kv 0.9kx 11.00µ 040

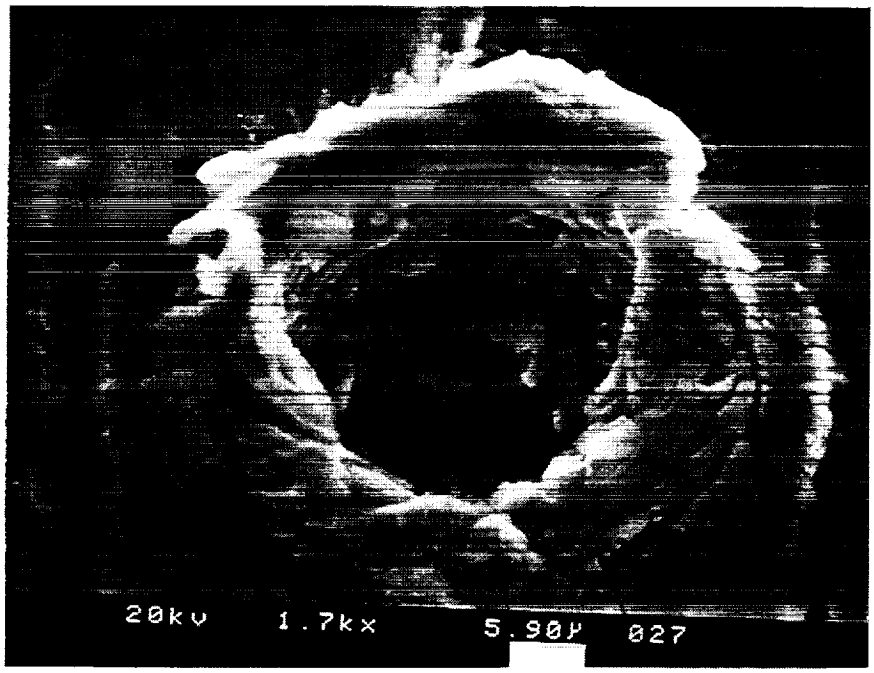

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

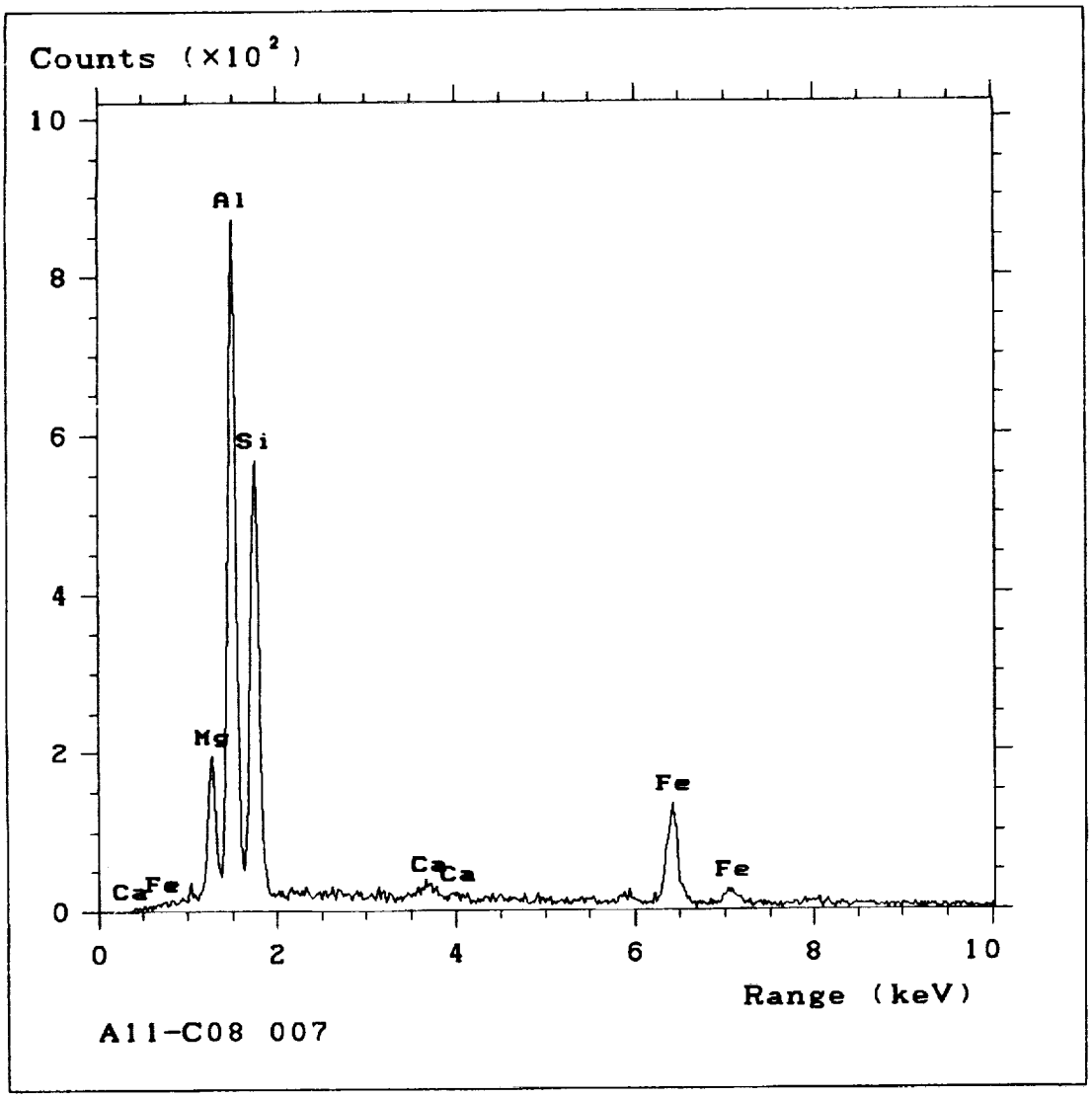

20kv 0.34kx 29.0µ 029

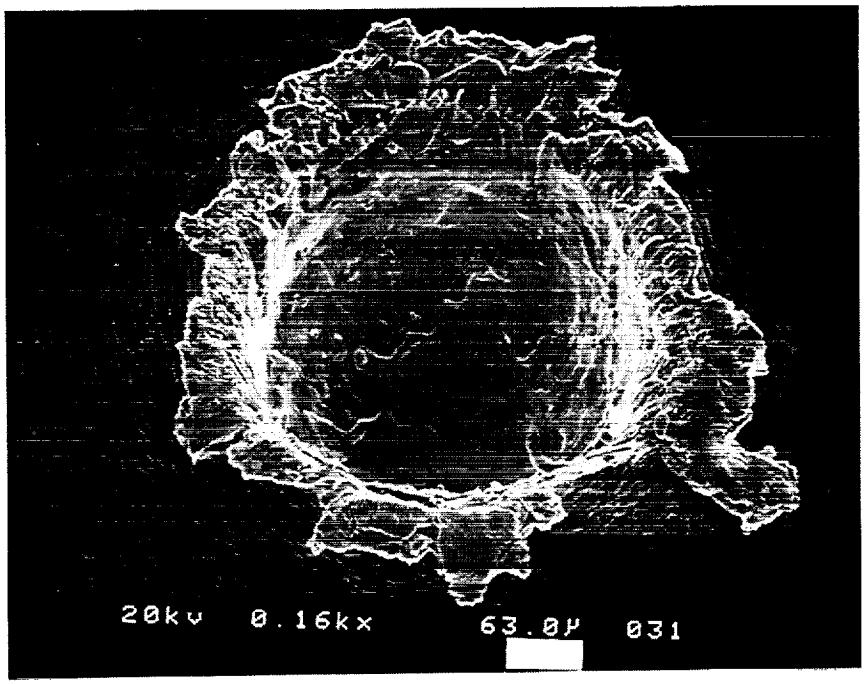

Counts (×10³)
4
3
2
1
0
0
2
4
6
8
10
Range (keV)
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)

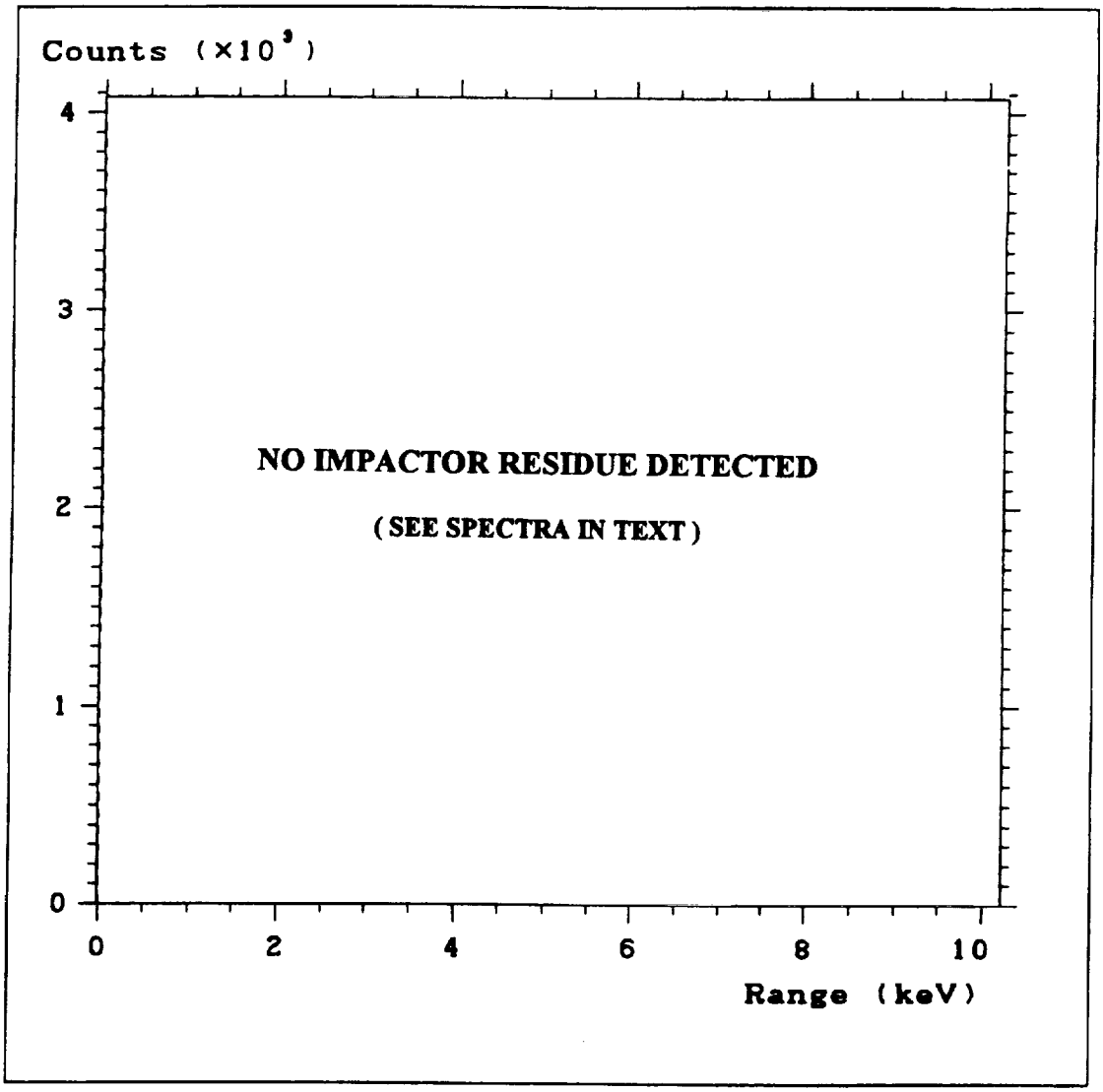

20kV 0.15kx 67.0µ 026

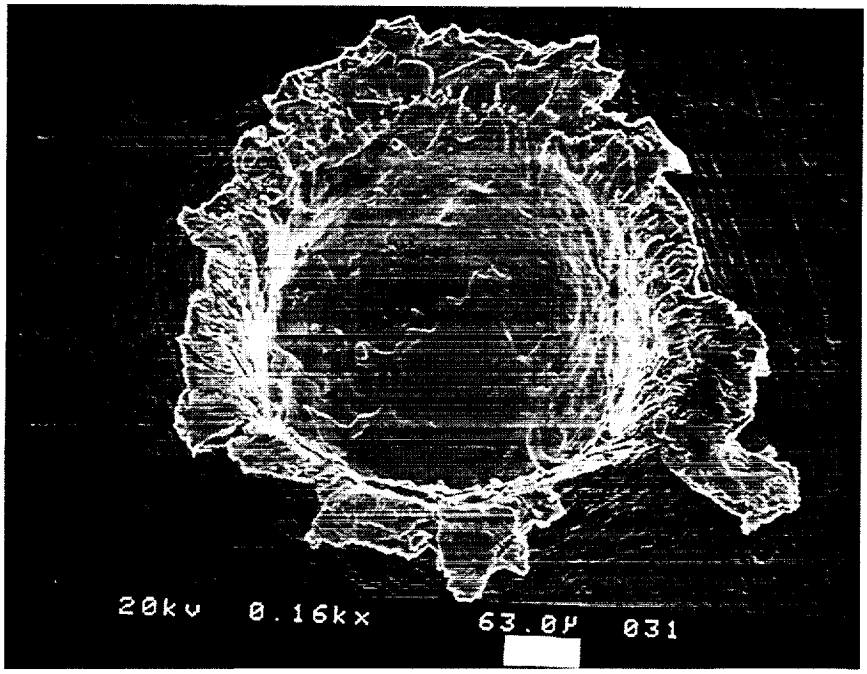

Counts (×10²)
5
4
3
2
1
0
Ti
Zn
Al
Si
Cl
Ti
Ti
Zn
Zn
0
2
4
6
8
10
Range (keV)
A11-C08 006

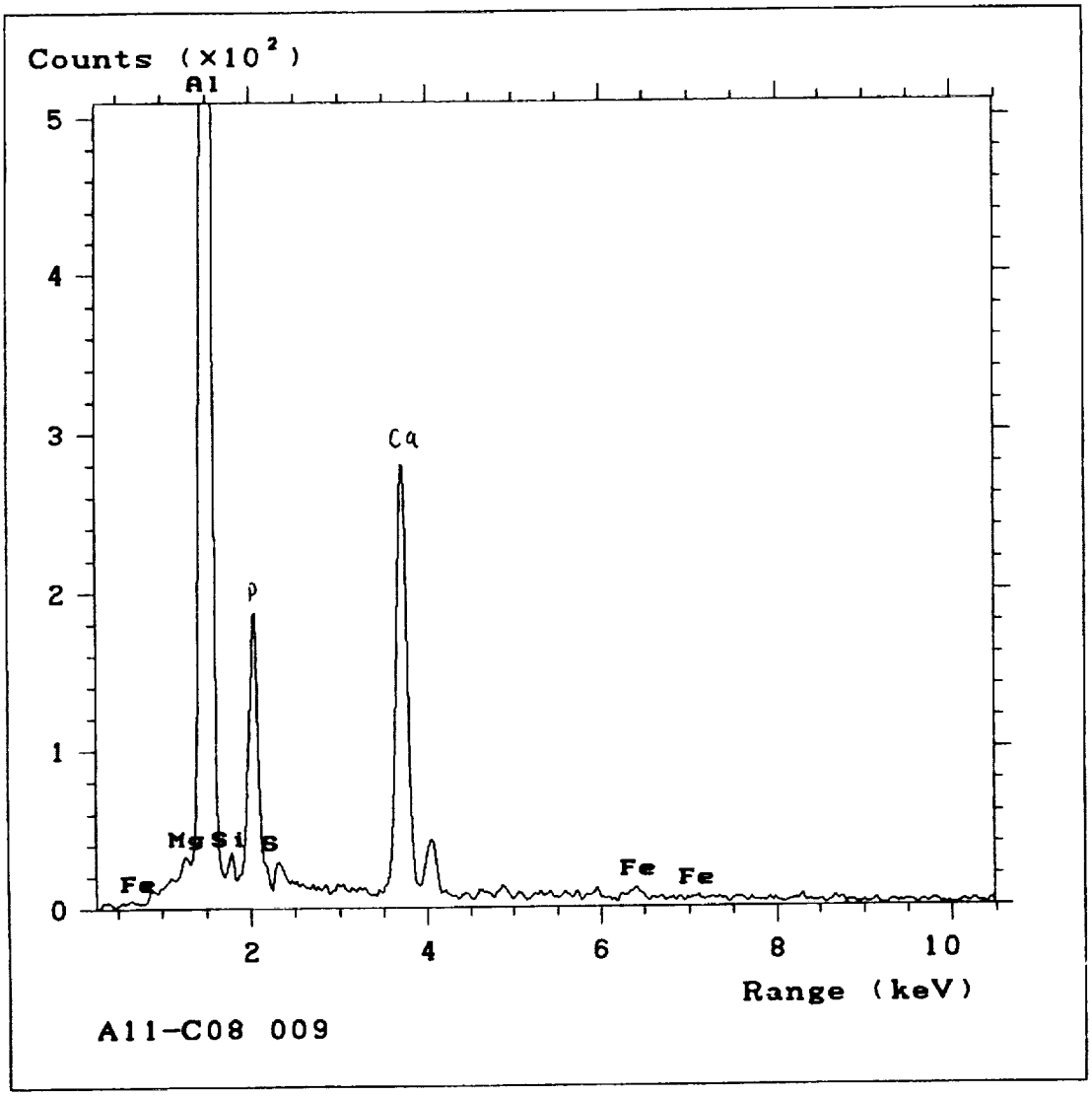

20kv 1.7kx 5.90µ 027

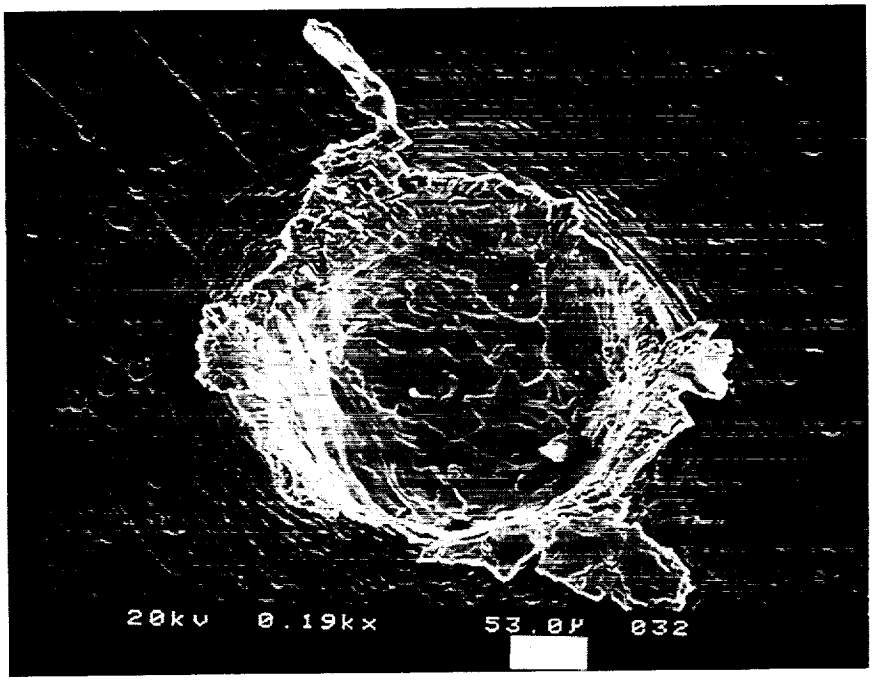

Counts (×10²)
10
8
6
4
2
0
Al
Si
Mg
Ca
Fe
Ca
Ca
Fe
Fe
0
2
4
6
8
10
Range (keV)
A11-C08 007

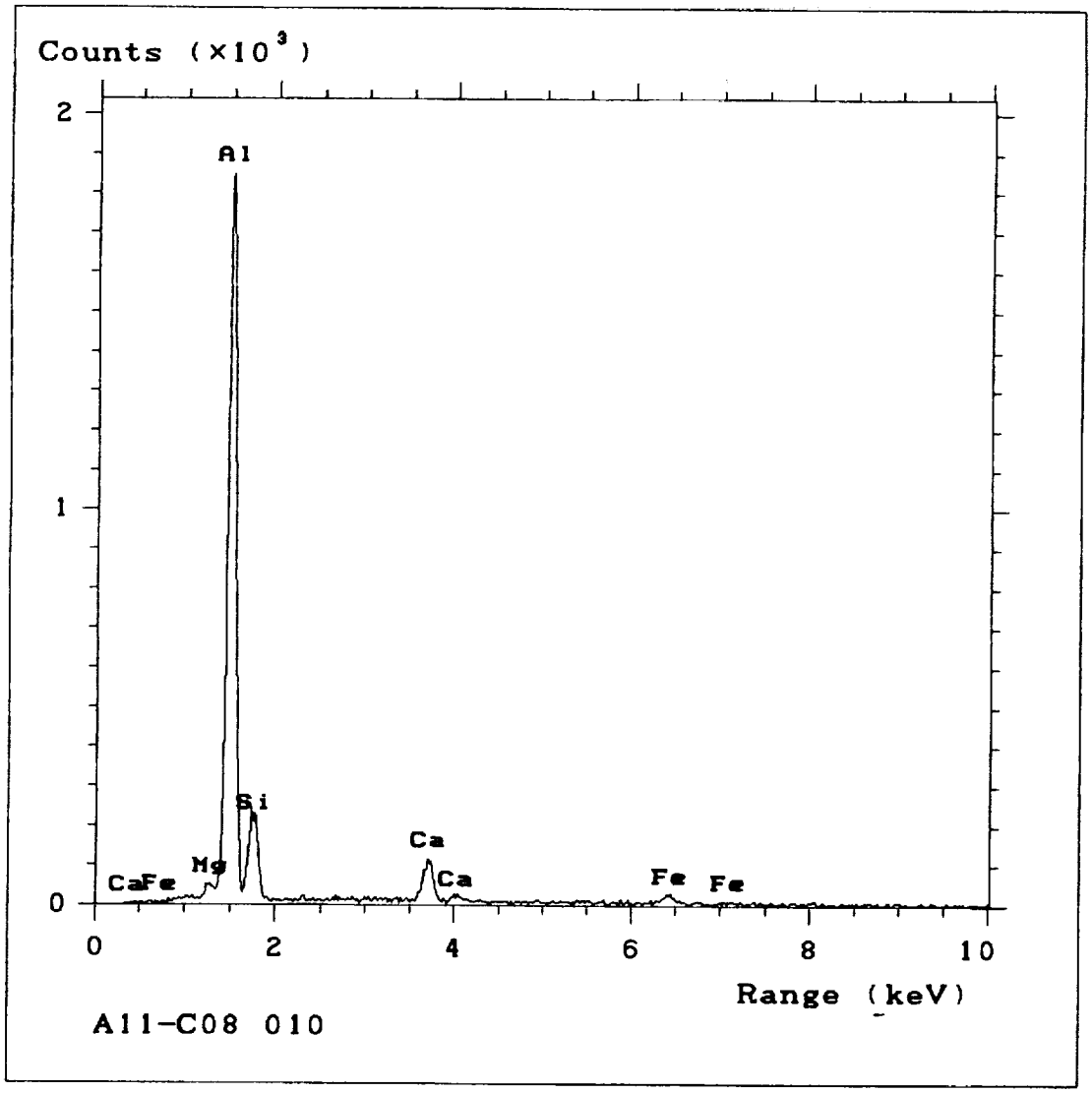

20kv 0.16kx 63.0μ 031

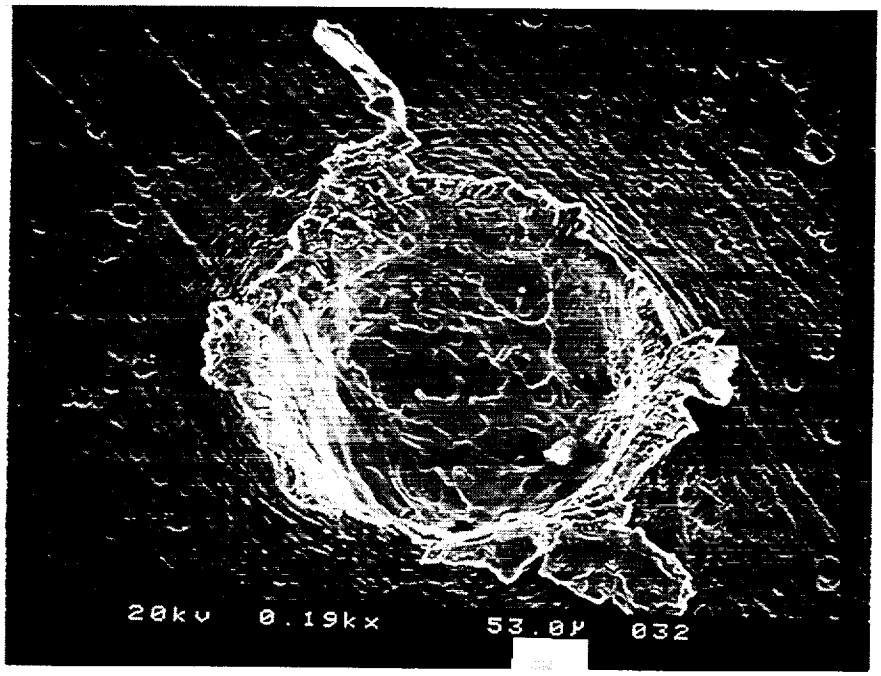

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

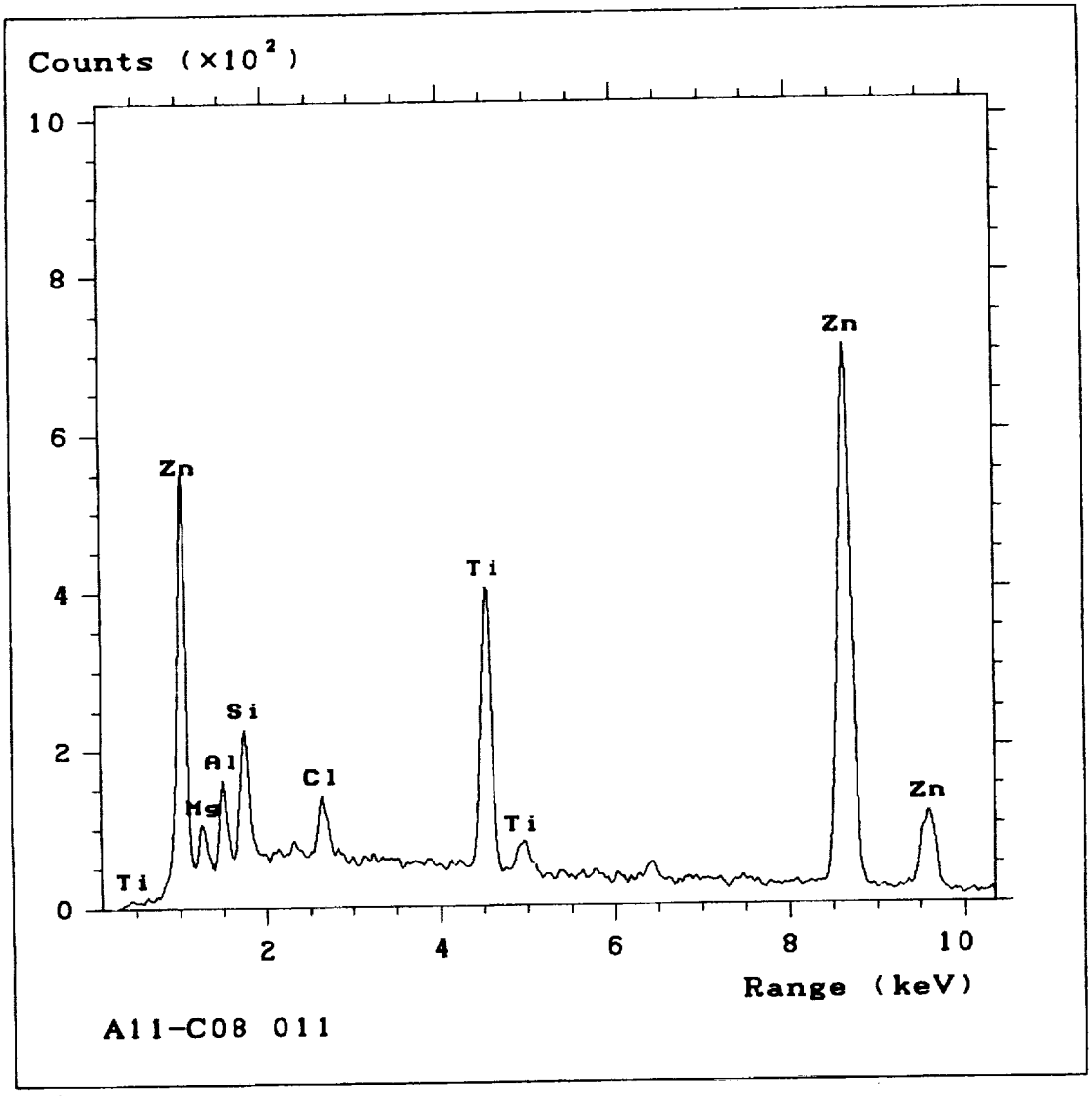

20kv 0.16kx 63.0µ 031

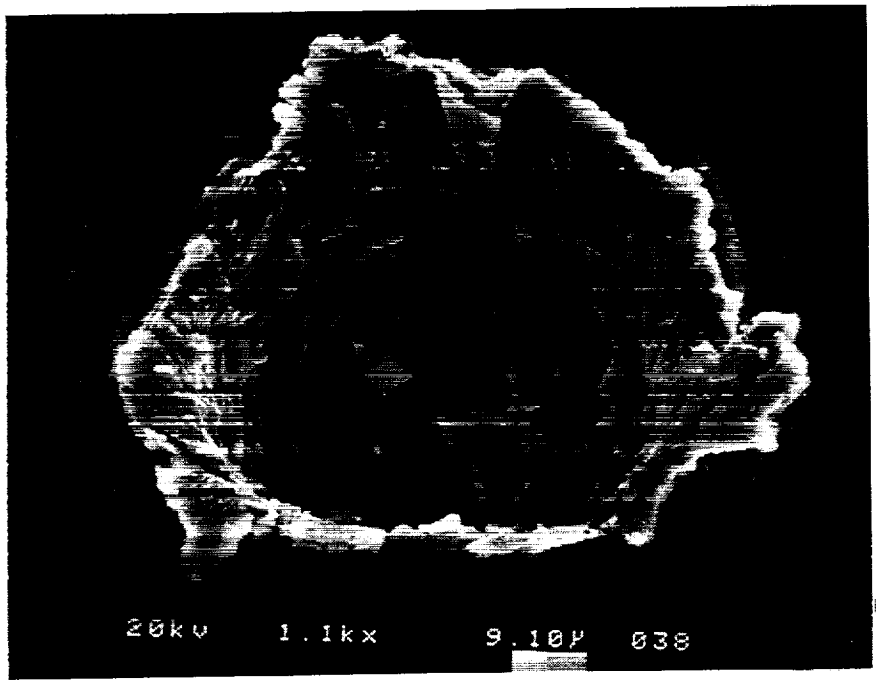

Counts (×10²)
Al
Ca
P
Mg
Si
S
Fe
Fe
Fe
5
4
3
2
1
0
2
4
6
8
10
Range (keV)
A11-C08 009

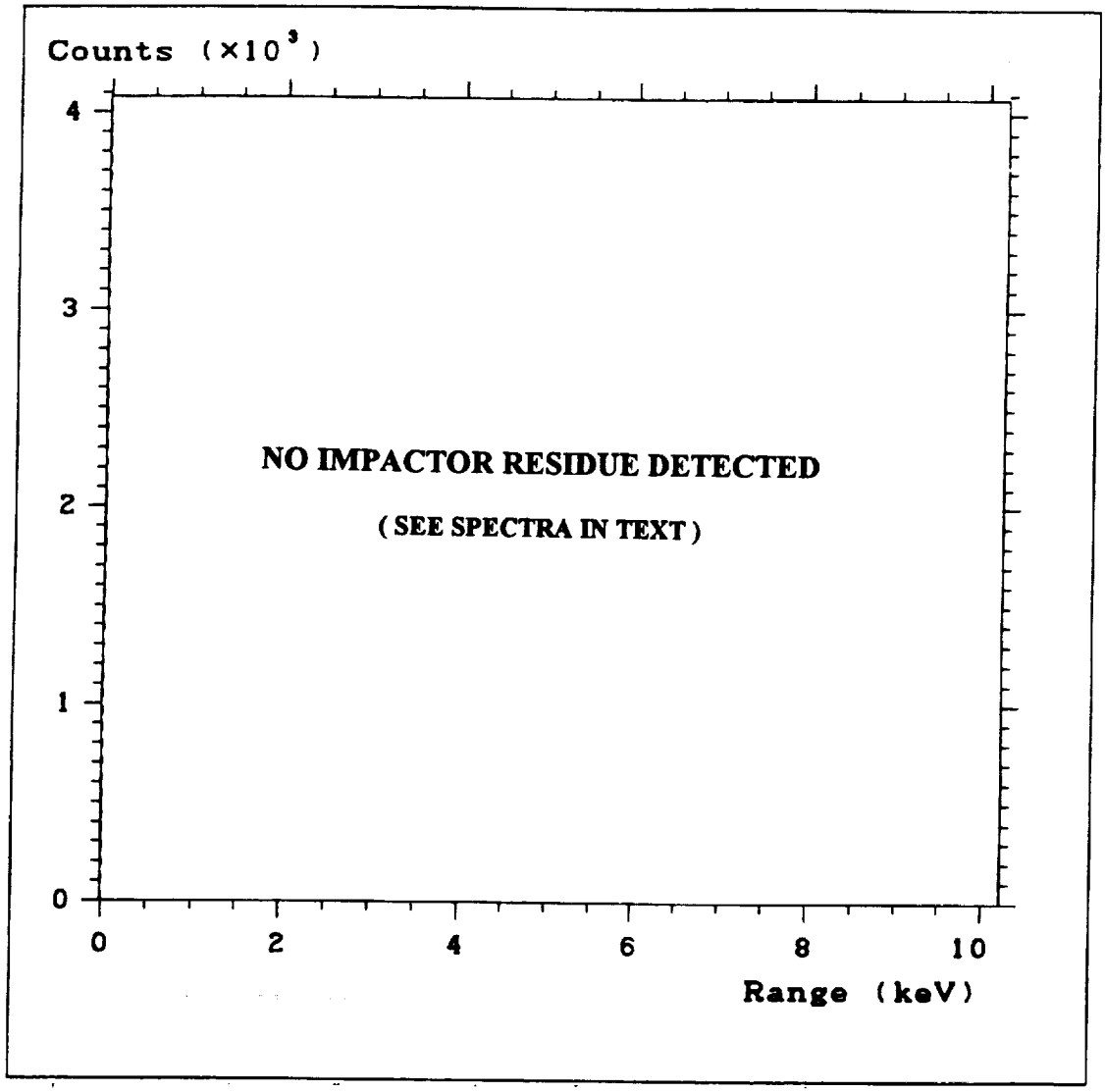

20kv 0.19kx 53.0µ 032

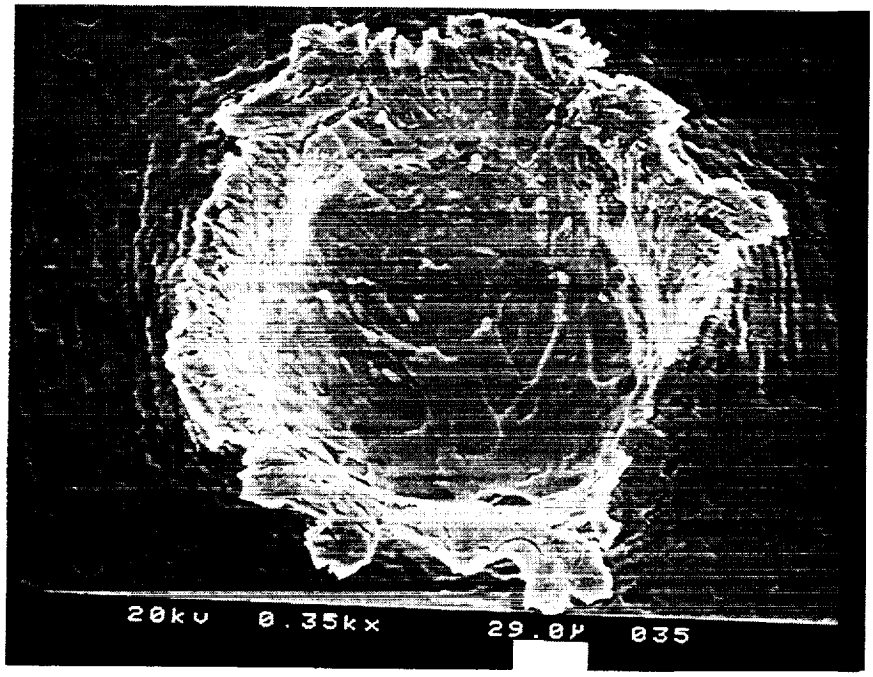

Counts (×10³)
2
1
0
Al
Si
Ca
Ca
Ca
Fe
Mg
Fe
Fe
0
2
4
6
8
10
Range (keV)
A11-C08 010

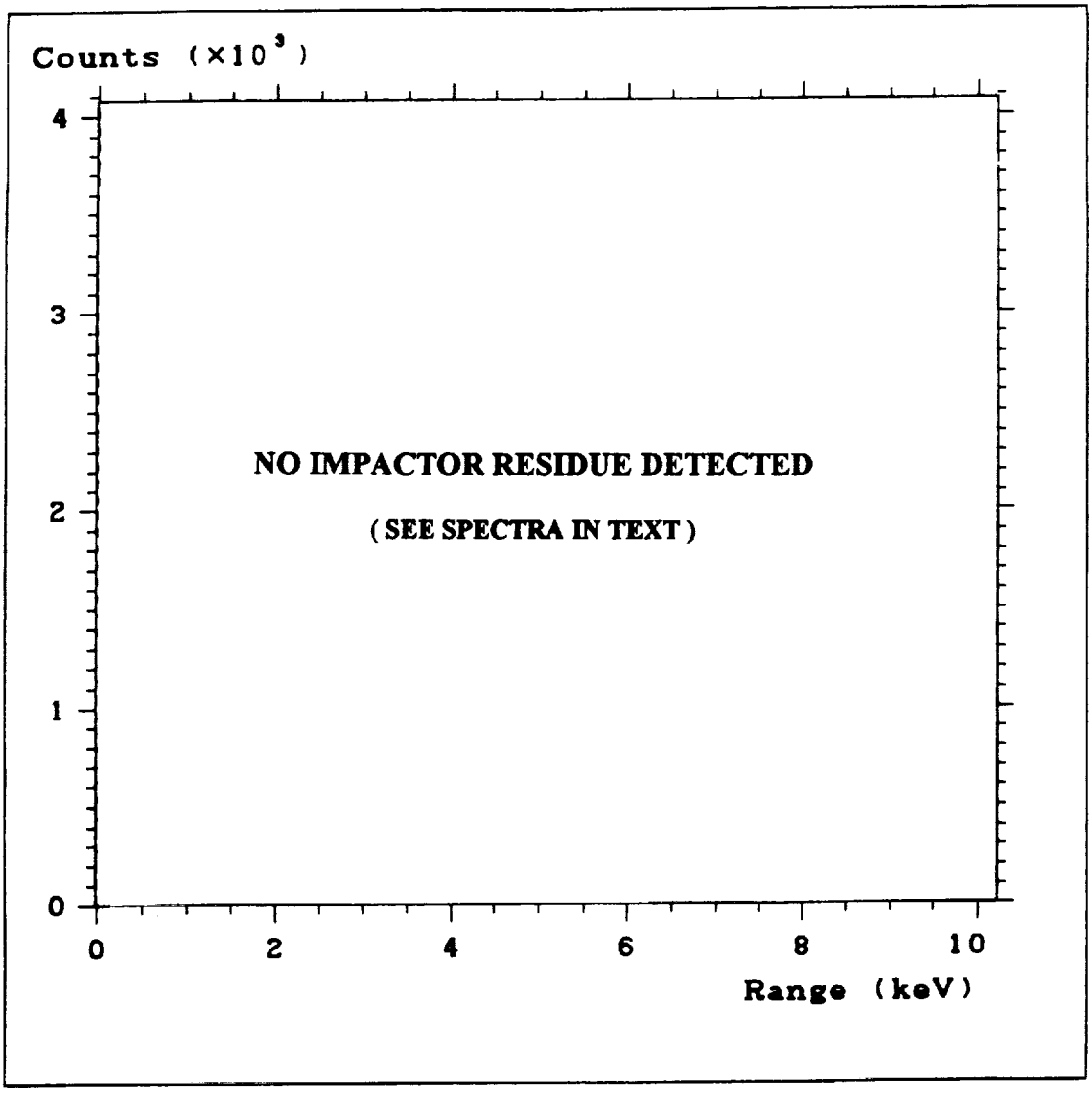

20kv 0.19kx 53.0µ 032

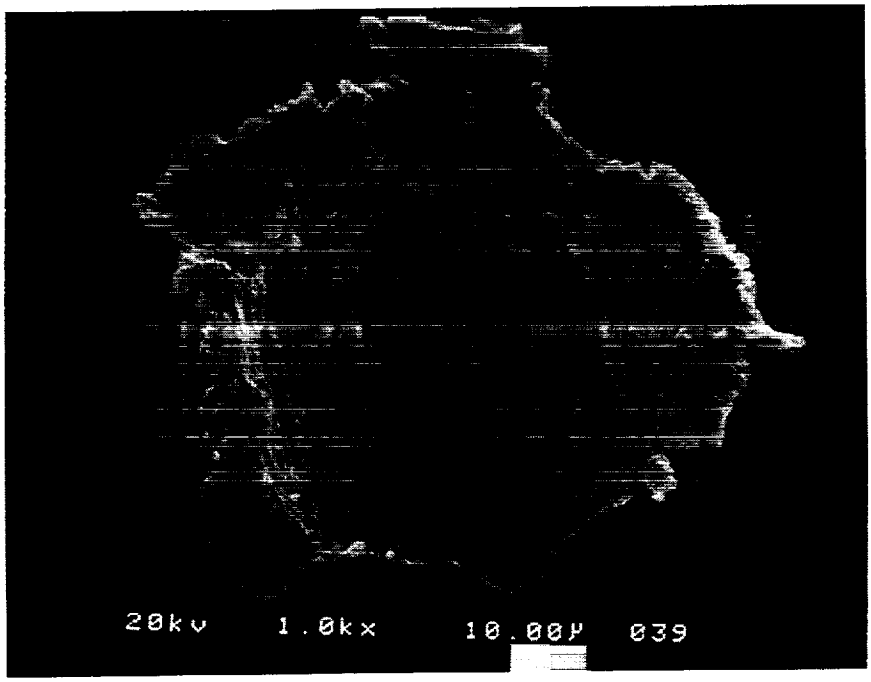

Counts (×10²)
10
8
6
4
2
0
Zn
Ti
Si
Al
Mg
Cl
Ti
Ti
Zn
Zn
2
4
6
8
10
Range (keV)
A11-C08 011

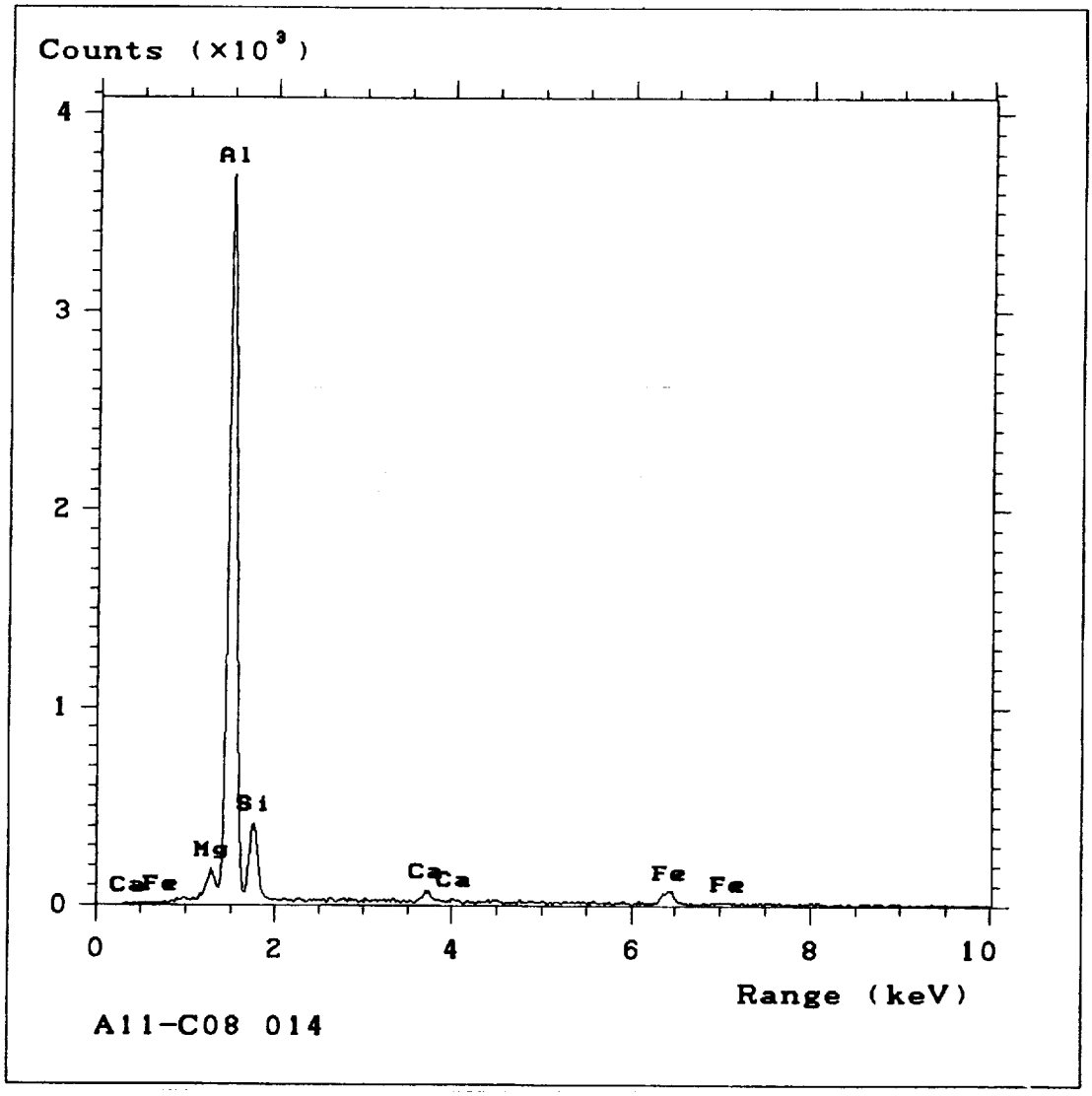

20kv 1.1kx 9.10µ 038

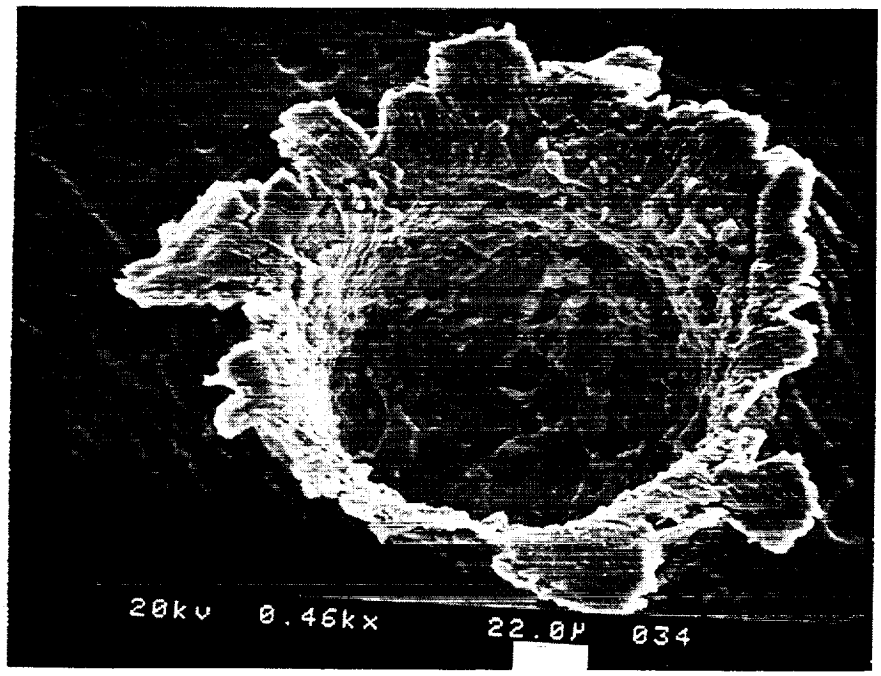

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)


20kv 0.35kx 29.0µ 035


Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)

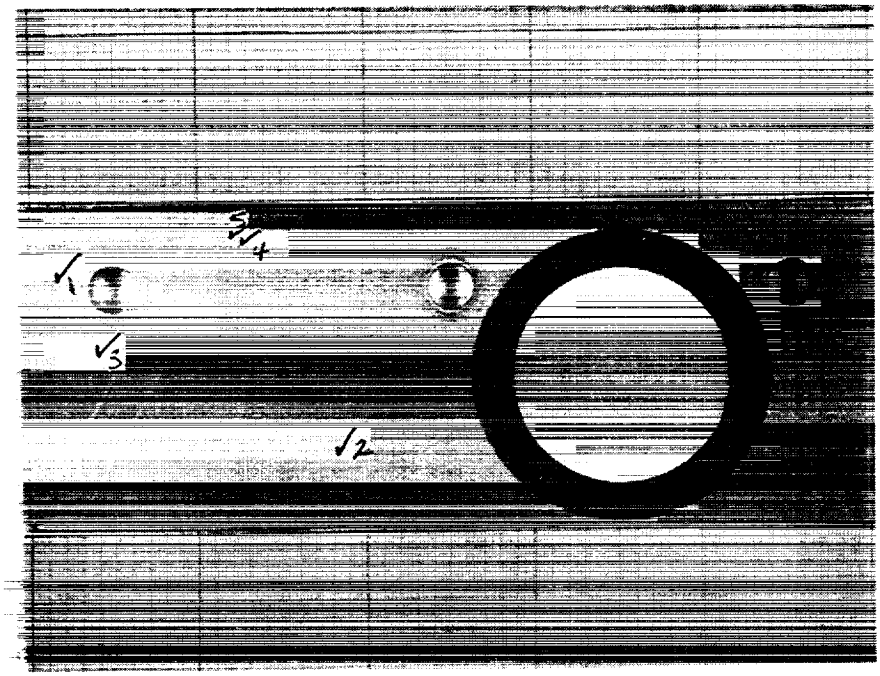

20kv 1.0kx 10.00µ 039

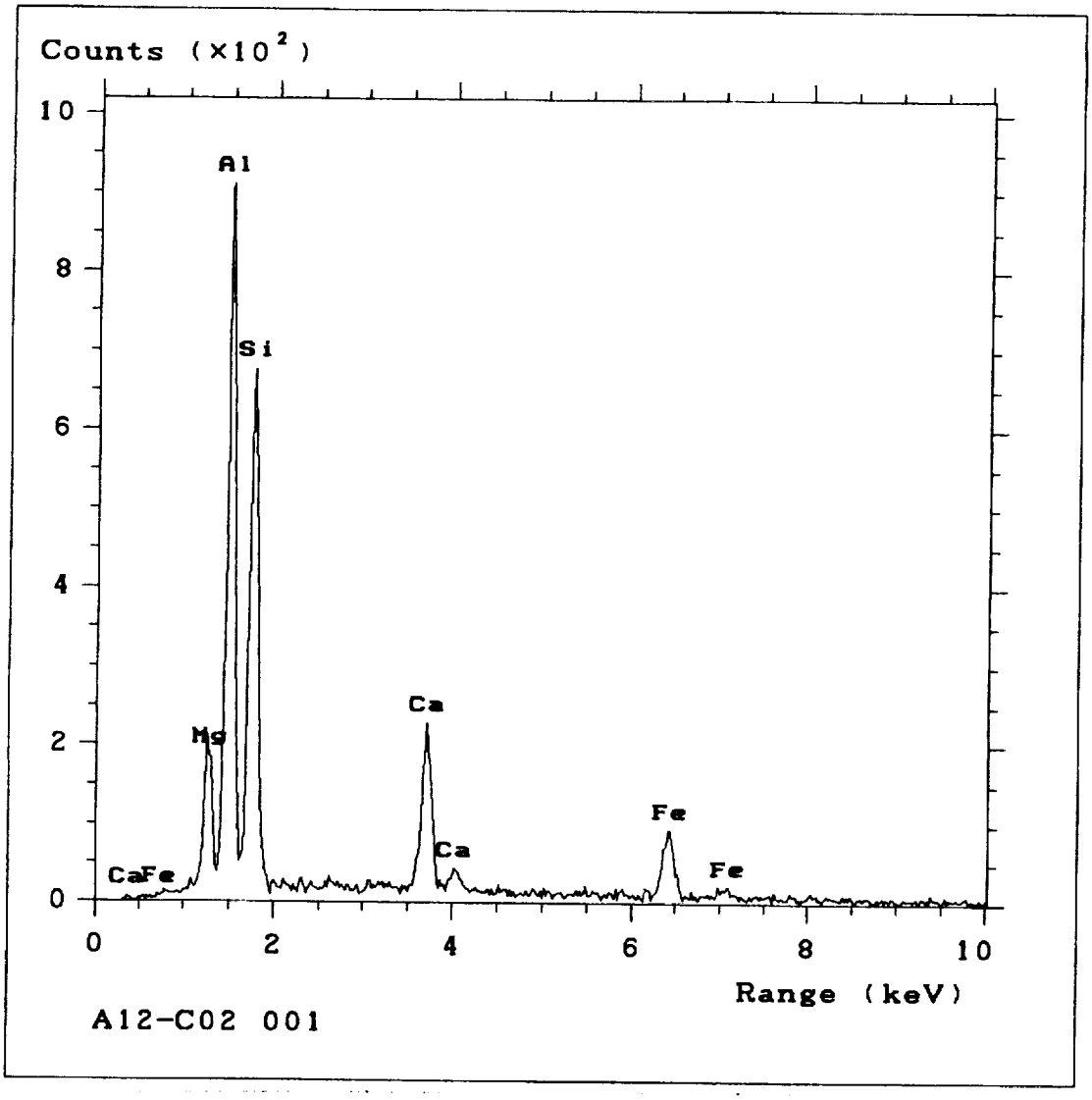

Counts (×10³)
4
3
2
1
0
Al
Si
Mg
Ca Fe
Ca Ca
Fe Fe
0
2
4
6
8
10
Range (keV)
A11-C08 014

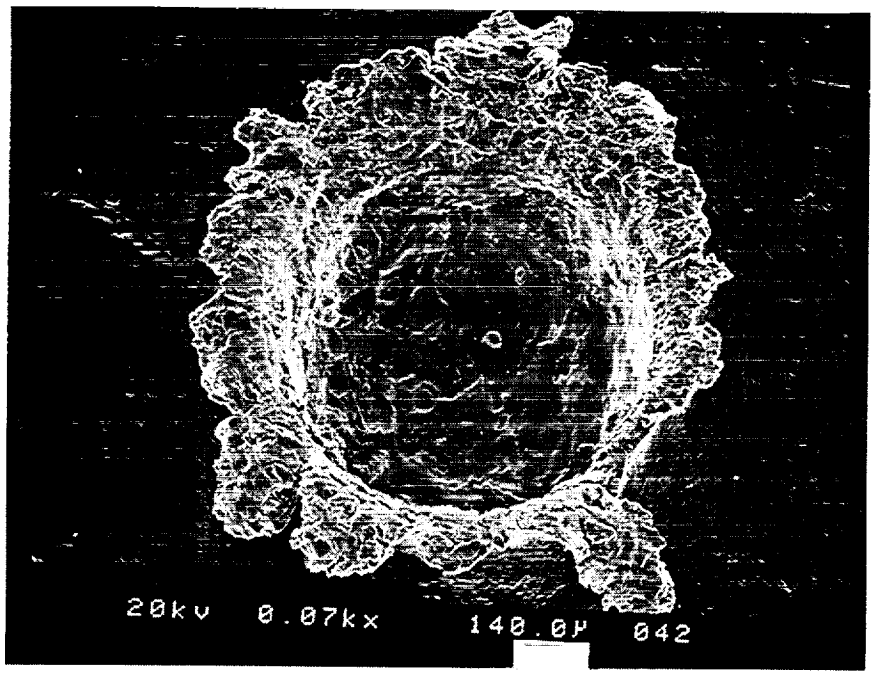

20kv 0.46kx 22.0μ 034

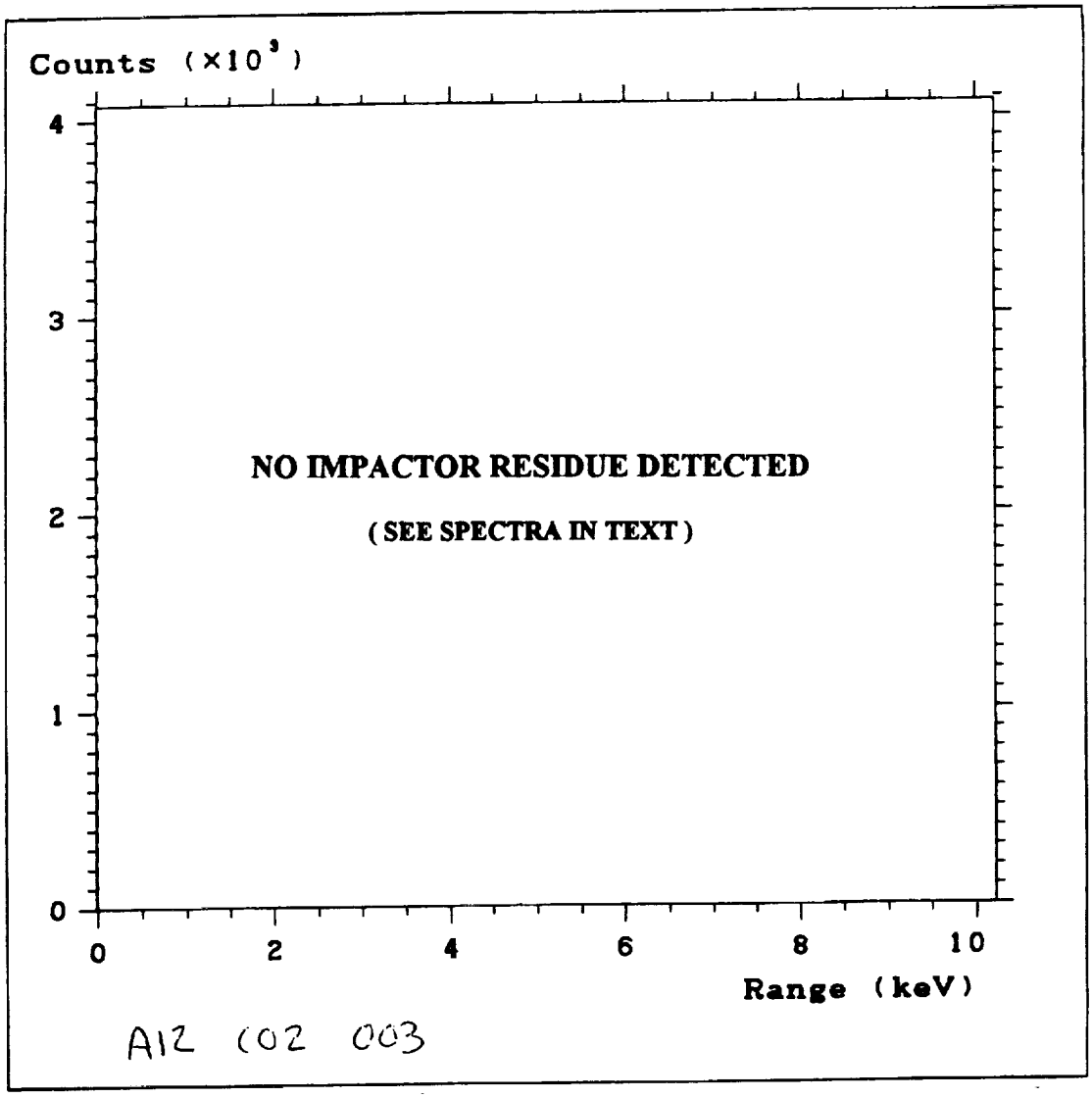
CLAMP NUMBER A12 CO2

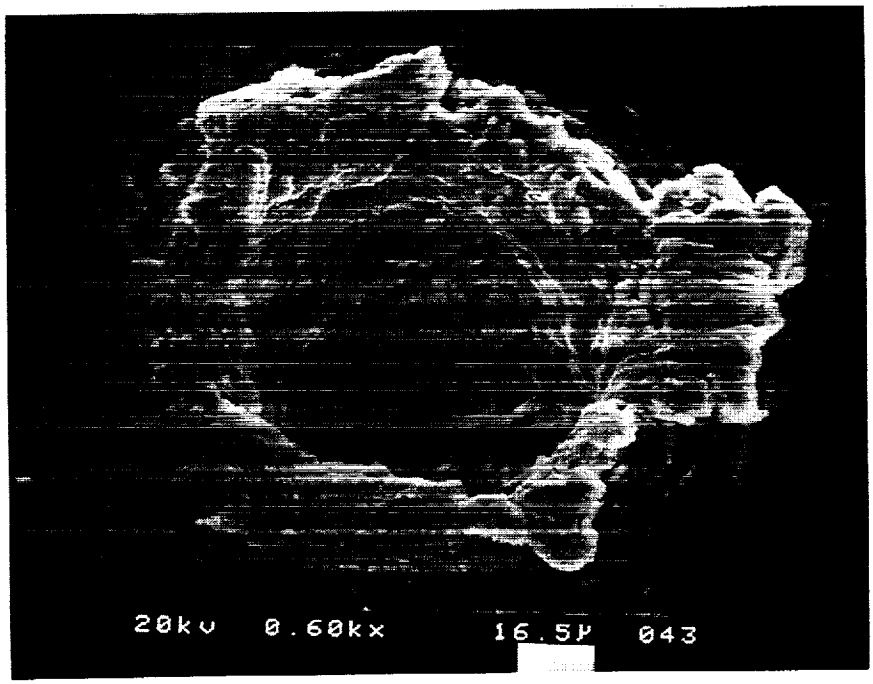
IMPACT NUMBER	DIAMETER	GENERAL COMPONENTS
001	900	Si, Mg, Ca, Fe
002	N/A	Clamp Flaw
003	130	Unknown
004	200	Trace
005	80	Trace

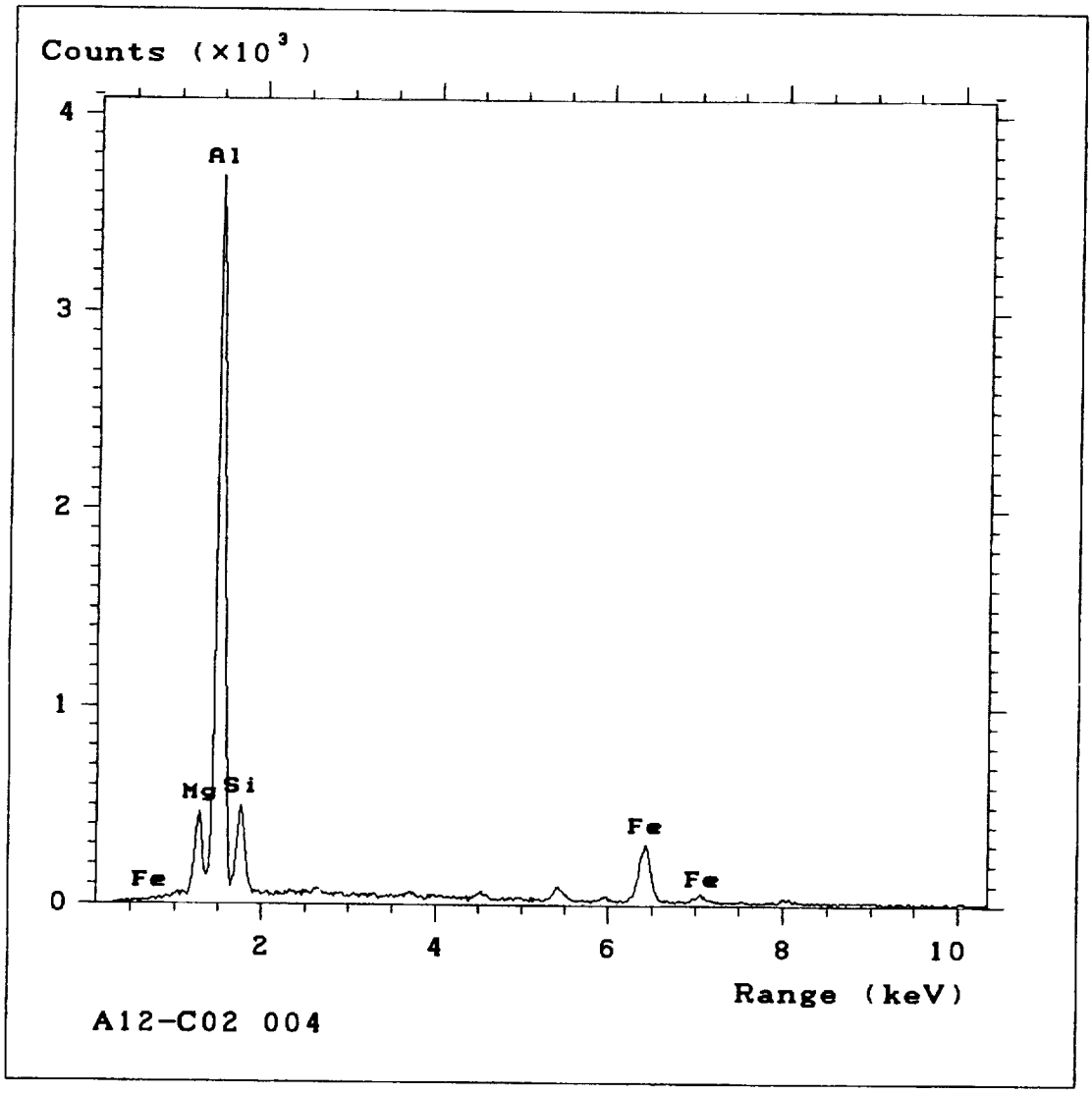


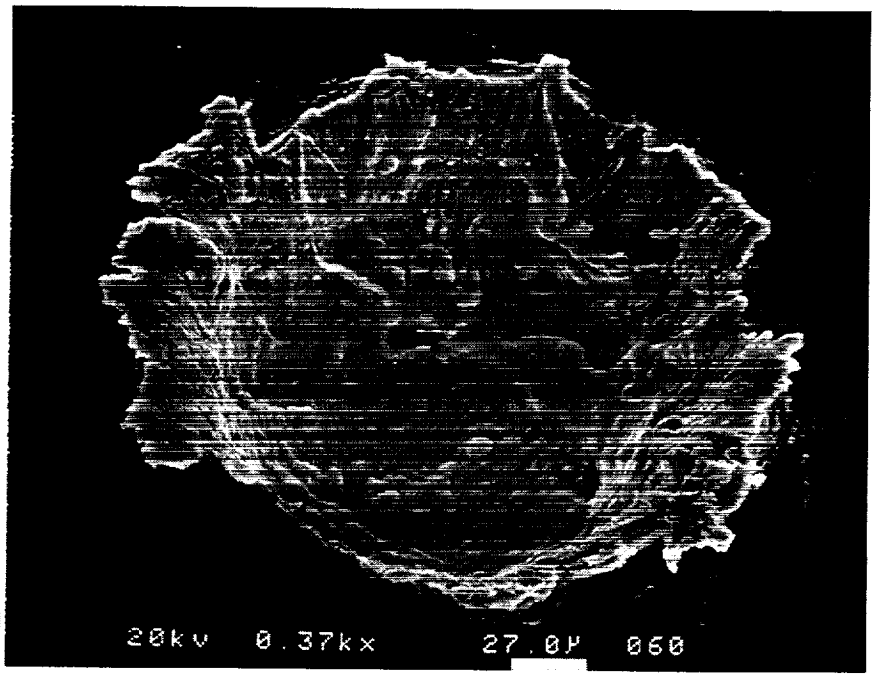

Counts (×10²)
10
8
6
4
2
0
Al
Si
Mg
Ca
Ca
Fe
Fe
Ca
Fe
0
2
4
6
8
10
Range (keV)
A12-C02 001

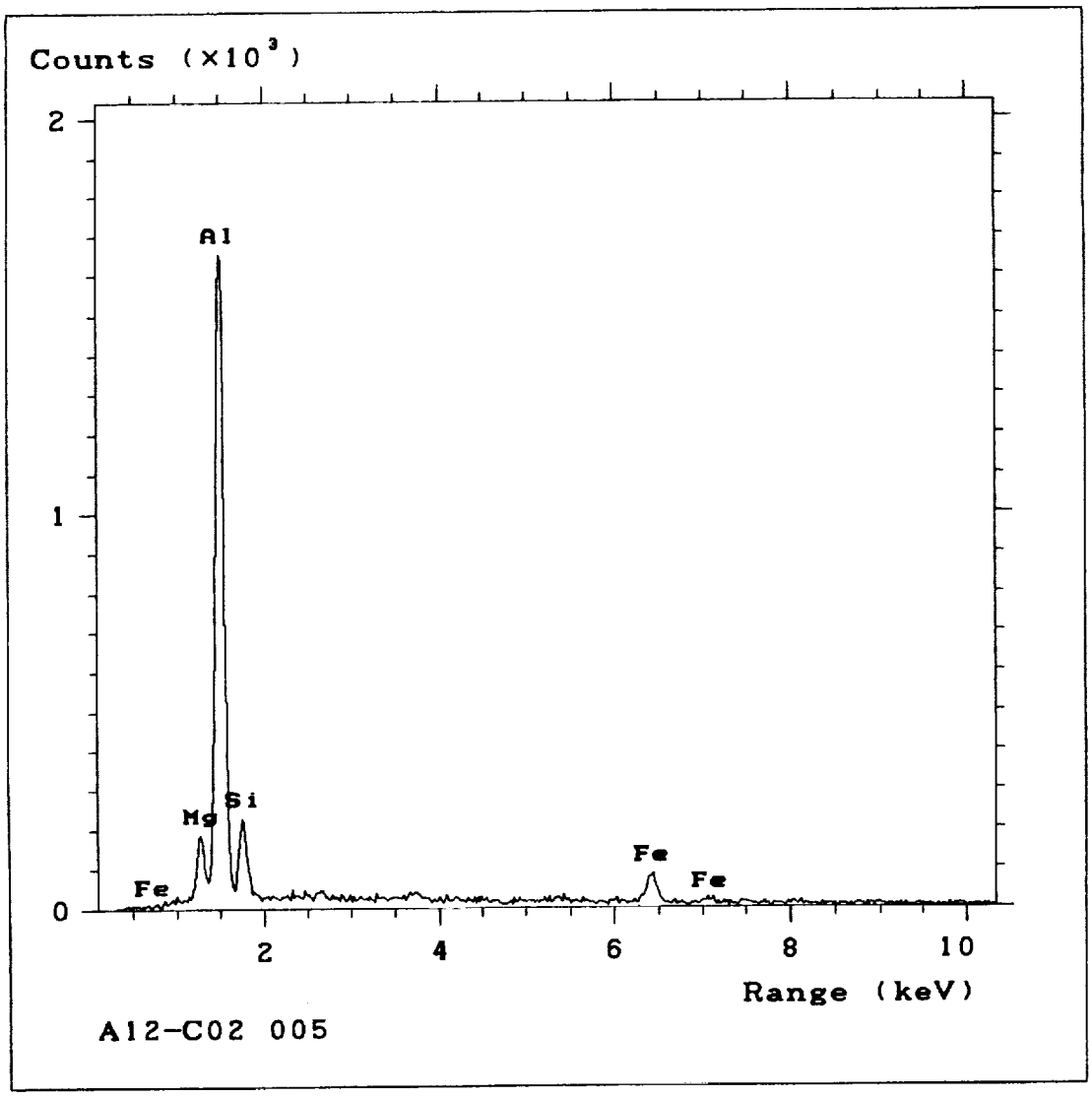

20kv 0.07kx 140.0µ 042

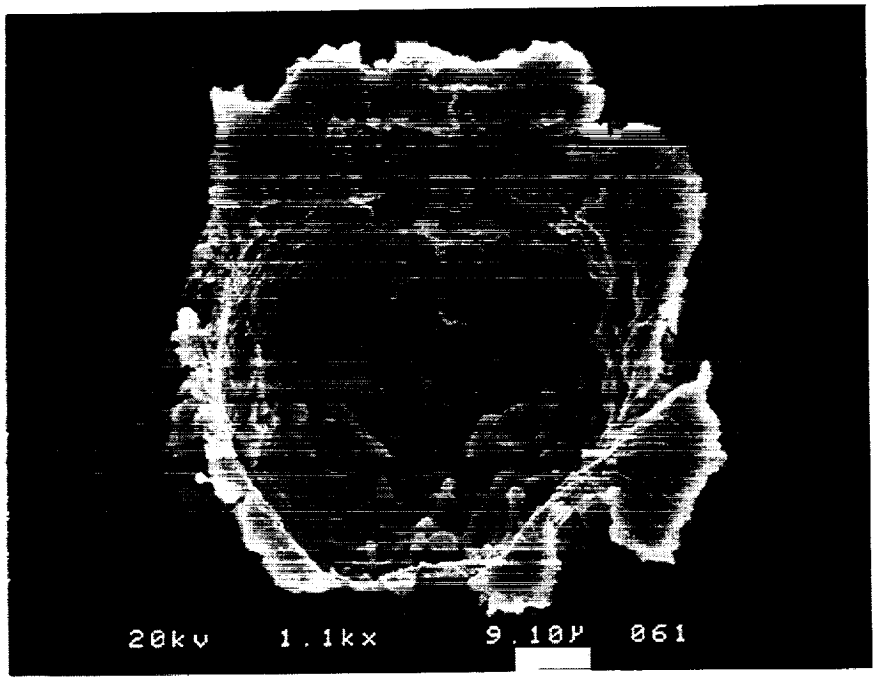

Counts (×10³)
4
3
2
1
0
NO IMPACTOR RESIDUE DETECTED
(SEE SPECTRA IN TEXT)
0
2
4
6
8
10
Range (keV)
A12 C02 003


20kv 0.60kx 16.5µ 043


Counts (×10³)
4
3
2
1
0
Al
Mg
Si
Fe
Fe
Fe
2
4
6
8
10
Range (keV)
A12-C02 004


20kv 0.37kx 27.0µ 060


Counts (×10³)
2
1
0
Al
Mg
Si
Fe
Fe
Fe
2
4
6
8
10
Range (keV)
A12-C02 005


20kv 1.1kx 9.10μ 061

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13. ABSTRACT *(Maximum 200 words)*

The Long Duration Exposure Facility (LDEF) was placed in low Earth orbit (LEO) in 1984 and was recovered 5.7 years later. The LDEF was host to several individual experiments that were specifically designed to characterize critical aspects of meteoroid and debris environment in LEO. It was realized from the beginning, however, that the most efficient use of the satellite would be to examine the entire surface of the Earth for impact features. In this regard, particular interest has centered on common exposed materials that faced in all LDEF pointing directions. Among the most important of these materials is the tray clamps. Therefore, in an effort to understand the nature of particulates in LEO and their effects on spacecraft hardware better, we are analyzing residues found in impact features on LDEF tray clamp surfaces. This catalog presents all data from clamps from Bay A of the LDEF. Subsequent catalogs will include clamps from succeeding bays of the satellite.

Subject Category: 43

14. SUBJECT TERMS
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