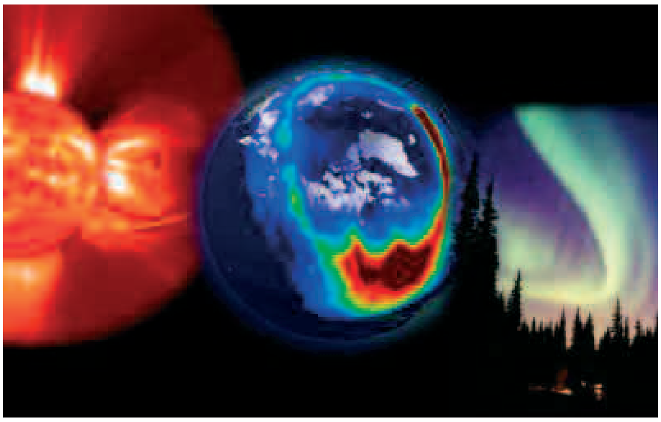
eurocomp
The newsletter of the Space Components Steering Board

Introduction

Welcome to the seventh issue of Eurocomp, the newsletter of the Space Components Steering Board (SCSB).

In the previous issue we highlighted the signature of the founding charter for the ESCC that opened the way for its members and bodies to implement its strategic mission. In this vein the European Space Agency (ESA) has announced an initiative to evaluate a number of component technologies and make them available to the space community. More information on this programme will be presented in the forthcoming issues.

In this issue, we focus on the ground simulation facilities the community uses to understand the space environment effects on electronic components. The natural space radiation environment contains energetic particles capable of causing significant damage to spacecraft components. Trapped particles in the magnetic field of the Earth (primarily protons and electrons) and cosmic rays (heavy ions or protons of solar or galactic origin) can cause total ionisation dose (TID) damage, displacement damage, or single event effects (SEEs) in electronics. These very different radiation effects in components can lead to degraded performance, temporary loss of performance or even catastrophic failures (e.g. burnout). However, in order to evaluate the radiation sensitivity of components, a great deal of ground simulation testing is carried out. Different irradiation sources and test sites are used, with Co-60 gamma being the most commonly used for TID testing, and low energy protons for displacement damage. Less well known are the irradiation sources and sites used for SEE testing.



The space environment:
a solar event – trapped particles – northern lights

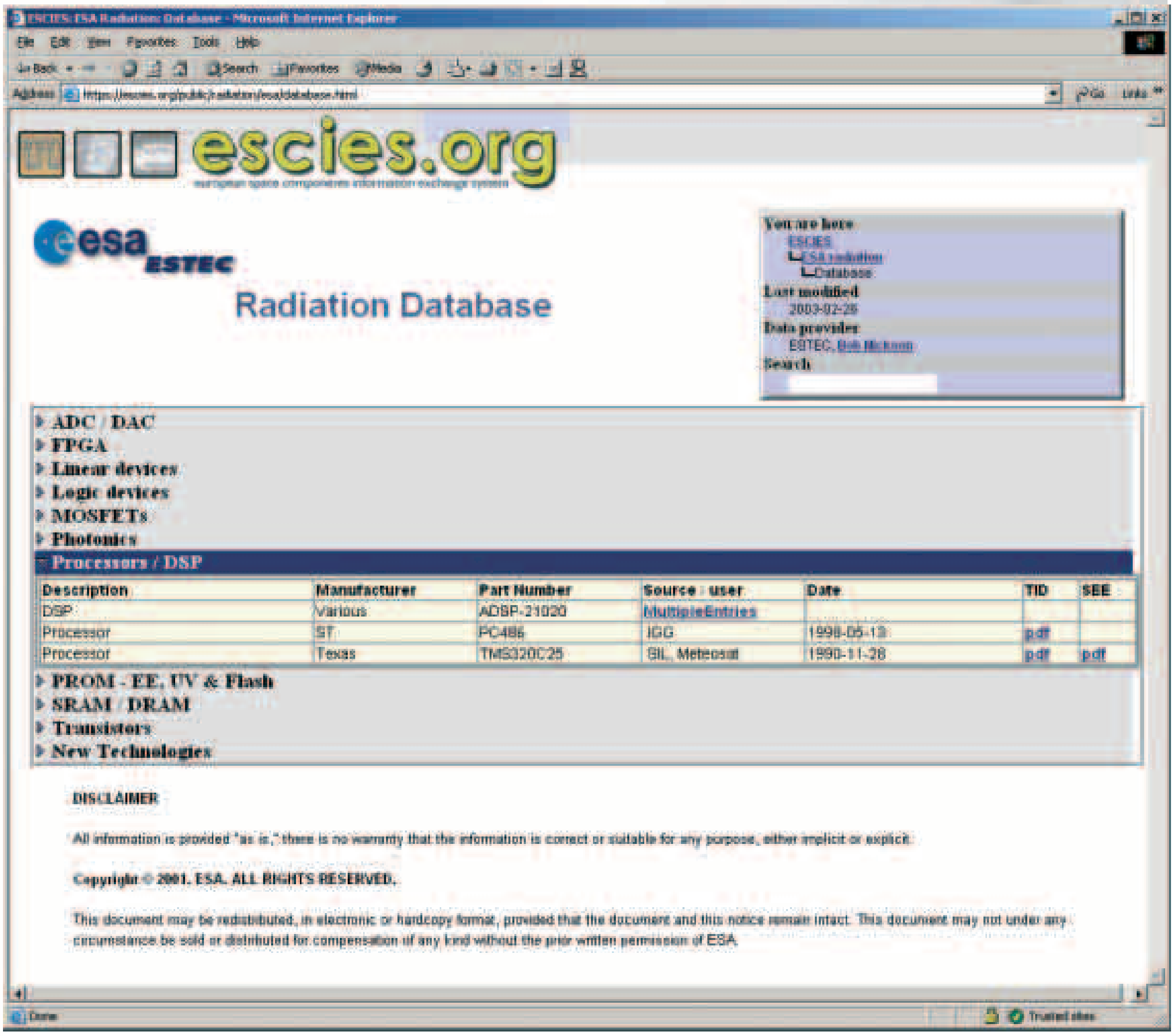
Several European accelerator facilities have ions and proton energy suitable for SEE testing. Three of these facilities – all under ESA contract – will be described here, and examples of heavy ion and proton single event upset (SEU) data given. R. Harboe-Sørensen (ESA) introduces this overview in an article entitled “ESA Sponsored European Irradiation Facilities for Component Studies”.

A. Coella-Vera (Alcatel Space Industries) and B.D. Dunn (ESA) present an overview of the special application in space of solders containing lead, and the current legislative directives prohibiting use of hazardous materials, in an article “European Space Industry and the Elimination of Lead from Electrical and Electronic Equipment”.

As usual, the busy web walkers at our ESCIES site (https://escies.org) offer a brief description of one of the many data banks available for access by the space community. In this case, data from radiation testing. Please take a look. They enjoy receiving feedback from the user community, so do get in touch with them with your comments or even helpful hints.

In this issue...

Radiation Resources in ESCIES



Web design by osoft

ESCIES, the European Space Components Information Exchange System, reached its fourth anniversary of operation in June. One of the most frequently consulted areas of information is the radiation section maintained by ESA. This contains general information on the activities of the radiation community, including meetings and conferences, as well as details of the various test facilities where EEE parts may be subjected to radiation test campaigns. Additional information addresses the radiation environment and monitoring instruments, and links to other space radiation web resources are maintained.

However, the major part of the content is given over to radiation test reports and relevant papers presented at community events. Some 250 reports are organised under 11 component categories in the 'Radiation Database', covering both total dose and single event effects testing. More than 120 papers are also presented, from RADECS and other events, including the presentation days organised by the ESA Components Division. The repository of reports and papers continues to grow and the content is publically available for download from ESCIES as PDF files.

In addition to the ESA-maintained radiation section in the public part of ESCIES, there is additional, though limited, data in the ESCIES 'registered users' area. It is anticipated that this radiation aspect of ESCIES will also grow significantly in the future with the addition of radiation test data generated in the frame of project procurements.

While ESCIES content continues to grow in all respects and ESCIES is accessed at ever increasing rates, it is clear that the radiation data is one of its key and successful components. To learn more please refer to *https://escies.org*, and specifically for radiation to *https://escies.org/public/radiation/esa/*

Readers interested in further information can contact the author at:
tony.gouder@esa.int

Elimination of Lead from Electrical and Electronic Equipment – the Dilemma of Tin-Whisker Growth

Introduction

The European Commission has enacted several directives concerning the protection of the Environment from hazardous substances:

- **Directive 2002/95/EC of the European Parliament and of the Council** (27 January 2003) on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- **Directive 2002/96/EC of the European Parliament and of the Council** (27 January 2003) on waste electrical and electronic equipment (WEEE)
- **Directive 2003/108/EC of the European Parliament and of the Council** (8 December 2003) amending Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)

Satellites generally do not contribute to hazardous waste on the Earth's surface (although there is certainly a problem in some crowded orbits), and therefore they are not concerned by these directives. The directives do apply to a very large span of applications, and there are very strong trends to eliminate the relevant substances by 2006 from those applications as required (with some exemptions) by the directives. However, it must be noted that, for the space industry, there are many technical reasons why the present tin-lead eutectic alloy is the preferred solder for assembling components on printed circuit boards, and indeed cost is an important factor, as many million euros have already been spent in European industry for the validation/qualification of electrical systems for spacecraft.

Internationally, only Japan is following the same route as Europe, with clear legislation to ban the concerned hazardous substances. The USA and China do not seem to follow the same blanket approach, and even if some legislation is enacted, there will be many exemptions with long transition periods.

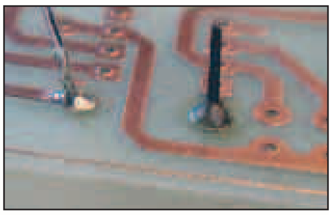
Lead in Solders

Lead is one of the substances banned in Europe, and in electronic equipment it is mainly used in component lead finishes and in solders.

There are many exemptions from the European lead ban:

- Lead in glass for cathode ray tubes, electronic components and fluorescent tubes
- Lead as an alloying element in steel containing up to 0.35% lead by weight; aluminium containing up to 0.4% lead by weight; and as a copper alloy containing up to 4% lead by weight
- Lead in high-melting-temperature type solders (i.e. tin-lead solder alloys containing more than 85% lead)
- Lead in solders for servers, storage and storage array systems (exemption granted until 2010)
- Lead in solders for network infrastructure equipment for switching, signalling, transmission, as well as network management for telecommunication
- Lead in electronic ceramic parts (e.g. piezoelectric devices)

Taking into account all of these, together with the lack of restrictive legislation in other large countries, the European space industry is confident that currently used tin-lead solders will continue to be available for the foreseeable future. From the technical standpoint, the space industry is

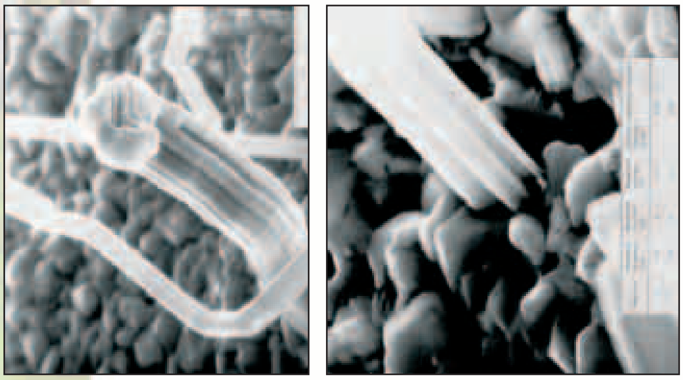


advised to follow and be aware of alternative solders being introduced in other areas, to be better prepared for future action if required.

Lead in Component Finishes

A different situation exists with lead used in the finishes of components leads. Driven by the accelerating movement to lead-free products, as required by many of their customers, worldwide manufacturers of electronic components are turning to alternative solders and component lead coatings. Although a number of alternatives are being considered, the general trend is toward pure tin coating on component leads and circuitry in lieu of traditional tin-lead alloys. The transition has resulted in renewed concern regarding the phenomenon of tin whiskering, first reported in the 1940s, which may cause unacceptable risks.

Tin whiskers are single crystals having very small dimensions, typically 1 - 5 microns in diameter and between 0.5 and 10 mm in length. They grow spontaneously from the solid (tin) phase, with growth occurring at the base of the whisker. The filaments are highly conductive and are known to produce electronic failure by short-circuit.

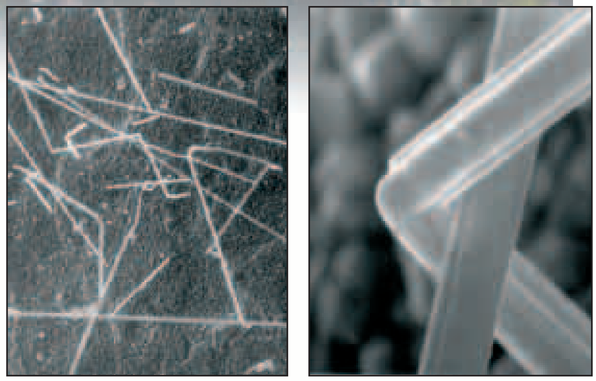


Details of the flutes or striations (2 um) on the shaft of a tin whisker emerging from plating (SEM photo)

A lack of industry understanding about tin whisker growth factors, and a lack of testing methodology to identify whisker-prone products, have made pure tin interconnections and plating risky for high-reliability systems like satellites. To emphasis this problem, it is worth remembering that certain recent telecommunication satellites have failed due to tin whiskers, which grew during the lifetime of those spacecraft and created electrical shortcircuits.

CTB Survey

The Component Technology Board (CTB) was asked to look into these issues and to make recommendations accordingly. In June 2003, at the initiative of the CTB, a letter was sent by the



European Preferred Parts List (EPPL) Manager to all the manufacturers included in the current issue of the EPPL, questioning the following topics:

- Their intention to follow the European lead-free directive on the manufacturers' products, in particular for space/hi-rel parts, and the level of notice to be provided to the customers
- The main technical modifications to the products affected by such process changes (materials to be used to replace tin-lead solder finish, any foreseen technical problems to be faced, etc.)

Only a few responses (10 from 61 letters sent) were received. However, most of the major suppliers were in the 10 responses.

A second letter was sent to those that did not answer, but to no avail.

The general trend of the received inputs is a lack of interest from the manufacturers in being compliant with the lead-free directive, unless explicitly required by the customers. One manufacturer was evaluating the possibility of following the directive, and some packages with lead-free solder finish have already been qualified against a dedicated flow, but the alternative is still under investigation.

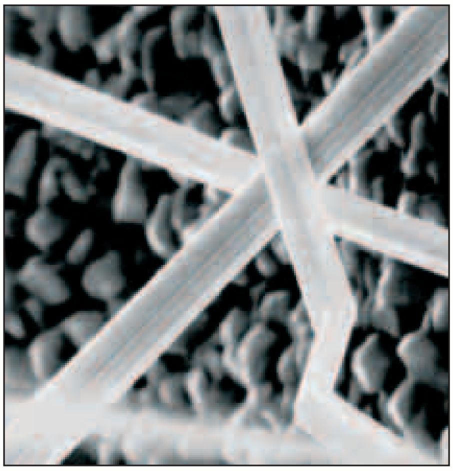
Only one passive manufacturer has all his EPPL products already lead-free, using a pure tin plating on the terminations.

The CTB conclusion is that there is a real risk of the space industry being confronted with the problem of some of their component suppliers, especially Europeans, switching completely to pure tin lead finishes. To help users, the CTB has enacted a series of recommendations that, in general, are in line with those retained in the USA by space organisations.

CTB Recommendations on Tin Whiskers

The uncertainties associated with tin whisker growth make it extremely difficult to predict if/when tin whiskers may appear. Some supposedly whisker-free tin platings on component terminations have already actually produced small tin whiskers, which calls into doubt their suitability for space use. There are currently no industry-accepted accelerated test methods to judge a particular product's propensity to form whiskers.

Existing literature on tin whiskers frequently reports contradictory experiences regarding the effects of various forms of environmental stresses on whisker growth. ESA is presently studying the effect of micro-stresses on the rate of tin-whisker growth.



At present, a number of organisations worldwide are working on understanding the whisker growth phenomenon and attempting to develop methods to test and model the propensity for whisker growth.

The following list of actions provide some suggestions, in order of priority, for reducing the risk of tin whisker induced failures.

1. Avoid the use of pure tin plated components if possible

Procurement specifications that have clear restrictions against the use of pure tin plating are highly recommended. Most (but not all) of the commonly-used military/space specifications in the US and Europe currently have prohibitions against pure tin plating. Many commercial customers have specific requirements to ensure that pure tin components do not enter their supply chain. The ECSS standards clearly prohibit the use of pure tin electroplated finishes for any space hardware, whether for standard parts or electronic components.

Studies have shown that alloying tin with a second metal reduces the propensity for whisker growth. Alloys of tin and lead are generally considered to be acceptable where the alloy contains a minimum of 3% lead by weight. Although some experimenters have reported whisker growth from tin-lead alloys, such whiskers have also been reported to be dramatically smaller than those from pure tin plated surfaces and are believed to be sufficiently small not to pose a significant risk for the geometry of today's microelectronics.

2. Verify post-procurement that pure tin plating is not supplied

It can be dangerous to rely on the part manufacturer's certification that pure tin plating was not used in the production of the product supplied.

Some cases have been reported in which the user procurement specification required 'no pure tin', but the product supplied was later determined to be pure tin. In some of these instances, tin whisker growths were also discovered.

Users are advised to analyse the plating composition of the products received as an independent verification, using appropriate control means (visual inspection, SEM, chemical, ...).

3. Strip and replate

If alternatives to tin plated parts cannot be obtained, the tin finish may be removed.

The decision to remove the tin plating from the affected surfaces and to refinish must be made based on cost and risk analyses.

Such processes should be reviewed to determine the potential for affecting the reliability of the original product.

There is at least one European company (3D+) that is developing an effective removal process based on sandblasting. If qualified, this process could be proposed as a service to the European industry.

4. Solder dip the plated surfaces using a tin-lead solder

If stripping and replating is not an acceptable risk mitigation option, a solder dip process should be considered as the preferred method, to replace tin by eutectic tin-lead.

Solder dip the plated surfaces using a tin-lead solder to completely reflow and alloy the tin plating. This method is similar to the 'de-golding' of component leads and is detailed in ECSS-Q-70-08.

Special precautions are required to prevent thermal shock induced damage, to prevent loss of hermeticity and to avoid thermal degradation.

This approach may have limited success since it may be difficult to ensure that the entire surface is properly reflowed. However, any non-fused tin which might be close to a glass-to-metal lead can be coated as advised in suggestion 5, below.

5. Apply a conformal coating

If pure tin finished parts cannot be avoided, the application of a conformal coating may be used to retard tin whisker growth, to contain whisker growth within the coating, and to prevent whiskers from shorting exposed conductors.

Some experiments using conformal coating or foam encapsulation have shown beneficial results, but the limitations of this strategy are not completely understood, and tin whiskers have been shown to grow through a conformal coating.

It has been demonstrated experimentally that a conformal coating can restrict the availability of tin sufficiently to minimise the risk of plasma formation. However, the coating material and the minimum thickness of coating necessary to prevent whisker growth or preclude plasma formation have not been determined.

Similarly, it has been shown that foam can prevent sustained arcing, but the effects of foam type, foam density, pore size etc. have not been evaluated.

Additional studies and evaluations are underway to try to answer the critical open questions, in order to provide more detailed suggestions in future.

6. Other approaches being explored

- Select a matte or low stress tin finish (considered unlikely to succeed)
- Reflow the pure tin plated surfaces

For more information:
Barrie.Dunn@esa.int &
Augustin.Coella-Vera@space.alcatel.fr

[Whisker photos are from an ESA study of a failed electronic unit that supported large numbers of the whiskers: BD Dunn – R Harboe-Sørenson]

ESA-Sponsored European Irradiation Facilities for Component Studies

Three European irradiation facilities under European Space Agency contract have beam lines and setup dedicated to component and material radiation characterisation and studies. These facilities, primarily used during Single Event Effect (SEE) testing and detector calibrations, have proton energies and ions similar to those in space. For protons, the energy range of 10 to 300 MeV is covered, and for ions, the LET range of 1 to 100 MeV/(mg/cm^2). Equipped with dedicated test chambers, dosimetry boxes and user interface capabilities, efficient and low cost radiation testing can be carried out routinely.

In general, an SEU is the effect of an ion or proton hit that causes a memory cell (or bi-stable element) to change state – either from 1 to 0 or from 0 to 1. However, depending on the device technology or function, other effects can also occur, such as single event latchup (SEL), single event burnout (SEB), single event functional interrupt (SEFI), or single event transient (SET). These SEE effects are all triggered by charged particles crossing sensitive regions of a device.

The first facility, the Proton Irradiation Facility (PIF) at the Paul Scherrer Institut (PSI), Villigen, Switzerland, was developed primarily for proton testing. Following commissioning in 1992, the ownership of the PIF was transferred back to PSI with the agreement that PSI should maintain, operate and further develop the facility. The utilisation agreement (annually renewed within a five-year period) also provides priority beam time allocations and preferential hourly rates for ESA, for ESA industrial contractors, research institutes and other interested users.

The second facility, the Heavy ion Irradiation Facility (HIF) was developed at the Centre de Recherches du Cyclotron (CRC) of the Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium. The HIF was commissioned in November 1996 and transferred back to UCL with a similar agreement to that for the PIF at PSI.

The third facility, the RADiation Effects Facility (RADEF) at the University of Jyväskylä (JYFL), Jyväskylä, Finland, has been under ESA development since April 2004. Initial test campaigns have shown that the heavy ion cocktail available at the RADEF is of great importance for future testing, as it offers a range of complementary features not available at the HIF at UCL. The main advantage is the higher ion energy, which results in a much deeper ion penetration range, possibly a factor of 3 improvement, when compared with penetration ranges obtained at the HIF. In addition to the heavy ion beam line, a proton beam line will also be developed under this contract. Commissioning and utilisation is expected to take place in early 2005.

I. Proton Irradiation Facility (PIF) at PSI

The PIF, constructed in cooperation between PSI and ESA, has been used extensively by the space community as well as by research teams since May 1992. Initially, irradiation experiments were performed in the large Nucleon Area (NA2) using protons of energies between 35 and 300 MeV. Later requirements for device testing at energies of 10 MeV or lower were also met by construction of the low energy facility in the biomedical OPTIS (Ophthalmologic Proton Therapy Installation Switzerland) area. The low energy PIF provides high proton fluxes over the energy range of 6 to 71 MeV. Using both the high and low energy PIFs, the full range of energies relevant for space applications can be covered. The two sites are similarly designed and can be readily tailored to individual user requirements and test approaches.

High Energy PIF

The proton beam delivered to the NA-Hall has an initial energy of 590 MeV. Before it is guided to the present temporary irradiation location (NA3) it is reduced to 254 MeV with a maximum proton intensity of about 1 nA. Degraders, aluminium plates of different thickness, are used to lower the initial proton energy. A computer interface controls the plate positions remotely and allows changing of the beam energy within a fraction of a second. Irradiated devices are mounted on a standard frame fixed on a movable XY table. A visible laser system allows quick alignment of irradiation positions, and further flux measurements and beam calibrations are carried out via ionisation chambers and plastic detectors. The irradiation procedure, supervised by computers, is fully automatic. Both irradiation position and selection of the proton energy are set from the measurement room, as well as all beam settings and controls.

In general, the whole facility operation and the data acquisition system are designed in a user-friendly manner, allowing experimenters to run their tests mostly by themselves. The involvement of PIF/Cyclotron operators is required only during setup and calibration or in special cases.

Low Energy PIF

The low energy PIF, initially operated from the OPTIS area, has now moved to a dedicated site nearby. It partially uses the same simple and reliable beam optics as designed for OPTIS, but with small modifications to the last part of the beam line. In general, the low energy PIF is designed in a similar manner to the high energy PIF. However, due to much better shielding and lower proton energies, there is no problem with delivery of higher particle intensities (10 nA).

A typical PIF beam preparation, including beam optics settings and flux calibration, usually requires about two hours.

Glossary of Terms

LET — Linear Energy Transfer (in MeV/(mg/cm2)): the average energy deposited by incident ions along their track, and a useful parameter to describe heavy ion properties (whereas energy (in MeV) is enough for protons)

Cross section (cm^2): — defined as the number of observed events divided by the total number of incident ions at a given LET; also called fluence (particles/cm2)

Glossary of the most common Single Event Effects (SEE):

Non- destructive effects

SEU: single event upset (or soft error), i.e. the logic state of a memory cell is changed

SHE: single hard error (stuck bit) i.e. memory cells stuck in a given logic state

SEFI: single event functional interrupt, i.e. the device turns to an undefined mode; a power reset is usually necessary to recover

SET: single event transient, i.e. transient signals mainly generated by analogue devices, that propagate in the circuit if not filtered

Destructive effects

SEL: single event latch-up

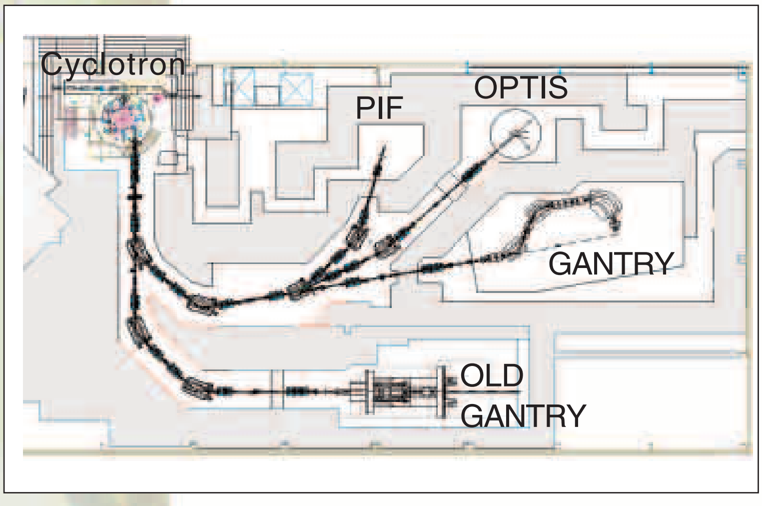
SEB: single event burnout affecting power MOSFETs

SEGR/ SEDR: single event gate or dielectric rupture,mainly affecting power MOSFETs and occasionally other devices (e.g. EEPROMs, FPGAs, some analogue devices, ...)

Future PIF Area Under Construction

Proscan Project

In order to guarantee continuity of biomedical exposures and to ensure better potential for patient therapy, extensive development studies were started by the PSI Radiation Medical Group. They resulted in a proposal for construction of a new cyclotron and irradiation sites: the Proscan Project. Within this project, a dedicated area is also planned for experiments and component testing. This new PIF will merge the low and high facilities into one and provide a wide range of proton energies from 5 up to 255 MeV for its user. The construction works for the Proscan project started back in 2002. The new cyclotron together with the new PIF will be commissioned at the end of 2006.



An Overview of the Proscan Experimental Sites

PIF Main Features

A) General
- Irradiation takes place in air
- Flux/dosimetry ~5% absolute accuracy
- HIF-compatible sample frame is fixed on XY table

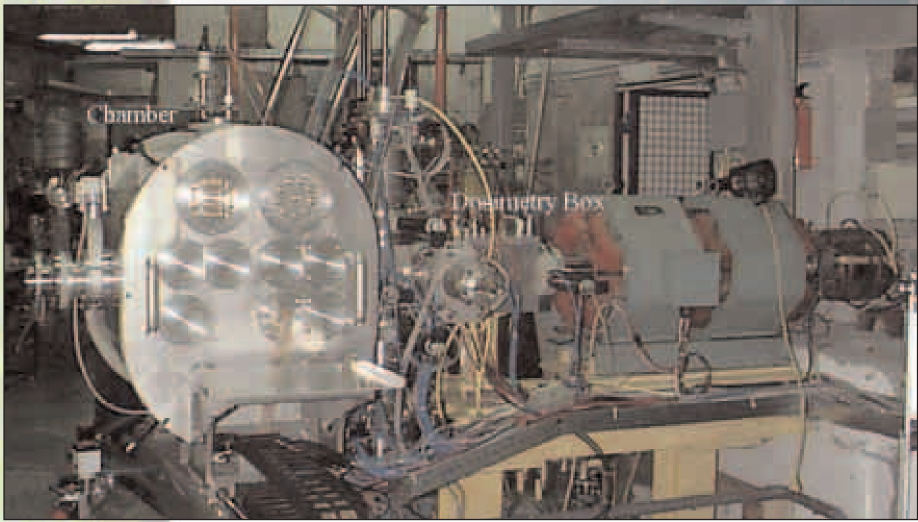
B) Low Energy PIF
- Energy range: 6 to 71 MeV
- Maximum proton flux : 5E8 p/cm^2/sec
- Beam spot ~50 mm diameter
- Beam uniformity > 90%

C) High Energy PIF
- Initial Energies: 254, 100 and 60 MeV
- Energy range: 30 to 254 MeV
- Maximum proton flux (254 MeV): 2.5E8 p/cm^2/sec
- Beam spot ~90 mm diameter
- Beam uniformity > 90%

For more details:
Dr. Wojtek Hajdas
Paul Scherrer Institut
CH-5232 Villigen, Switzerland
Tel. +41-(0)56-310-4212
Wojtek.Hajdas@psi.ch
pif.web.psi.ch

II. Heavy ion Irradiation Facility (HIF) at UCL

After an evaluation and assessment period in the mid-1990s, ESA initiated the setup of a permanent heavy ion beam line at the CYClotron of LOuvain



A View of the HIF Beam Line

tuning of the cyclotron magnetic field or by an RF frequency adjustment. This method yields a very short ion switching time – an attractive feature, since several ion types will be needed for SEE characterisation, which should cover the whole Linear Energy Transfer (LET) range of ions present in space. The main cocktail produced at UCL for SEE studies covers the LET range of 1.7 to 55.9 MeV/(mg/cm^2) as shown in Table 1. By tilting the device under test to 60°, an effective LET of 111.8 MeV/(mg/cm^2) can be reached.

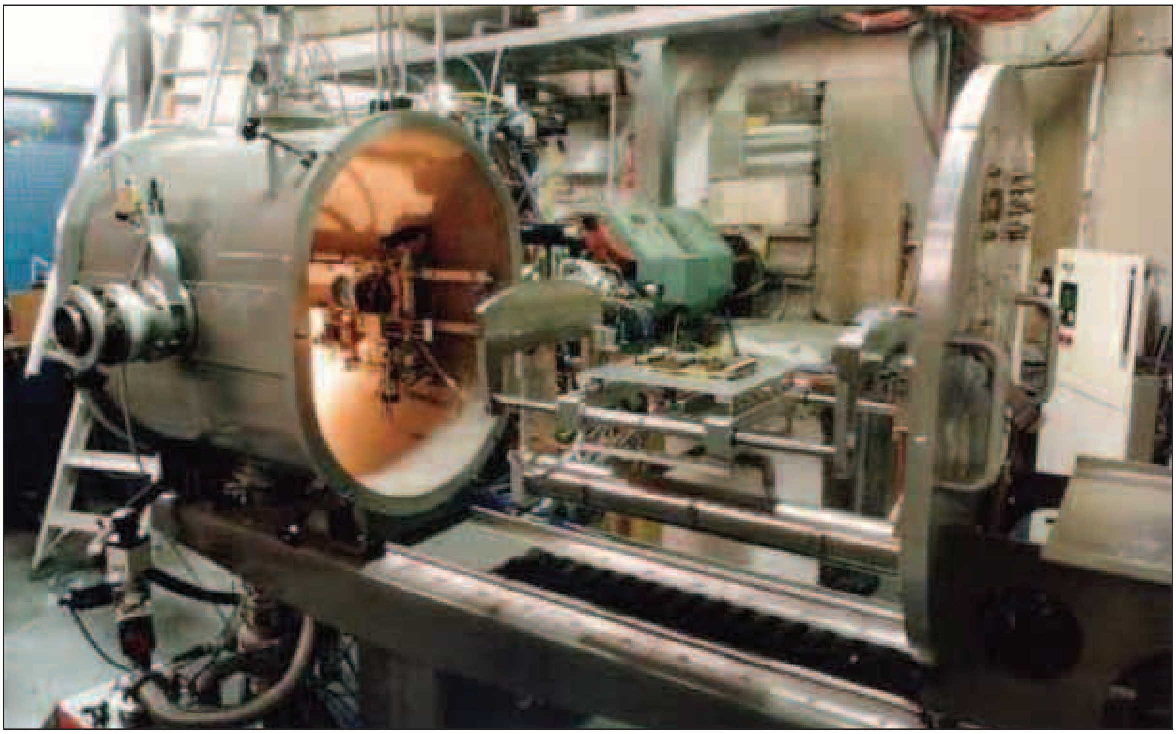
Table 1: HIF/UCL Ion Cocktail #1 produced for ESA

Ion Cocktail M/Q=4.94	Energy MeV	Range µm Si	LET MeV/(mg/cm^2)
$^{10}B^{2+}$	41	80	1.7
$^{15}N^{3+}$	62	64	2.97
$^{20}Ne^{4+}$	78	45	5.85
$^{40}Ar^{8+}$	150	42	14.1
$^{84}Kr^{17+}$	316	43	34.0
$^{132}Xe^{26+}$	459	43	55.9

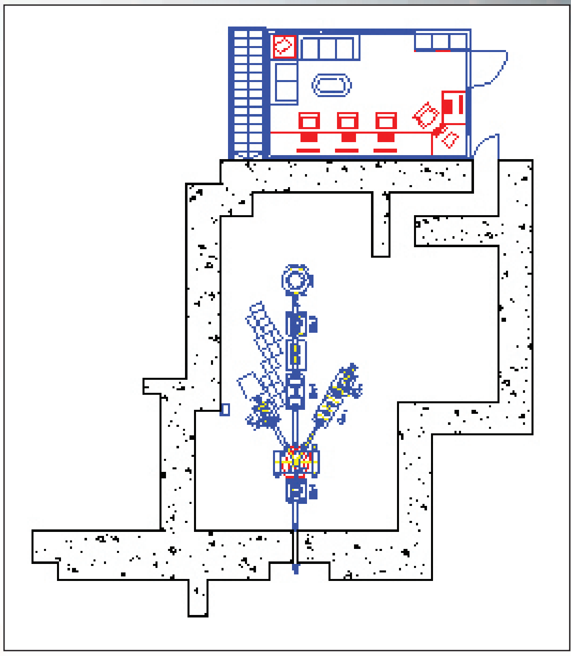
la NEuve (CYCLONE) at UCL. ESA and the space community have used this beam line HIF, dedicated for SEE testing, since 1996.

The HIF uses the multiparticle, variable-energy cyclotron CYCLONE. It is capable of accelerating protons up to 75 MeV, light and heavy ions up to Xenon (from 0.6 to 27.5 MeV/amu) and has an external Electron Cyclotron Resonance (ECR) ion source and beam transport systems to provide heavy ion beams. The ECR source allows the use of highly charged ions and ‘ion cocktails’. These are composed of ions with the same or very similar mass/charge ratios, both produced and accelerated at the same time. Once the ions are accelerated, the different ion types are separated by either a fine-

The HIF beam line is equipped with a large vacuum test chamber containing the test board frame and beam measuring systems. The test board frame is placed on a movable flange and is motor controlled



A View of the HIF Test Chamber and Test Table



RADEF New Cave Under Construction

in three directions, allowing alignment and tilt of irradiated devices.

The chamber is also equipped with a variable aperture iris, a light and a camera for device positioning. Device alignment is supported via a visible laser simulating the ion beam. On-line beam monitoring is carried out by a set of different detectors placed in the dosimetry box and in the test chamber. A user interface system, based on a computer MS Windows© environment, allows all test and irradiation details to be controlled and recorded. It has ten icon toolbars and four screens to help the user during a test:

- Board Position
- Data/Beam
- Beam Line
- Operator

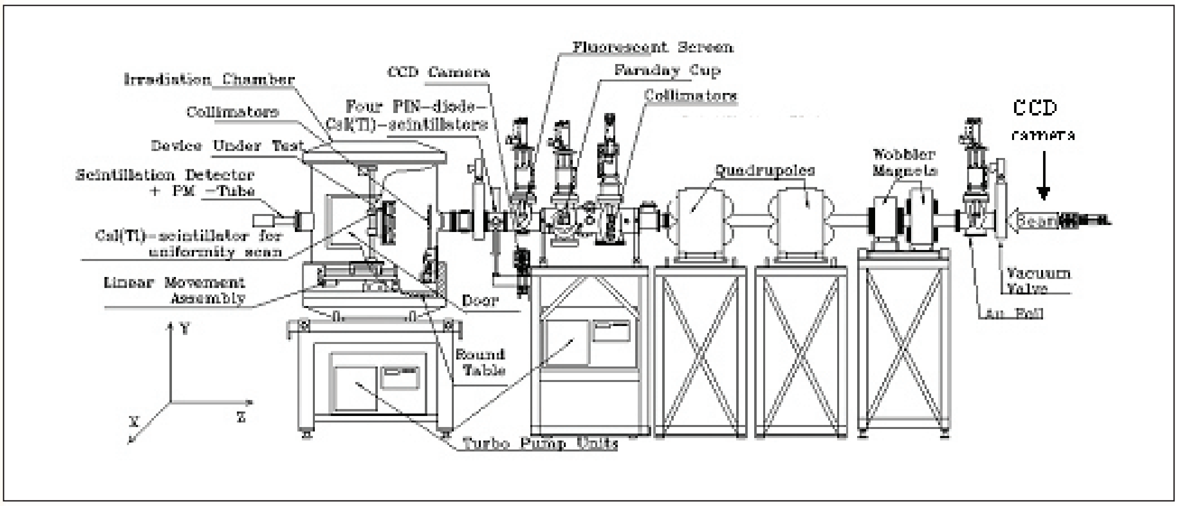
This control computer is placed in the experimenter room next to the beam line. As a new and attractive feature, flux adjustments can also be controlled from the experimenter room, and now a red light identifies when the beam is on!

In addition to the HIF beam line, CYCLONE has other beam lines, which can be used for radiation testing. The proton radiotherapy beam line, now modified for SEE testing, can provide proton energies of 10 to 75 MeV with a ±10% homogeneity over an area of 10 cm in diameter. The neutron research beam line, capable of producing quasi-monoenergetic neutron beams in the energy range of 25 to 70 MeV, have been used and assessed by several experimenter groups for SEE works. These two beam lines are not covered under the present ESA contract but are available directly from UCL/CRC.

For more information, contact:
Guy Berger
Université Catholique de Louvain
Centre de Recherches du Cyclotron
B-1348 Louvain-la-Neuve, Belgium
Tel. +32-(0)10-473225
Berger@cyc.ucl.ac.be
www.cyc.ucl.ac.be

III. RADiation Effects Facility (RADEF) at Jyväskylä

The increasing demand for radiation testing at accelerators attracted ESA and the space community to the RADEF some years ago. Initial test campaigns showed capabilities at RADEF that were not present at the HIF. Ions initially available were assessed and complemented with new types. Higher ion energies resulting in much deeper ion penetration ranges allowed successful reverse side



A Schematic of the Old RADIF Beam Line irradiation of thinned Integrated Circuits (ICs). Recognising that even more energetic ions could be produced and the need for increased usability of the present setup, ESA placed a contract with the University of Jyväskylä (JYFL) for the development of a 'High Energy Heavy Ion Test Facility for Component Radiation Studies'. This contract, running for a five-year period, consists of an initial development phase and a later utilisation phase. The development phase started in Q1 2004, with the commissioning and utilisation to take place in early 2005.

The K-130 cyclotron at JYFL is a versatile, sector-focused accelerator of beams ranging from Hydrogen to Xenon equipped with two ECR sources designed for high-charge-state heavy ions, and a multicusp ion source for intense proton beams. In conjunction with the two ECR sources, the cyclotron can run ion cocktails which allow a fast change of ions as needed for SEE studies. Earlier ion cocktails used covered a LET range of 2.0 to 62.0 MeV/(mg/cm2) with penetration ranges in Si of 57 to 44 µm respectively. A second cocktail covered a LET range of 2.0 to 29.4 MeV/(mg/cm2) with penetration ranges in Si of 208 to 99 µm respectively. New development goals will be to produce even higher penetration ion cocktails as shown in Table 2.

Table 2: Examples of high penetration cocktails

Ion	Energy [MeV]	LET [MeVcm^2/mg]	Range [μm]	Source
$^{14}N^{4+}$	149	1.5	258	6.4GHz
$^{21}Ne^{6+}$	223	3.3	198	6.4GHz
$^{28}Si^{8+}$	297	5.6	158	6.4GHz
$^{56}Fe^{16+}$	594	16.7	123	6.4GHz
$^{84}Kr^{15+}$	891	28.5	118	14GHz
$^{115}In^{33+}$	1231	43.7	109	14GHz

Ion	Energy [MeV]	LET [MeVcm^2/mg]	Range [mm]	Prod. Method
$^{4}He^{2+}$	130	0.056	5.56	Gas
$^{14}N^{7+}$	455	0.69	1.61	Gas
$^{16}O^{8+}$	520	0.90	1.43	Gas
$^{20}Ne^{10+}$	650	1.40	1.15	Gas

Another goal is to increase the usability of the facility from its present setup. This includes modifications to the beam line, to the test chamber and to the user interface. In addition to these improvements, a new test site will also be furnished. Altogether these improvements are needed in order to run the RADEF efficiently and in a user-friendly manner when performing SEE testing.

Worth mentioning are the improvements around the user interface. The users will get a chance to log into the local LAN network which will be built for RADEF users. All beam details will be displayed on a common screen and can be available on each user's monitor. Even control of the beam will be possible from one of the users' computers.

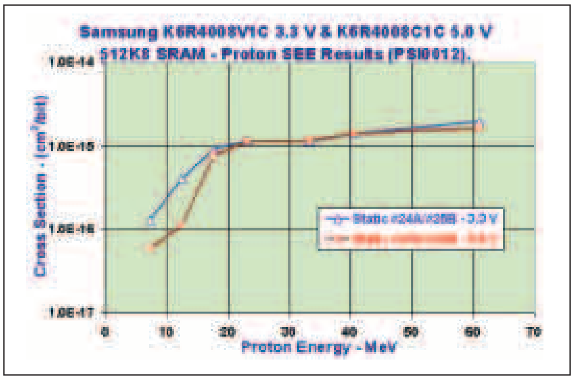
In addition to heavy ions, protons also play an important role in causing radiation SEE events. Therefore, a new proton beam line will also be installed within the new RADEF cave. This offers an extra option for users to perform proton SEE tests during the same test campaign. The same test setup and test equipment as used for the heavy ion test just needs to be moved to the proton beam line. The maximum proton energy available will be 65 MeV.

For more information, contact:

Dr. Ari Virtanen
University of Jyväskylä
FIN-40014 Jyväskylä, Finland
Tel. +358-(0)14-2602358
Ari.Virtanen@phys.jyu.fi
www.phys.jyu.fi/research/applications/SEEstation/

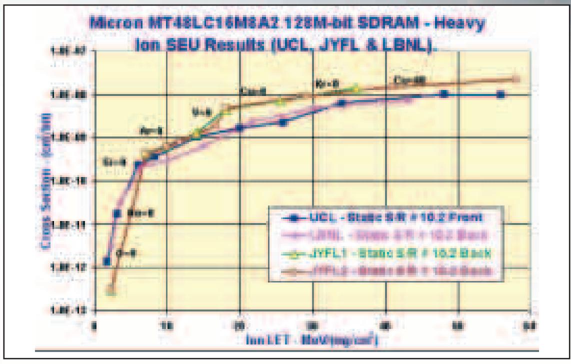
IV. Examples of SEU results

In order to illustrate how a typical SEU characterisation curve would look, earlier and recent heavy ion SEU data taken on Micron 128Mbit SDRAMs are shown in the figure below.



A comparison of SEU data taken at UCL and RADEF

Here SEU results are presented in a graphical form as SEU cross section (cm^2/bit) sensitivity versus ion LET (MeV/(mg/cm^2)). Front irradiated SEU data obtained at the HIF, Belgium, are compared with reverse side irradiation data (taken on thinned devices) at RADEF, Finland, and from a reference run at the LBNL, Berkeley, USA. Considering the variability in test setup and test mode, fairly good correlation can be reported between the three



Illustrates the move sensitive behaviour of the 3.3 V device to proton energy

facilities and modes of testing. With an SEU threshold around a LET of 1.5 MeV/(mg/cm²) and a saturated cross-section sensitivity of about 1 to 2E-8 cm²/bit, this Micron device shows a fairly common SEU behaviour as one would expect from a memory of that size.

The proton example is taken from some tests performed at PSI on Samsung 512K8 SRAMs at 3.3 V and at 5.0 V with SEU sensitivities as shown in the figure.

Please note that the SEU cross section results per cm² per bit are here presented versus proton energy in MeV. Please also note the sensitivity scale, with both devices having a saturated cross section level of about 1 to 2E-15 cm²/bit, but the 3.3 V having a lower threshold value, thus being the more SEU sensitive type. Finally, also notice the proton energy used which allowed all tests to be carried out at the low energy PIF.

More information about these radiation facilities can be obtained from:

Reno.Harboe.Sorensen@esa.int

Published by: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel. (31) 71 565 3400 - Fax (31) 71 565 5433

Editor: Karen Fletcher

Layout: Eva Ekstrand & Jules Perel

To change your subscription details, please contact one of the editorial board.