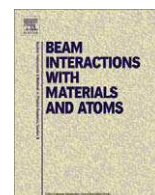




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# Charge cluster distribution in nanosites traversed by a single ionizing particle – An experimental approach

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## ABSTRACT

A method for modeling charge cluster formation by a single ionizing particle in nanoelectronic structures of few nanometres size is presented. The method is based on experimental modeling of charge formation in the equivalent gaseous nanosites irradiated by single charged particles and the subsequent scaling procedure to a needed medium. Propane irradiated by alpha particles is presented as an example.

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## 1. Introduction

In nanosites, such as DNA molecules or nanoelectronic structures, ionizing radiation induces elementary electric charges in the form of single or clustered charges. In living cells, radiation may cause single or double strand breaks (reparable or not reparable). In nanoelectronic elements radiation effects may be manifested by a large diversity of secondary effects, so-called single-event effects (SEE), depending on the hit region and on the type of interacting charged particles. There are several reports [1–3] on the formation of a single-event upset (SEU) in microelectronic devices caused by charged particles (cosmic rays, particles emitted in solar events, alpha particles from the contaminated materials with the natural radionuclides). As the size of the elements of electronic circuits are constantly decreasing (currently approaching a few nanometres), their capacity also decreases as does the charge necessary to manifest a SEE. It is only a matter of time until elementary circuits of RAM will attain a few nanometers in size. At these nanometre-sizes, single-event effects are of particular importance. As, at present, no such single nanometer-sized electronic structures exist, the only way to study the charge generation issue is by mathematical or experimental modeling. Experimental approaches [4] have recently become available for studying such topics. In these experiments, the nanometre-sized electronic structures were replaced by nanometre-sized gas targets. Here, nitrogen and propane appeared to be the most convenient media. Such ap-

proach was successfully applied in the microdosimetry devices as described extensively by Bradley, Rosenfeld and Zaider in [5]. The ability to obtain experimental data on the distribution of ionization clusters formed by charged particles within cylindrical volumes with sizes of up to  $1.3 \mu\text{g}/\text{cm}^2$  (13 nm at unit density) was shown in [6].

The present paper proposes a new experimental method for elucidating the spectrum of charges generated by a single charged particle in a nanometre-sized organic or silicon structure, by modeling the corresponding process in propane. Here, the main emphasis is placed on the formation of charge clusters caused by 3.8 MeV alpha particles in propane, as well as on the derivation of a scaling procedure that can be used to convert the results of the measurements to the charge formation in silicon and organic solids.

## 2. Material and methods

### 2.1. Experimental modeling of nanometre-size targets

It is assumed in this paper that ionization processes at a nanometre level can be modeled in a gas cavity of appropriate size. A gas cavity, which simulates a nanometre size volume (at unit density) was created as shown in Fig. 1(A).

A simulated nanometre size target (SNS) was obtained by injecting a pulse of propane into the interaction chamber (IC). The IC volume has a cylindrical form, 10 mm in diameter and 10 mm in height, with  $1 \text{ mg}/\text{cm}^2$  Mylar foils walls. The gas jet was created by the pulse operated valve PZ that injects gas from a volume  $R$  over the valve, through a nozzle with a 1 mm diameter

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