COMPARATIVE ANALYSIS OF TWO AND THREE CHANNEL HYPERVELOCITY DUST DETECTORS. S. Nambiar[1*], J. P. Pabari[1], Rashmi[1], S. Jitarwal[1], K. Acharyya[1], S. M. K. Praneeth[2], R. Singh[3] and D. Kumar[4]. [1]Physical Research Laboratory, Navrangpura, Ahmedabad-380009, INDIA. *Email: srirag@prl.res.in. [2]Space Application Centre, Ahmedabad, INDIA. [3]Institute of Plasma Research, Gandhinagar, INDIA. [4]BITS-Pilani, Hyderabad, INDIA.

Introduction: Ever-evolving interplanetary dust particles are a great source of knowledge about the history of our solar system. A study on the distribution of particles in a planetary system can help in detection of exoplanets as well [1]. A dust detector is proposed for future planetary missions, which will study the dust properties like mass, velocity and flux in interplanetary space in our solar system [2]. The detector design allows the capture of ions and electrons generated on the impact of a particle, using biased electrostatic collectors. The efficiency to capture these impact generated particles depends on the bias voltage applied and the configuration in which they are applied, other than the detector geometry. The SIMION software allows simulation of charged particles under a predefined electric field [3]. Here, simulations are carried out using the software to optimize and determine the best possible detector configuration giving maximum efficiency.

The Impact Process and Detector Configuration: The interplanetary dust particles travel at hypervelocity i.e. speed more than 1 km/s and evolve under the effect of gravitational force, Poyting Robertson drag and radiation pressure. An impact ionization dust detector makes use of this hyper-velocity to understand the particle properties. A particle on hitting the metal target of the detector at this velocity generates plasma, of which the ions and electrons are captured separately to measure the particle mass and velocity. The charged particles are collected using voltage bias applied to collector plates.

Figure 1 shows the detector design, where the highlighted plates depict four collector plates sitting above the target plates at the bottom. One of the meshes at top of the detector is negatively biased to deflect away low-energy solar wind electrons while the other mesh shields the electric field. The number of ions or electrons collected depends on the configuration and the position of impact on the target plate as well. Here we consider two configurations: (a) Two channel, where the target is grounded and all collector plates are biased either negatively or positively (hereon referred as case 2ch_N and 2ch_P respectively) (b) Three channel (hereon referred as case 3ch), where the target is grounded while two collector plates are biased positively and two negatively. Igenbergs et al. [4] used a three channel configuration for Mars Dust Counter (MDC) and Sasaki et al. [5] proposed a meshed two channel detector. The applied voltage should be such that it is able to separate out the ions and electrons in the plasma and at the same time keep the overall detection efficiency high.

Simulation Method and Parameters: SIMION software allows simulation of ions within a defined geometry and electric field. The dust detector geometry was imported to the software and appropriate bias voltage was applied. The charged particles, ions and electrons, are defined with the following parameters as initial condition: (a) Particle charge: One electron charge magnitude for electron and ion both. (b) Particle mass: 179 amu for ions, considering gold as target material. (c) Particle position and distribution: Simulation was carried out for all positions to cover the entire target plate of 230 mm × 230 mm area with 25 mm spatial resolution, while the distribution was taken as circular, centered at the position of each impact. (d) Particle velocity: Is provided in the form of direction and kinetic energy. The direction is given as a cone facing normal to target with a 45° half angle. A kinetic energy of 1 eV is taken for both ions and electrons [6, 7].

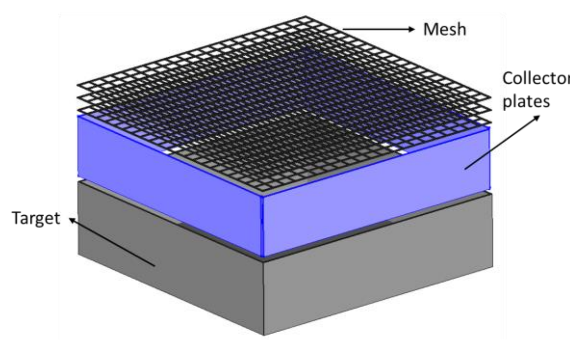

Figure 1: Dust Detector configuration

The ions and electrons are then allowed to flow in the electric field of the detector and their terminating location is recorded. Based on the fraction of ions and electrons which are captured at the appropriate location, efficiency is determined for each impact location. The simulation is repeated for all impact positions with 10^3 ions and electrons for bias voltage between 50 V and 600 V with steps of 50 V. Since, each charged particle is simulated individually, the effect of plasma generated by the impact is not considered here. This, however, does impact the comparison between different detector bias configurations.

Simulation Results: A contour plot was generated using the capture efficiency of impact generated charged particles, which is shown in figure 2 for the case of two channel configuration. The left pane shows the efficiency for the ion channel of the 2ch_N setup and the right pane for the electron channel of the 2ch_P setup, for a bias voltage of 200V. The contour is divided into following three sections: (i) Efficiency ≥75% represented by yellow (ii) Efficiency between 50% and 75% represented by blue and (iii) Efficiency <50% represented by white. For the case of 2ch_N, all the electrons are captured by the grounded target plate irrespective of impact position. The same is true for ions in the 2ch_P case.

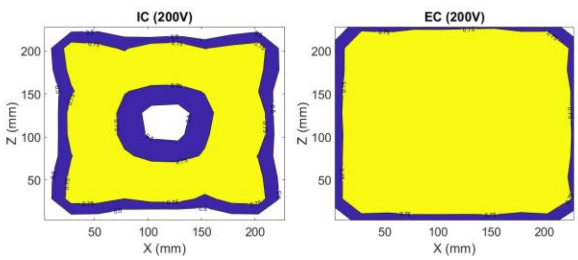

Figure 2: Capture efficiency contour plot for the cases 2ch_N and 2ch_P for a bias voltage of 200V.

As observed from Table 1, the relative area for the case 2ch_P is highest as compared to other configurations. The case of 2ch_N shows a strong dependency of efficiency on voltage bias. This is clear from figure 3, where the effective efficiency with bias voltage is plotted. 2ch_P relatively remains constant over the entire voltage range. 3ch configuration gives relatively lower efficiency and shows dependency on bias voltage as well.

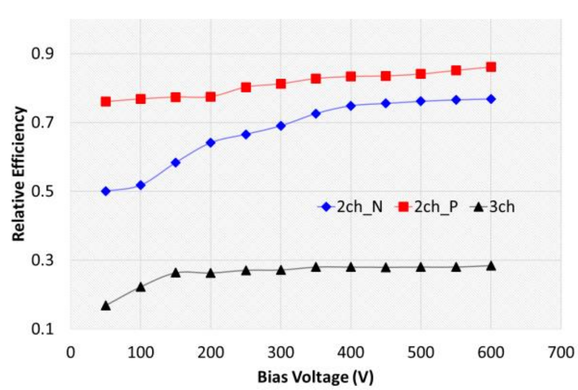

Figure 3: Efficiency vs bias voltage for two channel configuration

Table 1: Relative area with voltage bias with efficiency ≥75% for all configurations.

Voltage	Three Channel		Two Channel	
	EC	IC	2ch_N	2ch_P
50	0.29	0.36	0.00	0.63
100	0.36	0.44	0.09	0.64
150	0.45	0.50	0.31	0.64
200	0.47	0.49	0.45	0.64
250	0.50	0.50	0.49	0.70
300	0.50	0.51	0.53	0.72
350	0.52	0.52	0.60	0.75
400	0.52	0.52	0.64	0.76
450	0.52	0.52	0.64	0.76
500	0.52	0.52	0.64	0.77
550	0.52	0.52	0.64	0.79
600	0.52	0.53	0.64	0.81

Summary and Implications: The comparison between three channel configuration and two channel configuration shows that the latter gives better capture efficiency owing to the electric field being able to capture all the electrons generated from the impact. Between the cases 2ch_N and 2ch_P, 2ch_P shows better efficiency. The ions being heavier, are easily captured by the target which is grounded whereas the electrons are effectively captured by collector plates. In the case of 2ch_N, the capture efficiency strongly depends on the bias voltage, with higher voltage giving higher efficiency. Hence, the two channel configuration with a grounded target and positively biased collector plates should be selected for maximum capture efficiency. However, a limitation of this configuration compared to three channel detector is the lack of third channel information, which provides the indication of the start of event and also helps in distinguishing real events from noise. The two channel option can be explored for future models of the detector.

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