KFK-292

KERNFORSCHUNGSZENTRUM

KARLSRUHE

Oktober 1964

KFK 292

Institut für Kernverfahrenstechnik

Production of Plasma by Injection of Charged Hydrogen Clusters

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⁊ ıᴌODUCTION OF PLASMA BY INJECTION OF CHARGED HYDROGEN CLUSTERS

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Received 19 September 1964

For several years we have investigated the possibility of the use of charged molecular clusters for injection into thermonuclear devices [1,2]. The use of charged granules of solid hydrogen has also been considered by Prevot et al. [3]. It was shown experimentally that charged hydrogen clusters in the mass range of practical interest can be produced [2] by ionizing beams of condensed hydrogen [4]. The charged clusters may then be accelerated to the desired injection energy. The motives for our investigations are the following considerations:

1. Because of their low specific charge, clusters will easily penetrate strong magnetic fields into the interior of the confinement geometry much like neutral particles.
2. The trapping efficiency is expected to increase compared with neutral atom injection.
3. The broad mass distribution of clusters [2] which are accelerated by a constant voltage produces a correspondingly broad energy spectrum of plasma particles that may result in enhanced stability of trapped plasma.
4. Space charge problems during and after acceleration are greatly diminished owing to the low charge to mass ratio.
5. The partial loss of high energy particles in the production of a neutral beam by charge exchange or dissociation is avoided. There is, at least in principle, no loss of particles once the clusters are accelerated.

Trapping efficiency is expected to increase because (A) there are molecules injected instead of atoms and (B) these molecules are clustered.

A. The inization cross section of a hydrogen molecule is approximately twice that of an atom. Trapped molecular ions dissociate according to the processes $H_2^+ \rightarrow H^+ + H^0$ (cross section σ_1) and $H_2^+ \rightarrow 2H^+ + e$ (cross section σ_2). Thus the effective trapping rate will be increased by a factor $2 - \sigma_1/(\sigma_1 + \sigma_2)$.

Charge exchange between trapped plasma ions and injected beam does contribute to trapping, unlike in the case of atom injection [5]. For each plasma ion lost in a charge exchanging collision $(2\sigma_2 + \sigma_1)/(\sigma_2 + \sigma_1)$ new ions are trapped.

B. In the case of single particle injection, atoms or molecules, a plasma ion gets immediately lost after charge exchange with a beam particle, while in our case it still has to cross the rest of the cluster and has a chance to ionize more molecules before it gets lots. Thus the ratio of particles trapped to those lost in beam-plasma interaction is increased.

A calculation of plasma build-up by collisional trapping only was carried out under simplifying

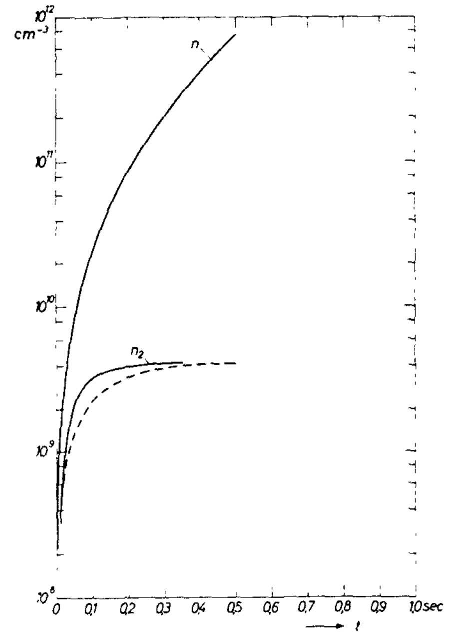

Fig. 1. Time dependence of plasma growth.
Solid curve: Injection of H_2^0 } $I/I_c = 0.8$
Broken curve: Injection of H^0 }
Velocity of injected particles: 1.7×10^8 cm/sec.
Neutral background: 10^{-8} Torr hydrogen gas.

assumptions for the case of molecular injection. The two coupled differential equations for the densities n_2 and n_1 of molecular and atomic ions resp. were solved numerically. The cross sections used were those of Schwirzke [6] and Sweetman [7]. Fig. 1 shows the time dependent solution for $I/I_c = 0.8$. For comparison the broken curve was calculated for atom injection under the same assumptions. The symbols used are: I: injected current (atoms/sec), I_c: critical current for exponential growth in the case of *atom* injection (atoms/sec), $n = n_1 + 2n_2$: density of trapped hydrogen nuclei. For the energy chosen the critical current for exponential build up with molecular injection turns out to be 70% of the corresponding value for atomic injection.

The influence of clustering was calculated assuming that a beam of clusters of 300 molecules each is injected. The combined effect of molecular injection and clustering reduces the critical current to 0.4 I_c, corresponding to an increase of trapping efficiency by a factor of 2.5.

I am indebted to Dr. Sweetman who kindly furnished graphs of dissociation cross sections prior to publication.

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