

# The Generation of a Highly Uniform and Dense Plasma by Distributing Hollow-Cathode on the Electrode Surface

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## Abstract

A highly uniform and dense plasma has been produced successfully in a parallel-plate reactor with a uniformity of  $\pm 2\%$ . Our approach is based on modifying the distribution of the current density over the flat-electrode surface by incorporating the hollow cathodes in order to compensate the non-uniform part of the current distribution.

Experiments have been carried out in a vacuum chamber of outer diameter of 300 mm with two parallel electrodes (200 mm in dia., Al) separated by 35 mm, one of which is a hollow-cathode type. The working gas pressure ranges from 0.01 to 0.2 Torr of Ar. The radial ion current distribution has been measured at distances of 10, 20 and 30 mm from the surface of the hollow-cathode using a negatively biased double probe.

## Introduction

In recent years, there has been growing interest in the subject of plasma-surface interactions, such as plasma etching, plasma deposition and surface modification of materials, resulting from the bombardment of exposed surfaces by the active ionic and neutral species.

In a D.C. glow discharge, in principle, the abnormal glow regime assures the uniformity of the current-distribution over the electrode surface because the whole surface is covered with the glow. But the uniformity in the radial direction is often degraded by the presence of so-called edge effects and the flow pattern of the operating gas. In an R.F. glow discharge, in addition to these factors, A.C. current conduction through the insulating surface which often surrounds the periphery of the electrode or chamber wall affects the uniformity.

The aims of this paper are to demonstrate techniques capable of improving the uniformity while at the same time producing a high density-plasma. The D.C. hollow-cathode discharge, when operated at low pressures, exhibits a considerable increase of the discharge current, the sustaining voltage remaining constant. This hollow-cathode effect has been observed to give a current increase of up to 900 fold<sup>1,2)</sup>.

A further current enhancement will take place if the two parallel-plates are replaced by a hollow cylinder. Therefore, the R.F.-powered, hollow-cathode discharge is one discharge source capable of producing high density plasmas. When the hollow-cathodes are distributed

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