Microwave coaxial plasma source (physics and applications)

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New microwave plasma source "Microwave Arc" (MA) based on the revealed strong nonlinear phenomena manifested in a high pressure microwave gas discharge physics is described. Main principles of its operation are presented. Experiments intended to the such a plasmachemical technology like nanocrystalline silicon production with help of MA plasmatron are described.

Investigations of fundamental problems of high-pressure microwave discharges, which carried out at the General Physics Institute of RAS (GPI), made it possible to create a new plasma source – coaxial microwave plasmatron MWA ("microwave arc"). Scheme of MWA is shown on the Fig. 1.

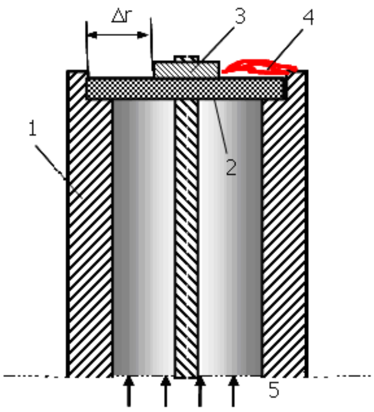

Fig. 1. Scheme of "Microwave Arc". 1-outer electrode; 2-quartz disk; 3-inner electrode; 4-discharge channels; 5-microwave radiation.

The following physical phenomena revealed and investigated at the GPI, provided the basis for MWA:

- Low-threshold microwave discharges (sparks) at a metal-dielectric interface and
-Thermal-ionization instability attaining strongly nonlinear phase.

Construction of MWA permits to realize both these phenomena and to generate dense and relatively hot nonequilibrium plasmoids, radiating intense UV.

Experiments dedicated to the application of MWA have been performed. Among such applications are following:

(i) MWA as an alternative to the usual (standard) spark plugs in combustion engines and aviation engines;
(ii) MWA as a basis part of plasmachemical reactor dedicated to the nanocrystalline silicon production.

It was shown that in the case of the use of the MWA igniter, the stable ignition range is expended to lean fuel/air mixtures or larger air flow velocities.

For nanocrystalline Si production experiments have been performed in a mixture of monosilane with argon at gas pressures of 100 Torr to atmospheric pressure. Scheme of experiment is shown on the Fig. 2.

The experimental device is a working chamber connected to a coaxial discharge initiator consisting of an inner (1) and outer (2) electrodes contacted with a quartz washer (3). The chamber (6) is made of quartz and it is convenient for observing the discharge behavior. The end flange also serves for the pumping out and admission of the gases at a prescribed pressure.

Discharge (4) originates at points of contact between the inner electrode and the quartz washer and, while propagating in the radial direction during the microwave pulse, closes the gap between the inner and outer electrodes. In this case, several constricted plasma channels may form during a microwave pulse. These channels are sources of high-energy ultraviolet light irradiating the surrounding plasma and thus creating the photoplasma (5), in which the process of monosilane decomposition with n-Si formation (9) is most efficient. Since the charge of the formed particle is positive and it moves toward lower electric potential region, a collector electrode (7) at a negative potential is inserted into the chamber.

For a mixture Ar (150 Torr)+SiH_4(50 Torr) at a specific energy release of 12.5 eV/molec and ~60% decomposition of SiH_4, the energy cost is estimated as 21 eV/molec. Under these conditions, we obtained nanosilicon, mostly in the form of crystalline particles of size 25-30 nm.

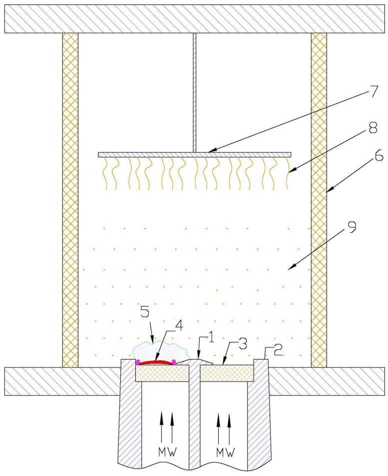

Fig.2. Scheme of experiment dedicated to nanocrystalline silicon production.