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DECOMPOSITION OF SF_6 IN THE PLASMA MEDIUM OF AN ELECTRON BEAM*

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Sulfur hexafluoride (SF_6) is commonly used as an etching/etching-aid gas in fabricating the submicrometer features of modern integrated circuits because it has a higher fluorine content than CF_4 but does not undergo polymerization. However, the destruction of SF_6 has attracted much interest because of the important environmental issues and the toxicity of sulfur compounds. Radio-frequency (RF) discharge plasma, which must be manipulated at low pressure, recently has become the most popular plasma technology used in the high-profit semiconductor industry, in both replicating patterns and depositing films. The discharge plasma can be manipulated at low substrate temperatures without changing its original properties and can replicate submicrometer patterns with anisotropic features. However, in the presence of an RF discharge, SF_6, acting as an etching/etching-aid gas, can be decomposed into lower fluorides of sulfur and can generate hazardous byproducts, such as S_2F_{10}, SO_2F_2, SOF_2, SOF_4, and SF_4. Particularly toxic is S_2F_{10}, which has an LC50. Because reducing or eliminating the toxicity of gaseous effluent from the RF discharge process is a serious concern.

In this work, plasmas in medium of an electron beam were used to decompose SF_6 [1-3]. The studies showed that in the conversion of sulfur hexafluoride plasma pulse the electron beam is realized effect. Mass spectrometric studies of the positive ion yield due to the electron impact ionization of sulfur hexafluoride molecules in the gas phase have been carried out. The exothermal reaction going is organized in the reactor volume. The oscillation-excited products of these reactions participate in the dissociation of initial halogenide molecules. The non-equilibrium plasma is formed due to the action of pulsed electron beam with the duration of not more than 10^{-9} s to the mixture of halogenides and gas-carrier. Nitrogen, hydrogen and oxygen are used as the gas-carrier. The processing of halogenides is performed by adding of diluent gas to the mixture of halogenide and gas-carrier up to the total pressure providing full absorption of nanosecond pulsed electron beam energy. The thermal dynamic modeling showed that in case of plasma of SF_6 and H_2 all the elements such as S, HF, H_2F_2 and SF_4 are stable products of decomposition of sulfur hexafluoride in the mixture with hydrogen. The calculations showed the possibility of condensed phase formation of sulfur monomer S, sulfur dimmer S2 and of other clusters. In our case, at the expense of dissociation of sulfur hexafluoride by electronic shock: $SF_6 + e \rightarrow S + 6F$ and dissociative adhesion of low-energy electrons: $SF_6 + e \rightarrow SF_6^- \rightarrow S + 6F$. The atomic fluorine is formed, which initiates reactions in a mixture with molecular hydrogen. The major reactions are: $H_2 + F = HF + H + 1{,}47$ eV. The energy which is released in the exothermic reaction can be spent for initial decomposition of sulfur hexafluoride. The technical result is in the fact that the energy-capacity of chemical element degradation to nanodispersed condition from its halogenide significantly decreases. The experiments are performed at the electron accelerator TEU-500. The parameters of electron beam are the following: electron energy is 400-500 keV, pulse duration at the half-height is 60 ns, frequency rate is up to 5 pulses per second, energy per pulsed is up to 200 J. The electron beam is injected to the closed reactor through the anode foil. The results allow one to define the range of the possible chemical compounds - reagents to carry out an efficient reaction, to determine the requirements to system and to chemical reactor, to estimate the efficiency of the technological process as a whole.

REFERENCES

[1] Parker RK, Anderson RE, Duncan CV. Plasma-induced field emission and the characteristics of high-current relativistic electron flow // Journal of Applied Physics. – 1974. – V. 4. – № 6. – P. 2463–2479.

[2] Mesyats GA. Pulsed Energy and Electronics. – M.: Nauka, 2004. (in Russian)

[3] Ezhov V.V., Vlasov V.A., Pushkarev A.I., Remnev G.E., Sosnovskiy S.A. Sulfur reductionfrom SF_6 by pulsed electronic beam // 8th Korea-Russia International Symposium on Science and Technology, Tomsk, 2004, v. 2, p. 212-215.