

Application of fluoride plasma for the formation of nanoscale structures on the surface of silicon

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The purpose of this work is to study the effect of the time of plasma-chemical treatment of silicon substrates in fluoride plasma. The plasma of sulfur hexafluoride (SF_6) was used as a source. An analysis was made of the obtained dependences of the roughness, height, and angle of inclination formed during etching, on the time of plasma-chemical treatment, and on the flow of fluorine-containing gas. The duration of treatment in fluorine-containing plasma affects the roughness of the etched surface and the geometry of the etched area, so with longer treatment in fluoride plasma, the roughness and angle of the resulting structure increase. The study of morphology was carried out on the installation of atomic force microscopy (AFM). It was found that as the time of plasma-chemical treatment increased, the angle of the etched structure increased, the dependence of the roughness on time had conventionally two segments, intensively increasing up to 60 sec. and an area with little changing roughness, but with a large dispersion. With an increase in the flow of fluorine-containing gas, the angle of the etched structure, the height of the structure, and the roughness of the etched surface increased linearly.

Keywords: plasma chemical etching, fluoride plasma, profiling of nanostructures, etching time, roughness.

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REFERENCES

1. B. D. Pant and U. S. Tandon, Plasma Chemistry and Plasma Processing **19**, 545 (1999).
2. B. E. Umirzakov, S. B. Donaev, R. M. Yorkulov, R. Kh. Ashurov and V. M. Rotshtein, Semiconductors, No. 4, 266 (2022).
3. A. M. Efremov, D. B. Murin, A. M. Sobolev et al., Russ Microelectron. **50**, 24 (2021).
4. J. Wu, X. Ye, J. Huang et al., J. Wuhan Univ. Technol.-Mat. Sci. **33**, 349 (2018).
5. V. I. Bachurin, M. O. Izyumov, I. I. Amirov et al., Bull. Russ. Acad. Sci. Phys. **82**, 127 (2018).
6. R. L. Bates, P. L. Stephan Thamban, M. J. Goeckner and L. J. Overzet, Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films **32(4)**, 0410302 (2014).

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7. S. S. Kaler, Q. Lou, V. M. Donnelly and D. J. Economou, Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films **34(4)**, 532 (2016).
 8. X. Man, N. Bao, Y. Hao, Y. Feng and X. Ma, Physica Status Solidi (a), No. **5**, 234 (2020).
 9. S. P. Malyukov, A. V. Sayenko and S. S. Zinovev, Proceedings – 2020 International Russian Automation Conference (RusAutoCon 2020), 368 (2020).
 10. A. V. Saenko, S. P. Malyukov and A. A. Rozhko, Applied Physics, No. 1, 19 (2022) [in Russian].
 11. K. Zekentes, J. Pezoldt and V. Veliadis, Materials Research Foundations **69**, 175 (2020).
 12. P. N. K. Deenapanray, C. S. Athukorala, D. Macdonald, W. E. Jellett, E. Franklin, V. E. Everett and A. W. Blakers, Progress in Photovoltaics: Research and Applications **14(7)**, 603 (2006).
 13. F. Gaboriau, G. Cartry, M.-C. Peignon and C. Cardinaud, IEEE Conference Record – Abstracts, 2002 IEEE International Conference on Plasma Science, 13597 (2002).
 14. H. S. Alvarez, F. H. Cioldin, A. R. Silva, L. C. J. Espinola, A. R. Vaz and J. A. Diniz, Journal of Microelectromechanical Systems **30(4)**, 668 (2021).
 15. V. S. Klimin, Y. V. Morozova, I. N. Kots, Z. E. Vakulov and O. A. Ageev, Russian Microelectronics **51(4)**, 236 (2022).
 16. I. N. Kots, V. V. Polyakova, Y. V. Morozova, A. S. Kolomiytsev, V. S. Klimin and O. A. Ageev, Russian Microelectronics **51(3)**, 126 (2022).
 17. V. N. Dzhuplin, V. S. Klimin, Y. V. Morozova, A. A. Rezvan, Z. E. Vakulov and O. A. Ageev, Russian Microelectronics **50(6)**, 412 (2021).
 18. Z. Vakulov, D. Khakhulin, A. Geldash, R. V. Tominov, V. S. Klimin, V. A. Smirnov and O. A. Ageev, Journal of Advanced Dielectrics **12(2)**, 2160019 (2022).
 19. Z. Vakulov, D. Khakhulin, E. Zamburg, A. Mikhaylichenko, V. A. Smirnov, R. V. Tominov, V. S. Klimin and O. A. Ageev, Materials **14(17)**, 4854 (2021).
 20. Z. Vakulov, A. Geldash, D. Khakhulin, M. Il'ina, O. Il'in, V. S. Klimin, V. N. Dzhuplin, B. Konoplev, Z. He and O. A. Ageev, Materials **13(18)**, 3984 (2020).