Proceedings of the 5th International Conference on Nanotechnology: Fundamentals and Applications
Prague, Czech Republic, August 11-13, 2014
Paper No. 148

The Development of New Inorganic Resists Based On Vanadium Oxides for Micro- and Nanoelectronics Applications

Vadim Kuroptev, Genrich Stefanovich
Petrozavodsk State University
33 Prospect Lenina str., Petrozavodsk, Russian Federation
v.a.kuroptev@gmail.com; gstef@yandex.ru

Extended Abstract

The major focus of the research conducted by the interdisciplinary laboratory of perspective materials development on the basis of nanocomposites (Institute of ICT and nanotechnologies of Petrozavodsk State University (Russian Federation)) was to fabricate, test and develop processes for inorganic resists enabling and accelerating the availability of advanced process technologies for pattern transfer of features with critical dimensions of 100 nanometers and less. The developed resists are composed of amorphous vanadium oxides thin films which exhibits the most important properties for submicron lithography – mainly high resolution, high sensitivity and high thermal and plasma stability.

Transition metals oxides, such as vanadium oxides, have demonstrated properties that put them ahead of alternative polymer and inorganic resists. These oxides have a wide variety of important properties that are relevant to resist applications. Many transition metals exhibit multiple oxidation states and individual oxides can undergo structural and phase transformations (Pergament, Stefanovich, 2013) under the action of different external perturbations (such as thermal, electron and ion bombardment or optical irradiation) which accounts for their high sensitivity.

In particular, amorphous transition metals oxides have extremely high resolution potential, and once exposed they become thermally and plasma stable, enabling their using in lithography. Our researchers have invented novel techniques for preparing metastable amorphous transition metals oxides suitable for resist applications.

We designed, tested and refined techniques (anodic oxidation (Chudnovskii et al., 1999), thermal evaporation, pulsed laser deposition (Cheremisin et al., 2009), RF magnetron sputtering) for the preparation, exposure, and development of amorphous vanadium oxides films which possess the high resolution, high sensitivity and other characteristics required for resist applications in submicron lithography. These films have led to the development of a new inorganic resist with sensitivities below 15 $\mu C/cm^2$ (for anodic oxides and electron-beam exposing), 200–300 $\mu C/cm^2$ (for oxides fabricated by vacuum methods and electron-beam exposing), 13 mJ/cm^2 (for oxides fabricated by vacuum methods and UV laser exposing); less than 100 nm resolution; and high thermal (heating up to 500° C) and plasma stability (low rate of etching in comparison with Si and SiO_2 in conventional dry processes (CF_4, SF_6, CHF_3)) in thin (~ 100 nm) films. Such parameters are a record for inorganic materials.

The structure, chemical and physical properties of vanadium oxides, as well as their alteration under electronic, photon and ion irradiation were investigated also. It has been established, that the greatest sensitivity is observed for the oxide with a stoichiometry close to VO_2 with metal-insulator transition (MIT), and having a metastable amorphous structure (Stefanovich et al., 2000). Under electronic, photon or ion irradiation of the film there is a set of parallel, coordinated and interrelated processes: excitation ofthe MIT; redox reactions on external and internal oxide borders, stabilizing the vanadium (IV) oxide metal phase; irreversible radiation stimulated crystallization.

Furthermore special features of vanadium oxides (electrical switching and forming, phase transition "metal–insulator" and etc.) determine promising using of it not only as resist material (especially for transition from development of microelectromechanical systems (MEMS) to nanoelectromechanical systems (NEMS)), but also as functional material simultaneously for fabrication of novel temperature and pressure sensors, diodes (Putrolaynen et al., 2007), transistors and memory elements (Lee et al., 2008).

This work was supported by the Strategic Development Program of Petrozavodsk State University (2012–2016) and Russian Federation Ministry of Education and Science as a part of a state program in the scientific field, projects № 2014/154, № 3.757.2014/K.

References

Cheremisin A., Putrolaynen V., Velichko A., Pergament A., Kuldin N., Grishin A. (2009). UV laser modification and selective ion-beam etching of amorphous vanadium pentoxide thin films. Physica Status Solidi A, 206, 1484–1487.

Chudnovskii F., Kikalov D., Pergament A., Stefanovich G. (1999). Electrical transport properties and switching in vanadium anodic oxides: effect of laser irradiation. Physica Status Solidi A, 172, 2, 391–395.

Lee M.-J., Kim S. I., Lee C. B., Yin H., Ahn S.-E., Kang B. S., Kim K. H., Park J. C., Kim C. J., Song I., Kim S. W., Stefanovich G., Lee J. H., Chung S. J., Kim Y. H., Park Y. (2008). Low-temperature-grown transition metal oxide based storage materials and oxide transistors for high density nonvolatile memory. Adv. Funct. Mater, 18, 1–7.

Pergament A., Stefanovich G. (2013). Comment on "metal-insulator" transition without structural phase transition in V_2O_5 film. Appl. Phys. Lett., 102, 176101.

Putrolaynen V., Velichko A., Pergament A., Cheremisin A., Grishin A. (2007). UV patterning of vanadium pentoxide films for device applications. J. Phys. D: Appl. Phys., 40, 5283–5286.

Stefanovich G., Pergament A., Stefanovich D. (2000). Electrical switching and Mott transition in VO_2. J. Phys.: Condens. matter, 12, 41, 8837–8845.