Conference Paper

Selection of Conductive Film Thickness for Submicron Metallization

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Abstract

The integration scale increase is accompanied by the proportional decrease of all sizes of elements of an integrated circuit (scaling law). As a result, the width and thickness of metallization conductors decrease. Depending on the topological norm, the thickness of metallization becomes less than 100 nm. The results of research on the effect of conductive film thickness on the basis of Al-Ti-Mo on resistance of layers are presented. Films with the thickness of d = 3–100 nm are obtained by electron evaporation. The critical thickness of metallization is defined, after the exceeding of which a sharp increase of layer resistance is observed. The effect of material metallization on the critical value of the thickness is determined. The carried out calculations and research of the reflexion factor of metal layers well coincide with the results of the experiments.

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1. Introduction

The development of high-speed, very large-scale integration circuits (VLSI) requires decreasing of all dimensions of elements, including the thickness of metallization. The conductive film metallization thickness has become less than 50 nm, and that of the diffusion barrier layers (DBL) has already reached 10 nm [1–4].

2. Materials and Methods

On a certain growth stage, a film consists of separate isles forming a reticulate structure first and then forming a continuous film. During the transition from an island film into a continuous one, its surface resistance becomes several orders higher. There is also an essential change in the optical transmission (reflection) spectrum [5–6].

The transition to submicronic metallization requires additional research in order to select critical metallization thickness. To solve this problem, electrical and optical measurements of conductive films based on aluminum and titanium with the thickness over the range of 10–100 nm were conducted.

The deposition of aluminum and titanium films on silicon plates was carried out by electron vacuum evaporation under the pressure of 10^{-5} Pa using an Orion-B installation with a velocity of 0.5 nm/s. The film thickness control was carried out by means of a quartz sensor with an accuracy of 0.1 nm.

Samples with various thicknesses of conductive films had good adhesion and a smooth surface.

The structure of the films was studied by means of a Certus Optic U atomic-power microscope.

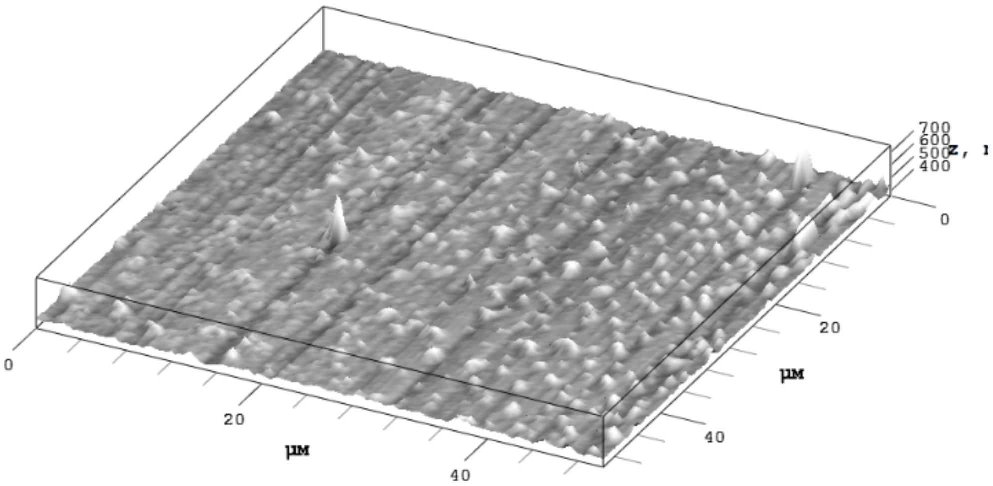
Received scans show a rough surface. With the growth of the film thickness from 10 nm to 100 nm, the roughness of aluminum increases from 10 nm to 40 nm, whereas the thickness of titanium decreases from 50 nm to 10 nm. This difference can be connected with the fact that during electron evaporation, the one-way reception of molecular flow causes a tendency to form a columnar structure in, for example, aluminum films.

The specific surface resistance of conductive films was measured by means of the four probe method. Results of this research are presented in Figure 2.

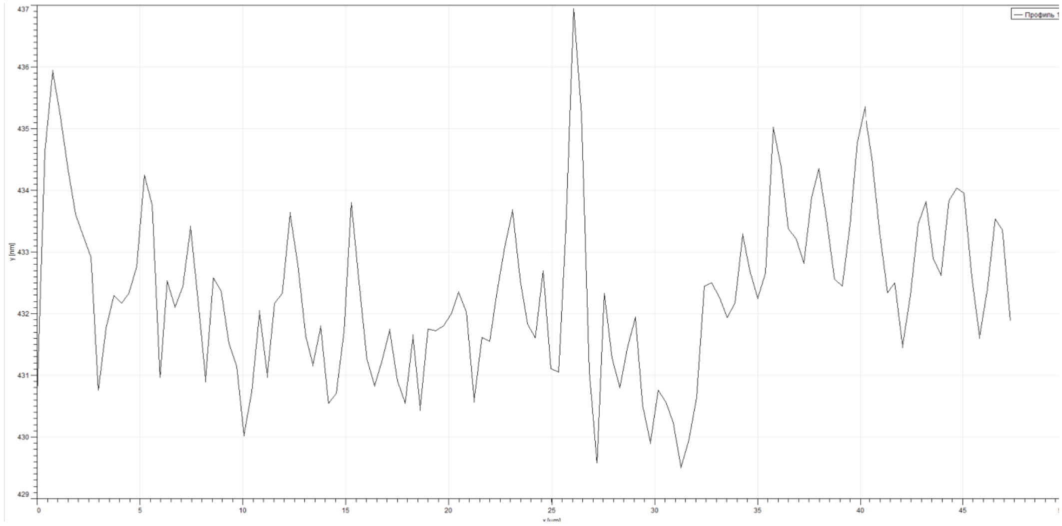
With the reduction in thickness of aluminum and titanium films, the specific surface resistance increases by approximately 20 times, that is, the known size effect is developed. This effect of films with submicronic sizes is caused by electron scattering on surfaces [7].

3. Results

The specific volume resistance for films with the thickness of 100 nm is 2–7 times higher than the resistance of the corresponding massive materials, depending on the conditions of sputtering and storage of samples. The conducted research allows us to approximately evaluate the critical thickness of conductive films so that the films with a metallization thickness lower than the critical one are technologically inexpedient to choose. Thus, the critical thickness is 25–30 nm for aluminum metallization and less than 40—50 nm for titanium metallization.



(a)



(b)

Figure 1: 3D-image (a) and a cross-section profile (b) of a sample of aluminum with 10 nm thickness.

4. Discussion

The obtained results were confirmed by the further optical research of the dependence of reflectance on film thickness. The calculation was conducted for the system 'silicon-film-air' in a wide range of wavelengths. Figure 2 presents the dependence of the radiation wavelength of 550 nm and with the angle of 45 degrees from film thickness. The thickness equal to zero corresponds to the silicon substrate.

The reflectance of aluminium films with the thickness of 100 nm is 0.924 and that of titanium films is 0.57. The calculation shows a sharp reduction of the reflectance of aluminium films at the thickness of less than 30 nm. A feeble change of the reflectance in this range for titanium films is observed.

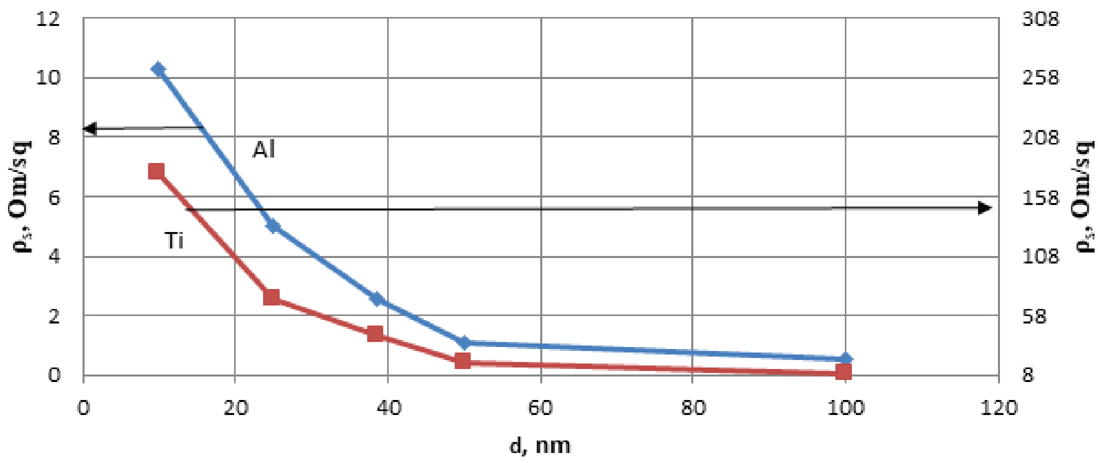


Figure 2: Dependence of specific surface resistance on the thickness of aluminum and titanium films.

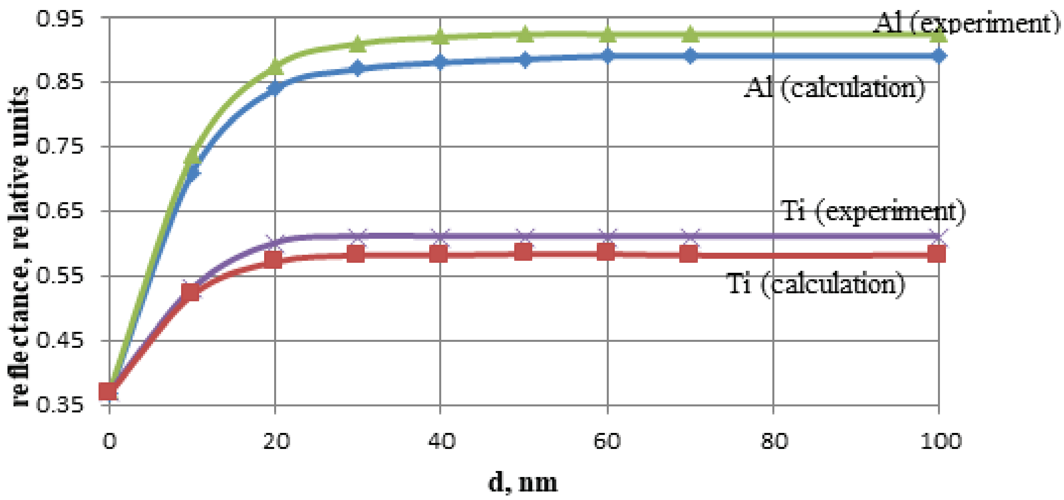


Figure 3: The dependence of the reflectance on layer thickness.

Optical measurement of all samples was conducted, the results for which are presented in Figure 3. Close coincidence of optical characteristics with the results of the calculations and experiments is observed.

5. Conclusion

All conducted research allows us to recommend that the critical thickness of conductive metallization films based on aluminium should be more than 30 nm, and of those based on titanium should be more than 50 nm.

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