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The refractive index of the waveguide layer in such optically layered structure \( n_2 \) exceeds the refractive index values of adjacent layers \( (n_1, n_3) \), \( (n_2 > n_1, n_2 > n_3) \).

In addition, it is necessary to provide a certain minimum thickness of the waveguide layer at a given frequency. If action of laser radiation results in formation of a layer with a refractive index \( n_3 \) and closer to surface a layer of thickness \( h_1 \) with a refractive index \( n_2 \) provided \( n_2 > n_3 > n_1 \), then [7]

\[
h_{\text{min}} = \frac{\lambda}{2\pi\sqrt{n_2^2 - n_3^2}} \arccos \frac{n_2^2 - n_3^2}{\sqrt{n_2^4 - n_1^2}}. \tag{22}
\]

In particular, for silicon at a wavelength of 1.25 \( \mu \)m the minimum thickness of the waveguide layer is \( h_{\text{min}} \approx 70 \) nm according to expression (22).
Let us consider the calculated spatial distribution of the silicon dielectric permeability under the femtosecond laser pulse action (see Fig. 10) in terms of the possible conversion of the incident light into surface plasmon-polaritons and waveguide modes. The surface polariton excitation requires transition of the semiconductor surface into a metal-like state, while formation of a dynamic optically-layered structure with a certain minimum thickness of the waveguide layer is necessary for the excitation and propagation of waveguide modes.

As follows from the numerical model (Fig. 10, curves 1-2) in case of relatively low emission a metal-like layer is formed at the surface. Within the layer thickness is about 50-60 nm dielectric permeability becomes negative. This provides the conditions for excitation of surface plasmon-polaritons (TM-type SEW), which is confirmed experimentally by formation of the microstructures perpendicularly to the polarization vector.

If emission rate is high as in case of thermo-emission (Fig. 10, curve 3) an optically layered structure is formed. Although the dielectric permeability does not change its sign, excitation of waveguide modes is possible.

Combination of both photo- and thermal-emission (Fig. 10, curve 4) results in formation of a dielectric layer of thickness ~ 60 nm and a metal-like layer of thickness about 40 nm. The refractive index of this dielectric layer is higher than both the refractive index of the air on one interface, and the refractive index of the metal-like layer on the other interface. Presence of such an optical structure enables excitation of waveguide mode, which results in the formation of periodic relief, which is parallel to the polarization vector on the incident radiation (see Fig. 6, right).

The above consideration showed that multiphoton emission and thermionic emission noticeably vary the optical properties of a semiconductor during a femtosecond pulse action. In particular, layer with different optical properties is formed at the surface and enables excitation of either surface polaritons or waveguide modes in the semiconductors. The considered model allows one to qualitatively and quantitatively interpret available experimental data. This approach allows one to use experimentally observed surface microstructures as relatively simple means of investigation of dynamics of the semiconductor surface properties under femtosecond action.

4. Conclusion

The results of numerical simulation have shown that influence of emission processes on the electron gas temperature and lattice temperature of metals is negligible. Therefore, the emission can be neglected when assessing the parameters of metals processing by femtosecond laser pulse, which simplifies the numerical calculations.

The Coulomb explosion occurrence in metals requires high-power incident radiation, which is impossible for the real exposure conditions.

However, in semiconductors both types of extrinsic emission noticeably change distribution of dielectric permeability near surface providing conditions for excitation of surface polaritons or waveguide modes depending on laser power magnitude.
The proposed method allowed to estimate the cross sections of multiphoton absorption in metals. For example, for metals absorption cross section: $\sigma=10^{-17}\text{cm}^2$ for one-photon absorption, $\sigma=10^{-28}\text{cm s}$ for two-photon absorption, $\sigma=10^{-61}\text{cm}^3\text{s}^2$ for three-photon absorption.

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5. **References**


