DEPOSITION OF OPTICALLY TRANSPARENT COPPER FILMS ON DIELECTRIC SUBSTRATES USING THE PLASMA FOCUS INSTALLATION

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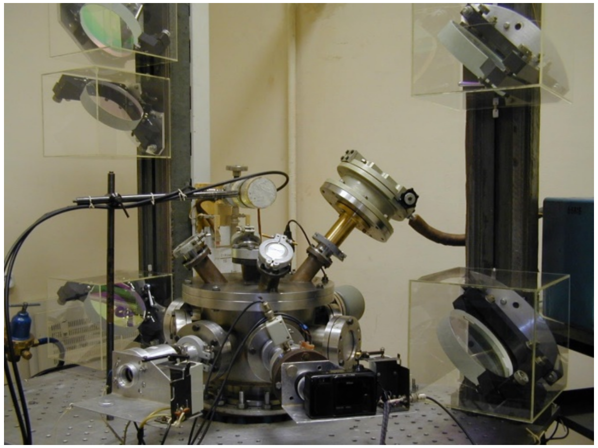
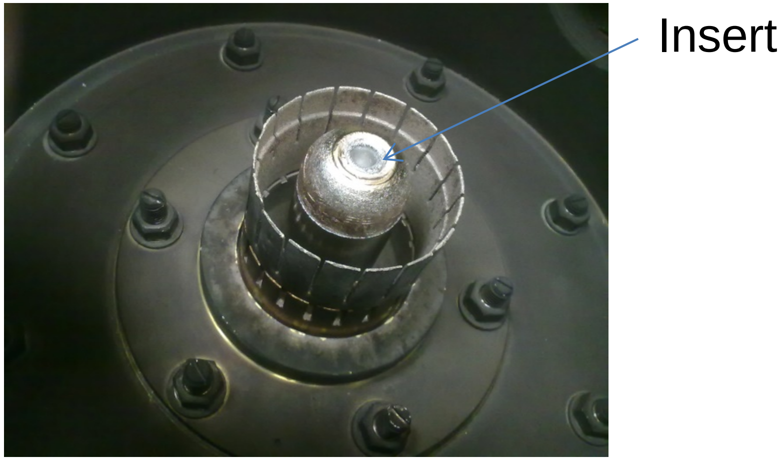
<u>The aim of this work</u> was to obtain uniform optically transparent copper films on silicate glass substrates using ablation of the copper anode at the Plasma focus (PF) facility.



a

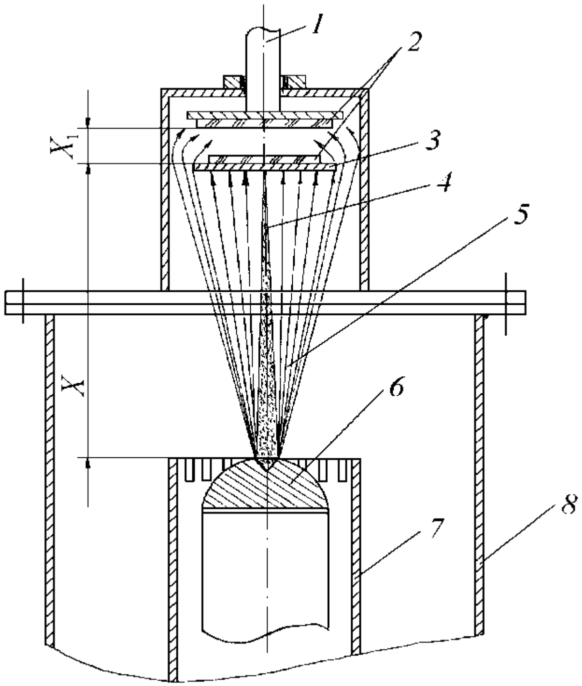


b

The vacuum chamber (*a*) and the anode assembly (*b*) of the PF-4 installation (FIAN)

During the formation of a plasma pulse, the installation's anode is subjected to an intense electron and plasma beam. During ablation, metal vapors are ejected from the anode, which contain multicharged ions and neutral atoms. This state of metal vapor is called "metal" plasma. The method of intensive sputtering of anode inserts made of various materials can be used to obtain coatings and films on metal and dielectric surfaces.

Scheme of experiment on deposition of thin optically transparent Cu films on glass substrates



Plasma focus facility (PF-4, LPI, Russia) with the Mather geometry of the electrodes.

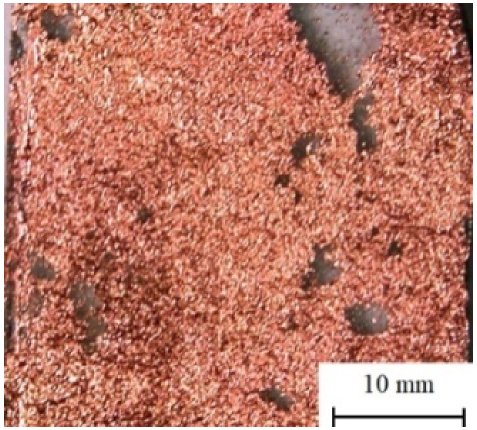
The stored energy in capacitor banks with a capacity of 48 μF at a voltage of 12-14 kV was 3.5-4 kJ. The duration of the plasma pulse was ~100 ns. The plasma-forming gas was argon at a pressure of ~ 1-2 Torr in the working chamber.

1-sample holder rod; 2-glass substrates; 3 – metal screen (Cu); 4 – ion beam; 5 – plasma jet; 6 – copper anode; 7 – copper cathode; 8 – working chamber of the installation.

The deposition of Cu films on glass substrates was performed, installing a protective Cu screen on the path of motion of a copper plasma jet. The screen size of ~35×35 mm protected the substrate from large Cu drops and ion beam effects.

By changing the distance X from the screen to the anode and X_1 – the distance between the sample holder and the screen, Cu was uniformly deposited on the substrates. In our case, the optimal distances were X=150 mm, X_1=15-20 mm.

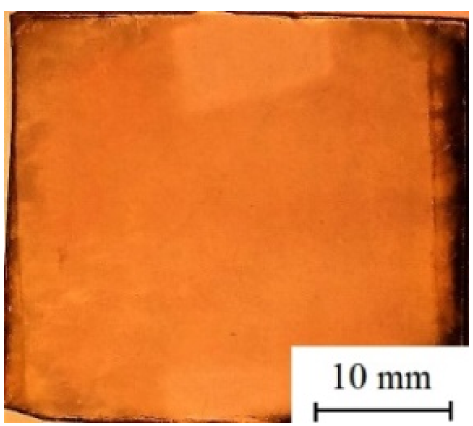
A silicate glass plate with a Cu-deposited film under irradiation with 30 plasma pulses.



Direct deposition of copper films from "metal" plasma on glass substrates.
The distance from the substrate to the installation anode is 170 mm. Feature 20-150 rel. units*).

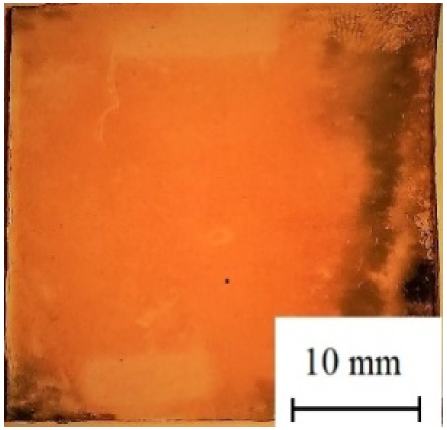
*) A feature is a short jump on the derivative of the current that occurs at the time of maximum compression of the plasma shell on the axis OZ of the installation. The amplitude of this feature characterizes the energy of the plasma pulse in relative units.

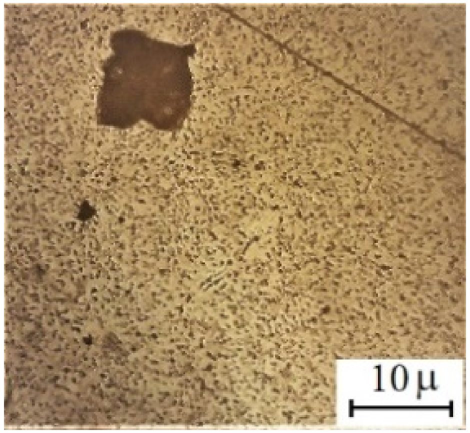
Direct deposition of copper films from "metal" plasma on glass substrates leads to mechanical destruction and uneven distribution of metal on the substrate. Due to different coefficients of linear expansion of the glass and copper film, it is separated from the substrate and destroyed



The substrate was placed on the sample holder behind a metal screen (Scheme). The amplitude of the feature is 10-110 rel. units.
In this case, the deposited Cu films on glass substrates are obtained fairly uniform.

Glass substrate with deposited Cu film and film structure

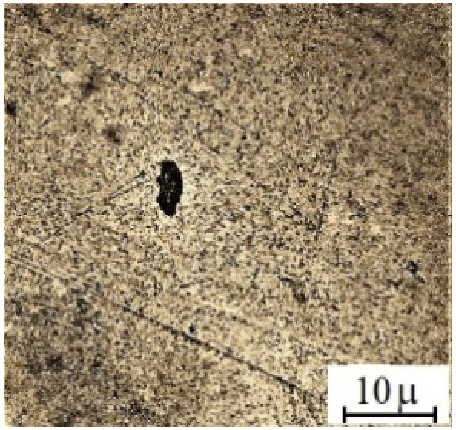




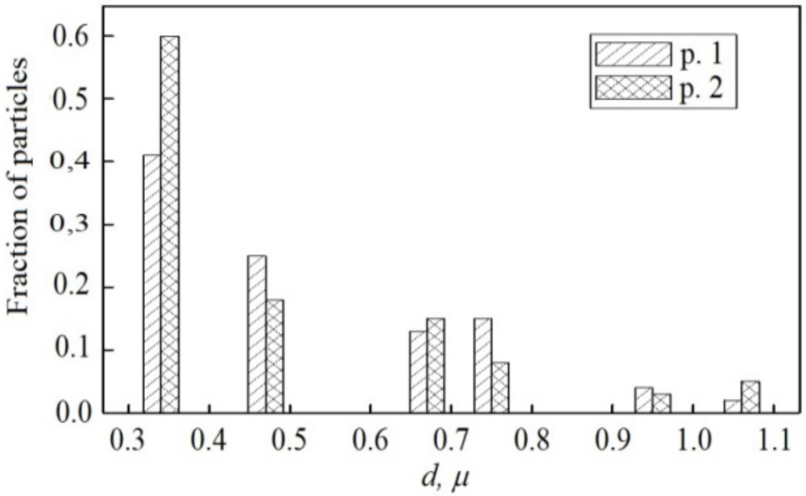
The substrate was placed on a metal screen (Scheme). The number of plasma pulses n=24. The amplitude of the feature is 10-120 rel. units.

Cu films are not continuous and represent a set of particles. In general, Cu particles are arranged on the substrate surface in a stochastic manner. However, in some places on the surface, you can see ring-shaped structures, the size of which can be large. The nature of these structures is currently unclear. No fractal structures are observed in the films.

Histograms of the size distribution of Cu particles



The number of pulses of the plasma is n=30. The amplitude of the feature is 10-110 rel. units. The substrate was placed on the sample holder behind a metal screen. The amplitude of the feature is 10-110 rel. units



Histograms of the size distribution of Cu particles: p.1 - at the edge of the substrate; p. 2 - closer to the center of the substrate.

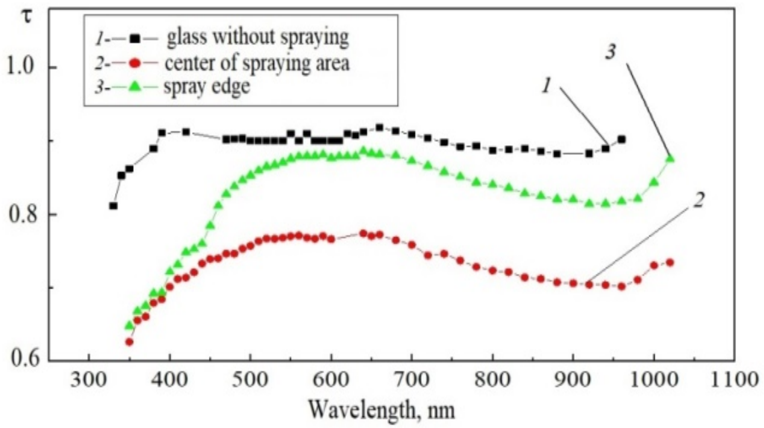
The particle size ranges from units of microns to tenths of a fraction or less.

When irradiating glass substrates with a small number of plasma pulses ~10-15, Cu films were dielectric. With an increase in the number of plasma pulses to ~ 20-30 or more, the films were electrically conductive.

The adhesion of Cu films was determined by mechanical abrasion. The adhesion of Cu films to the glass surface was quite high, which is explained by the penetration of small Cu particles under the glass surface to a depth of tens of nanometers and the fusion of hot metal particles into the glass.

After deposition of Cu films on the surface there is a fine dust containing components of silicate glass- Na, K, Mg, Si, etc.

Transmission spectrum of copper films on a glass substrate



Transmission spectrum of copper films on a glass substrate at two points: 1-clear glass; 2-closer to the center; 3-closer to the edge of the deposition area

The heterogeneity of the films is ~ 10%.

The transmission spectra show a broad maximum in the wavelength range 450–750 nm, which is characteristic of Cu and its oxides CuO and CuO_2.

The presence of a wide maximum on the transmission spectra of films is associated with a significant effect of light scattering on small particles.

These considerations are consistent with particle size statistics and photos, where it is seen that the films consist of many small droplets.

CONCLUSION

Optically transparent thin homogeneous (~10%) copper films on silicate glasses with a size of ~3.5×3.5 cm^2 were obtained.

Depending on the energy of the plasma jet and the number of plasma pulses, both dielectric and electrically conducting films can be deposited at the Plasma focus installation.

Copper films have good adhesion to the glass substrate.

During prolonged storage in air, the films oxidize, which requires the application of protective coatings.