The Development of Test-Device based on Surface Discharge for Imitation of Erosion Monitoring Process in the Fusion Reactors

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It is well known [1] that interaction plasma with divertor and the reactor first-wall elements leads to damage of their surfaces via erosion process and to dust generation. The dust accumulation in the reactor zone is negative phenomena because it influences on plasma properties and can cause an explosion. For investigation this process with the view of limitation undesirable implications, a non-contact methods with high spatial resolution and high accuracy in geometry measurements may be used. According to [2], the surface erosion inspection can be realized by means of dual wavelength speckle interferometry providing the record of topogram. The speckle interferometry records objects with the optical rough surface and has submicron precision. However to obtain high-quality topograms, it is necessary to neutralize a lot of factors that negatively influence on the recording process. Therefore, a speckle-interferometer can't be incorporated in fusion reactor immediately without addition investigations. In particular, it is reasonable to represent the erosion of reactor elements via imitation, which will allow optimizing speckle-interferometer in laboratory conditions.

For this purpose, a gas-discharge test-device based on the removable electrode systems with the colliding surface discharges [3] was developed (see Fig.1 and Fig.2). The device could work in air at normal condition and it was used for visualization of thermal-mechanical interaction between discharge and surface. In contrast to [3], the electrode system has a high-resistive, diffusely reflective coating on a fiber-glass plastic, dielectric barrier. This coating provided registration of quality

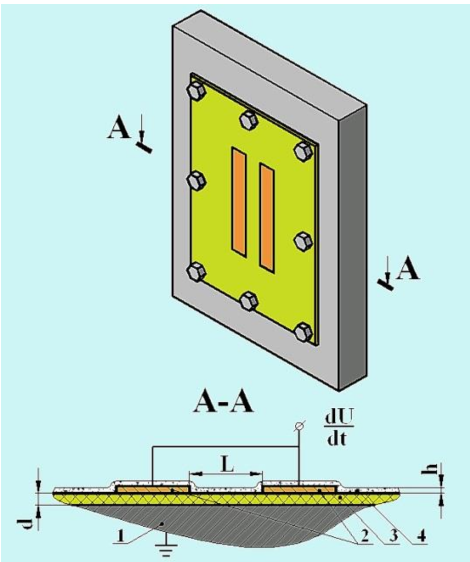


Fig.1. Design of gas-discharge test-device for erosion imitation process: 1- stainless steel base; 2-discharge electrodes; 3-dyelectric layer; 4 - reflective coating

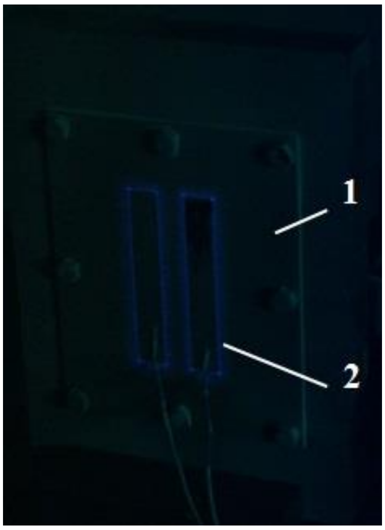
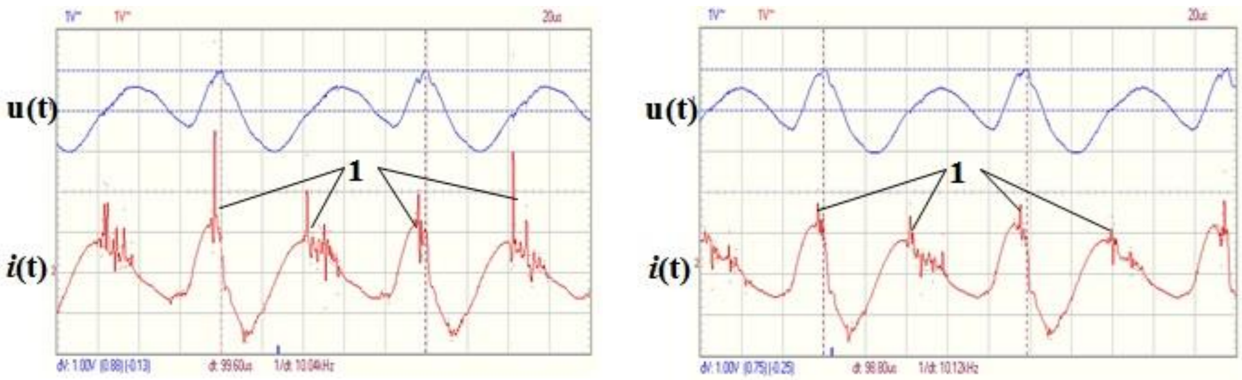


Fig.2. View of the developed gas-discharge test-device: 1-electode system; 2 - surface discharge. Parameters of the electrode system: d=1.5 mm, L=10 mm h=0.1-0.3 mm



a) b)

Fig.3. Comparative oscillograms of surface discharges on the developed gas-discharge test-device at high-voltage excitation with amplitude Ua≅5 kV: a) ordinary surface discharge; b) surface discharge in porous layer of reflective coating. 1-series of micro-discharges. Typical scales: u(t)-5kV/div; *i*(t)-38 mA/div; t-20μs/div.

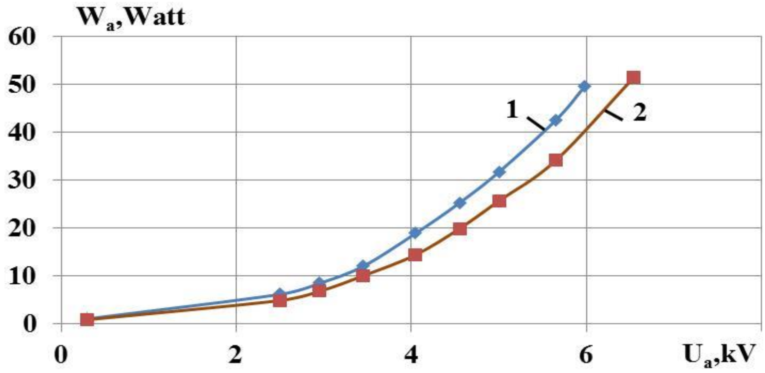
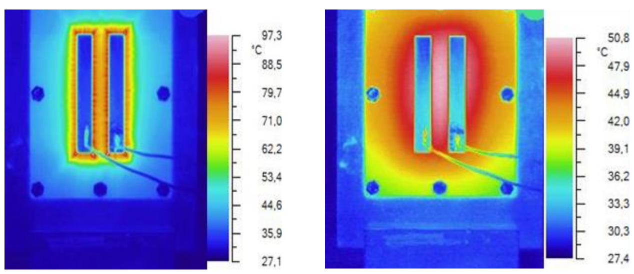


Fig.4. Active power W_a vs voltage amplitude U_a of the gas-discharge test-device for erosion imitation process: 1-ordinary surface discharge; 2-surface discharge in porous layer of reflective coating.
Parameters of the electrode system: d=1.5 mm, L=10 mm h=0.1-0.3 mm

speckle-interferograms, although it changed discharge generation conditions. In fact, the discharge burned in the porous layer of the reflective coating with a thickness of h = 0.1-0.3 mm that changed the resistance of the gas discharge gap. This is confirmed by oscillographic studies presented in Fig 3. In Fig.3a you can see voltage u(t) and current i(t) of surface discharge on the clean dielectric layer in contrast to same parameters of surface discharge in the porous medium (Fig.3b) at the equal conditions. According to Fig.3a and Fig.3b, the reflective coating degrades the discharge process by reducing number of micro-discharges series and their amplitudes. It leads to reduction of the active power of surface discharge (Fig.4) and slows down the surface erosion.

The active power dissipation of the heated gas-discharge test-device was recorded by IR camera (Mikron M7604F) with spectral range λ= 8.0-14.0 μm and spatial resolution 320 ×240 pix. The obtained IR images of electrode system are presented in Fig.5.



a) b)

Fig.5. Brightness temperature distribution on the surface of the gas-discharge test-device during heating (a) and cooling (b) processes

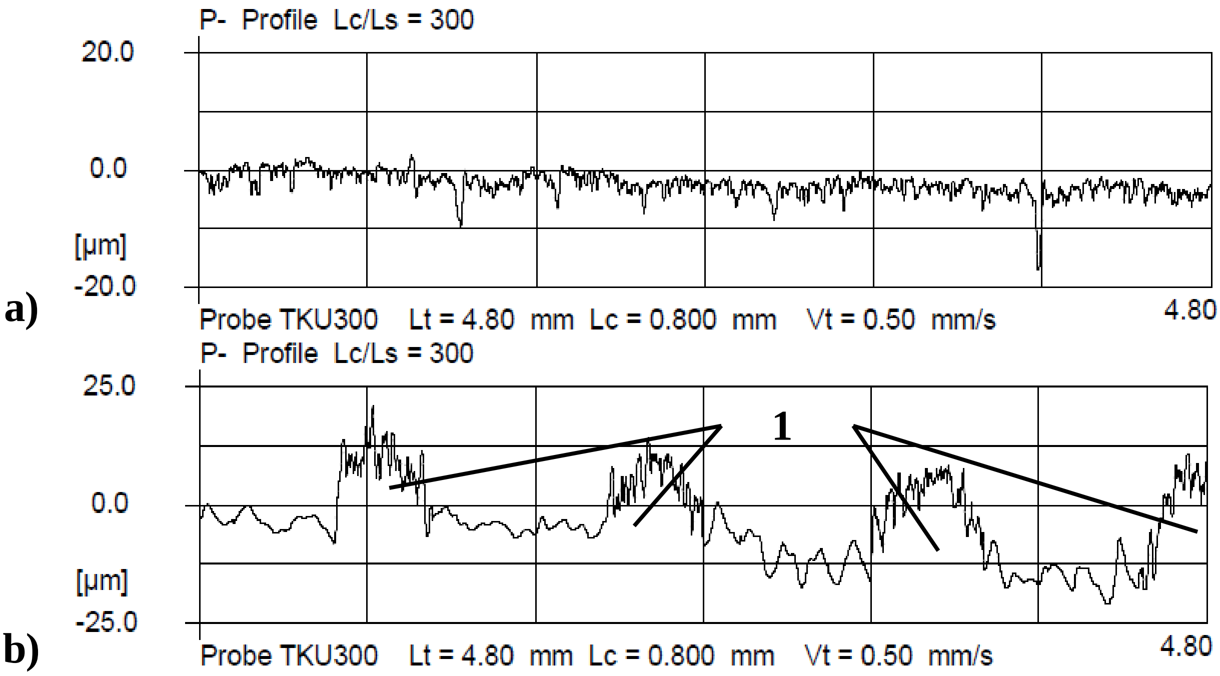


Fig.6. Surface erosion of gas-discharge test-device under plasma action (data from W55-profilometer): a) - surface profile before plasma generation; b)- surface profile after plasma generation process. 1-fiber-glass elements of dielectric

Fig 5a demonstrates temperature distribution during discharge generation process. Here, heating zone matches surface discharge area where the brightness temperature achieves 98^0C. In these conditions, the surface discharge evaporates the bonding medium from fiberglass plastic around discharge electrodes. As a result, the erosion zone with area of about several square centimeters and depth from ten micron up to 0.1 mm is formed (see Fig.6). After several hours generation, the surface discharge leaves fiber-glass elements on the dielectric surface of electrode system (Fig.6 b). This phenomenon may be useful for imitation erosion process of the reactor first-wall elements as well as for the dual wavelength speckle interferometers testing.

In cooling process (see Fig 5b), the temperature of electrode system decreased exponentially, that could lead to thermal deformations of the test-device. These deformations were detected by Noiseproof Digital Speckle Pattern Interferometer (see Fig.7) with optical scheme in Fig.8.

Fig.7. View of the receiving-emitting unit of Noiseproof Digital Speckle Pattern Interferometer

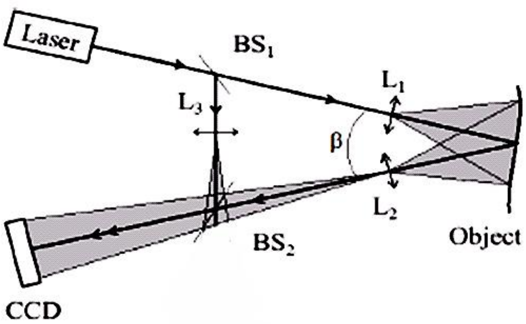
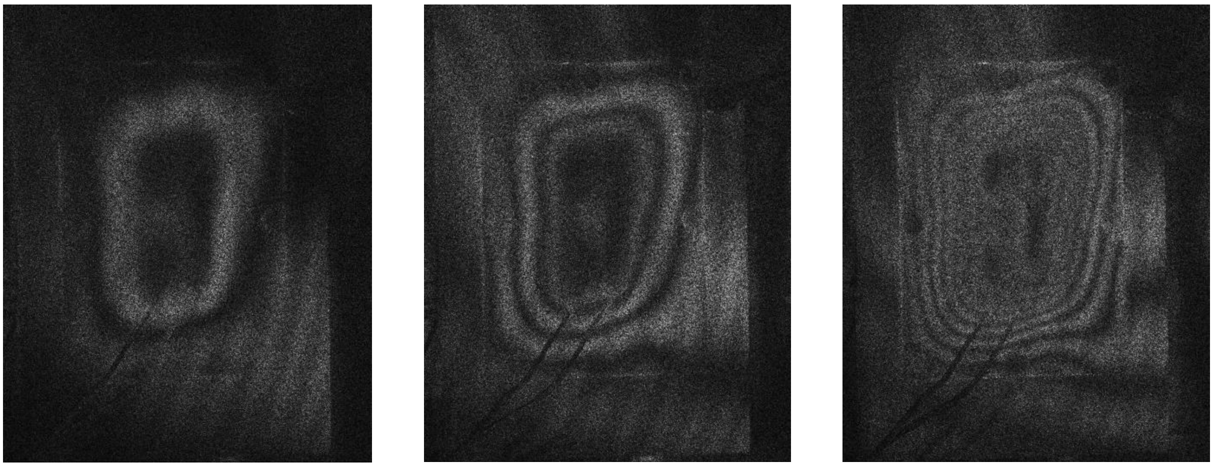


Fig.8. Optical scheme of Noiseproof Digital Speckle Pattern Interferometer: L_1, L_2 –lens; BS_1, BS_2 –beam splitters; CCD- focal plane matrix



a) b) c)

Fig.9. Speckle-interferogram of the test-device deformation after plasma dissipation (initial stage of cooling process): a) - Δt=0.5s; b) - Δt=1s; c) - Δt=2.5s.

The Digital Speckle Pattern Interferometer was equipped by CW laser with a wavelength λ=532nm and coherence length of 50m. Due to the new method of image processing [4-5], this interferometer provided the registration of test-device deformation without isolation from vibration.

The interferogram examples of the test-device deformation are presented in Fig.9. Interferogram set (see from Fig.9a to Fig.9c) demonstrates deformation evolution of electrode system after plasma dissipation. Decoding of the interferograms allows us to obtain the deformation field with high precision (λ/2=266 nm).

So, the gas-discharge test-device allowed us to observe both thermal deformation of electrode system and surface erosion of dielectric barrier. The device may be useful for testing of digital speckle-interferometers. Also it may be useful in the study of ‘plasma - wall’ interaction in the barrier discharges [6-7].

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