Accidental and Methodical Defects of Generation of Precision and Ultraprecision Surfaces of Polymer Optics

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ABSTRACT

Widespread adoption of precision and ultraprecision articles from the polymeric materials creates a need for the understanding of a mechanism of the new high quality surfaces generation by the controlled fracture processes in the single-point diamond machining. The efficacious way for this understanding is a creation of the model of the surface layer forming process as result of the formation of its accidental and methodical defects by the precision microcutting.

Keywords: polymer optics, single-point diamond cutting, surface generation, precision, defects

1. INTRODUCTION IN MICROCUTTING PROCESS INVESTIGATION AND MODELLING

At present time the precision and ultraprecision polymeric optical and photonic articles find application for a great many science and industry sectors production, e.g. for luminescent and nuclear detectors, tiles for accelerators of charged particle and calorimeters, planar and flexible lightguides, solar light converters, usual and aspherical lenses, etc. Many of these articles have large dimensions (the maximum up to 3000 mm for one side) and materials often used for their manufacturing include amorphous vitreous thermoplastic polymers, such as polystyrene (PS), polymethylmethacrylate (PMMA) and compounded plastics on their base with the different functional components.

The most effective technological method for optical surfaces generation process of optical polymer components from polystyrene is the single-point diamond micromachining -milling and turning.

One of effective methods for direct control of the new surface generation process by precision cutting is the mechanoluminescence method - estimation of luminescence intensity which are characterized by photoemissivity. The mechanoluminescence is a result of the polymeric material destruction and the flow of photons is a product of microdestruction process. It is an original information carrier about polymer strain and defects formation process and the photon impulse registers practically without inertia, which allows the use of this method directly in the real-time precision microcutting process for the investigation of direct fractures with new surface formation and for control of precision machining of polymers at the micro-mechanics level. In combination with piezo-dynamometry and microvisual analysis by CCD camera this method allows to build up the deformation model and as result - the model of the controlled fracture processes with new surfaces generation.

For the investigation and modelling of thermodynamical characteristics a method of registration of temperature expansion dynamic into the polymer directly in surface generation process by single-point macrocutting was developed with using of the mesomorphic thermo-films and the infrared camera as the most progressive method for this investigation.

The quality control of polymeric optics precision machining process and comprehensive inspection of finished optical components require using for measuring non-destructive devices which enable topographical measurements in the nanoscale. The most effective a non-contact (that is especially important with soft materials as polymers) technique for measuring surface microstructure defects is an interferometry method. For surface layer conditions testing we have been using the white-light optical profilers WYKO RST500 and the control of the macrogeometrical parameters as result of positioning and forming accuracy was realized by a 3D Topographic Analysis (Rank Taylor Hobson Form Talysurf Series).

The structural diagram of the precision and ultraprecision surfaces generation process investigation and modelling as well as creation of new technological process of high quality polymeric optical components manufacturing process is shown in figure 1.

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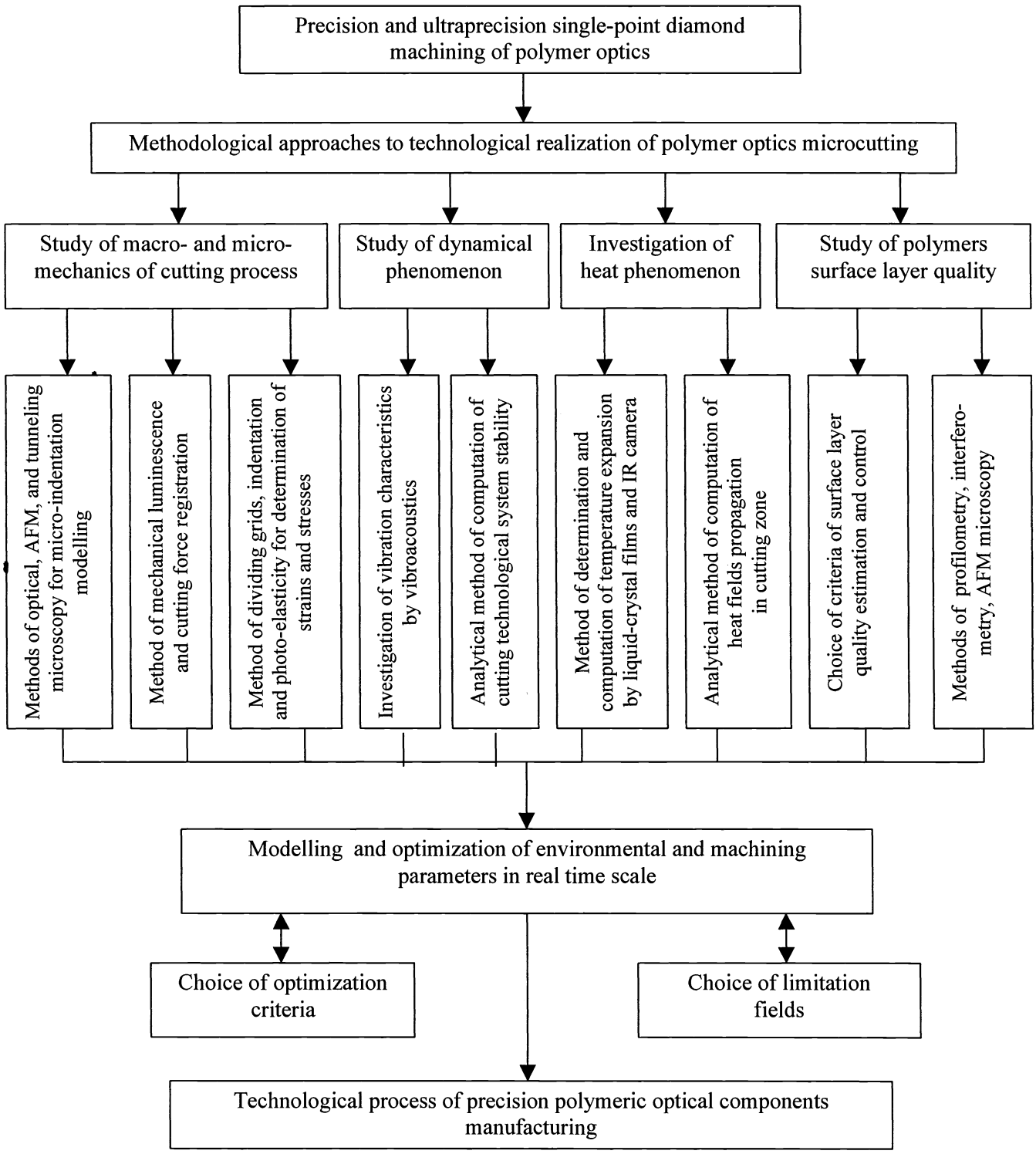

Figure 1. Structural diagram of comprehensive investigation, modelling and optimization of high quality polymer optics manufacturing

First direction in the investigation of the defects formation process in the new surface is a control of the physical-chemical parameters (as many as possible) of the real technological process with directional controlled fracture and generation of new polymer optics precision single-point diamond machining surfaces and their effect the materials surface conditions in the real-time scale. This way is most efficacious but more difficult than second direction - modelling the surface generation process by separate simple models, which are imitating each real process phenomenon, and by virtue of the finished surface testing data analysis.

2. TECHNOLOGICAL AND ENVIRONMENT ACCIDENTAL AND REGULAR FACTORS OF POLYMER OPTICS SURFACE DEFECTS FORMATION

For comprehensive estimation of all physical-chemical parameters, which effect stability of the surface layer quality and its defect level we must take into account the rheology of specific polymer. In that way the first group of the accidental and regular factors is performance attributes and condition of the workpiece – quality of initial material, presence of primordial defects and inclusions, internal strains, and others. Next group is quality of material for cutting tool and accuracy of tool manufacturing. All these factors are very important for normal course of new surface generation process and for providing of high level of operation characteristics of the ready-made polymer optical components. But if conditions of workpiece and cutting tool are conforming with passport of quality and technological process requests then the factors of the precision machining technological process play a vital part. The accuracy and stability of machinery work.; observance of the operation conditions (such as the specified value of cutting speed, feed rate, and cutting depth); accuracy and reliability of the auxiliary equipment for basing, fixing, control, and shifting of workpiece and outfit, etc. Any rejection or deviation from optimal parameters of this process certainly reduce to surface layer defects appearance and worsening of manufactured productions as a consequence. Some examples of the surface defects which was caused by technological factors are shown in figure 2.

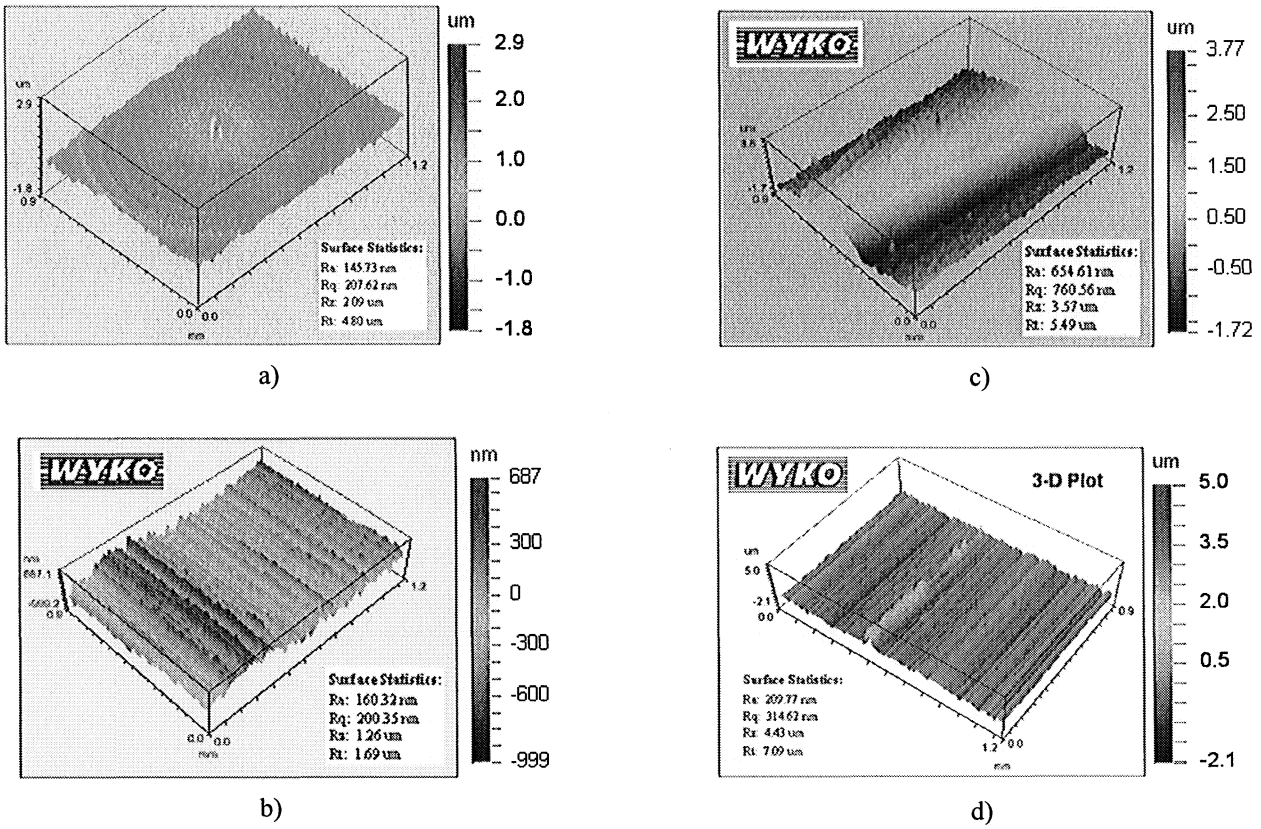

Figure 2. Effect of technological factors on surface defects
a) defect in centre of turned aspherical concave surface; b) error of surface form caused by uncertainty of CNC command; c) "step" after change of cutting tool rout direction; d) defacing of surface caused by momentary stop of feed moving

Two another groups of the quality destabilizing factors are dependent on the environment. Conditionally these factors divide between the rigorously accidental natural environmental factors and the prepared medium factors group. In which connection the influence of the natural factors weaken with correct and regular organization of the technological zone artificial surroundings.

3. MODEL OF MICROMACHINING ERRORLEVELS AND PRECISION

As result of the investigation of the polymer controlled fracture in microcutting process and estimation of surface layer quality an errorlevels model of the accuracy and failsafety laying in the precision micromachining technological process was created. A comprehensive scheme of this model, which illustrates the accidental and regular factors influencing onto the precision and defectless of manufactured polymer optical components is shown in figure 3.

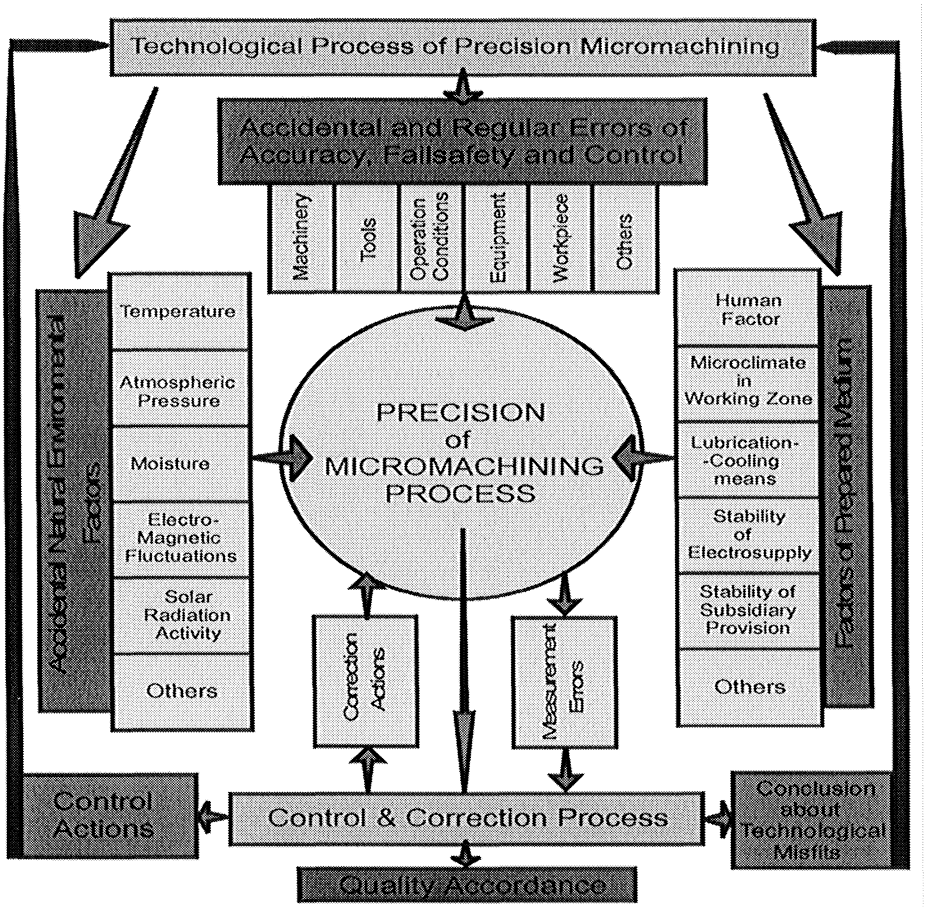

Figure 3. Comprehensive scheme of the accidental and regular factors influencing onto the precision and defectless of manufactured polymer optical components.

CONCLUSION

The summation of the obtained data, the results of database analysis and design of the dynamical model of the thermoplastic polymers flaw defection in the high quality surface layer generation process by the diamond single-point micromachining led the way to new technological decisions for the manufacturing of a wide variety of polymeric components for optical and photonic application.

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