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In-process surface roughness measuring device for information-based real-time polishing process adjustment and optimization

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ABSTRACT

In this paper we present a feasible variant of a device for in-process roughness measurement during an optical polishing process. The system, already presented as Tirm respectively I-Tirm, has been technically varied and can now be integrated into almost any lever polishing process with little effort. This enables new possibilities regarding real-time optical manufacturing process monitoring and optimization.

Keywords: Polishing, Tirm, I-Tirm, micro roughness measurement, metrology

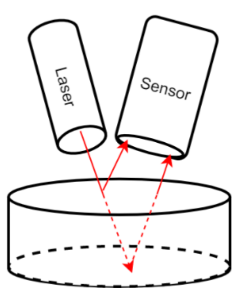
1. INTRODUCTION

Measuring a surface quality (i.e., micro roughness or finish) during real-time polishing process allows conclusions to be made as to whether and how quickly the surface roughness tends to converge towards an asymptotic value. This measured value provides immediate evaluation and feedback on system reactions to parameter changes (intentional and unintentional) and forms an informational basis for further process optimization as well as for the identification and adjustment of disturbing variables.

With Tirm or I-Tirm, we already introduced a method of roughness measurement during polishing in 2002 [1]. The system is essentially based on the intensity measurement of a reflected laser beam and has already been tested in various technical variants on conventional polishing processes with foil and polishing agent, but as well on laser polishing processes [2, 3]. The systems presented so far were subject to various technical limitations, which in many cases restricted their practical suitability or required considerable preparation, e.g. the use of a transparent polished base or the application of a specimen that had already been polished on one side. In order to expand its impact for wider range of applications, we re-utilized this principle in a technical variant so that the technology now does not require a special prepared specimen or transparent overlay.

2. EXPERIMENTAL SETUP

Figure 1 shows the schematic diagram describing the method of in-process measurement. A part of the laser beam is reflected from the top surface subsection of the workpiece surface (i.e., unit under test) and are directly transferred to the photo-optical sensor. Other parts of the laser beam are not reflected from the top area. A laser-transmission through the workpiece and a reflection from the bottom surface area with undergoing the procedure of transmitting through the top surface area again occurs, too. Both beam paths are monitored and measured by the photo-optical sensor.



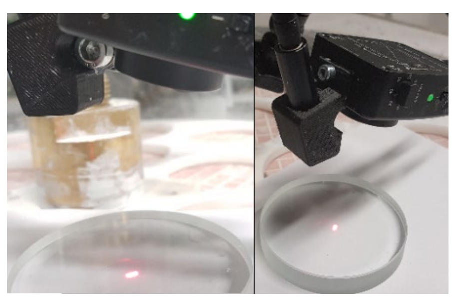


Fig. 1: Schematic measuring principle of the in-process surface roughness measuring device (left) and actual experimental hardware set up using the laser and photo-optical sensor (right)

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3. IN-PROCESS REAL-TIME POLISHING PROCESS MONITORING

To verify the concept of two beam monitoring method, Fig. 2 reports the experimental outcome monitoring the time-sequence data using a paper mask in front of the sensor aperture. The experiment is divided into four stages. The first stage is the raw signal from the laser. The second stage is the laser blockage using the paper mask at the sensor aperture. Stage three partially opens up the paper mask, so only the directly reflected laser beam from the upper surface is captured by the sensor. The last stage is a validation stage, where the paper mask is totally removed from the aperture in order to recover the original signal.

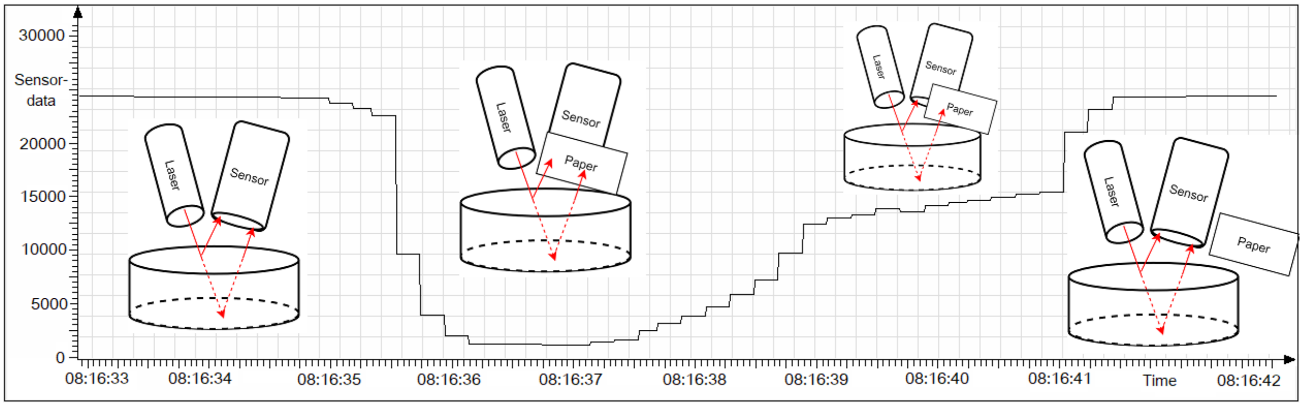

Fig. 2: Experimental validation of the two beam measurement data signal using a beam blocking mask in front of the photo-optical sensor aperture.

Real-time in-process polishing process monitoring data to differentiate non- or semi-transparent glass from transparent glass is presented in Fig. 3. Figure 3 displays the data from the photo-optical sensor as a function of the polishing time. The trajectory shows the photo-optical sensor data encoded from 0 – 10 V into a decimal-value from 0 to 32767 (i.e., 15 bit).

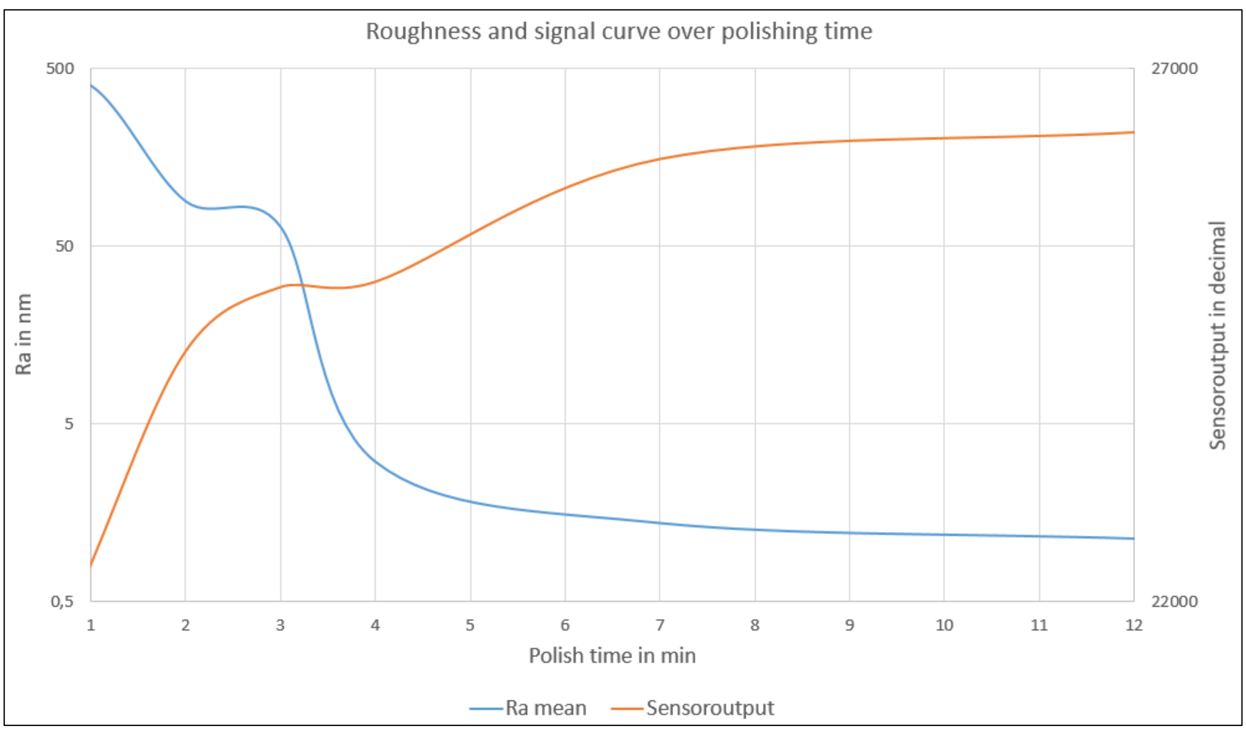

Fig. 3: Photo-optical sensor signal and the surface roughness evolution during the optical polishing process of the experimental sample workpiece surface area.

The trajectory directly describes the time-different photo-optical sensor data in relation to the transparency of the glass. The evolution of visual quality of the polished glass transparency during the polishing process is shown in Fig. 4. The surface roughness value (in Ra) represents the transparency of the glass in different stages of the polishing process.

The experiment was carried out using a glass workpiece and the surface roughness measurements had been made every minute. The experiment lasted and monitored for 12 minutes of polishing time as the graph has converged to a steady state starting approximately 6 minutes of the polishing time.

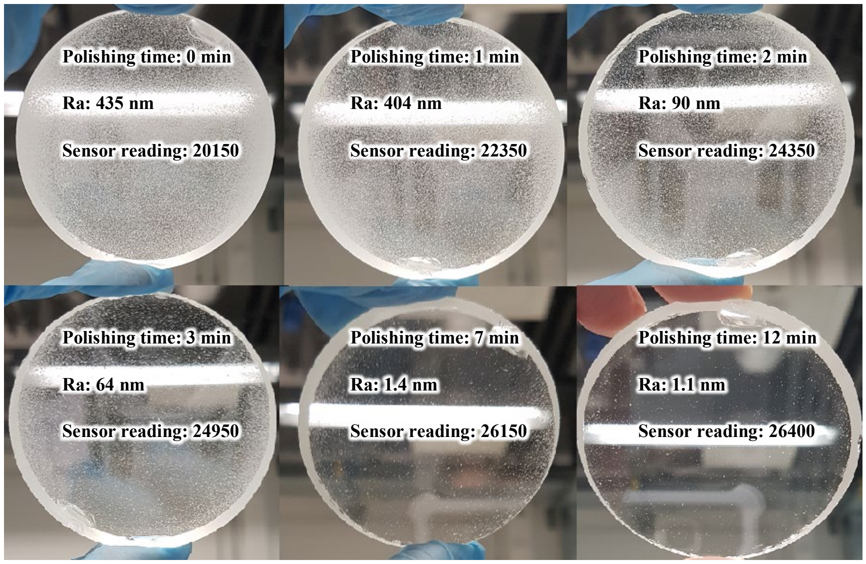

Fig. 4: Visual quality and the surface roughness (i.e., Ra) evolution of the experimental polishing sample surface during the polishing process until the surface roughness Ra value reaches about 1.1 nm.

4. CONCLUSIONS

With this real-time monitoring method, the in-process surface roughness measurement of both surfaces of the window (i.e., plane-plane) optical components has been successfully accomplished. It shows the validity of the two beam method using the direct reflection from the top surface and another reflection from the bottom surface combined with transmissions through the glass. A transition from non- or semi-transparent glass to a transparent glass window can be measured and evaluated using a pre-calibrated (or known) data-set of the sensor value of the reflected laser beam for a mass production process monitoring and/or quality control. Also, this technology is planned to guide and adjust polishing parameters (e.g., polishing compound distribution rate, polishing speed, etc.) during optical fabrication runs for real-time process optimization based on the information acquired by the surface roughness measuring device.

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