

IMPACT OF IMPULSE SHOT PEENING PARAMETERS ON PROPERTIES OF STAINLESS STEEL SURFACE

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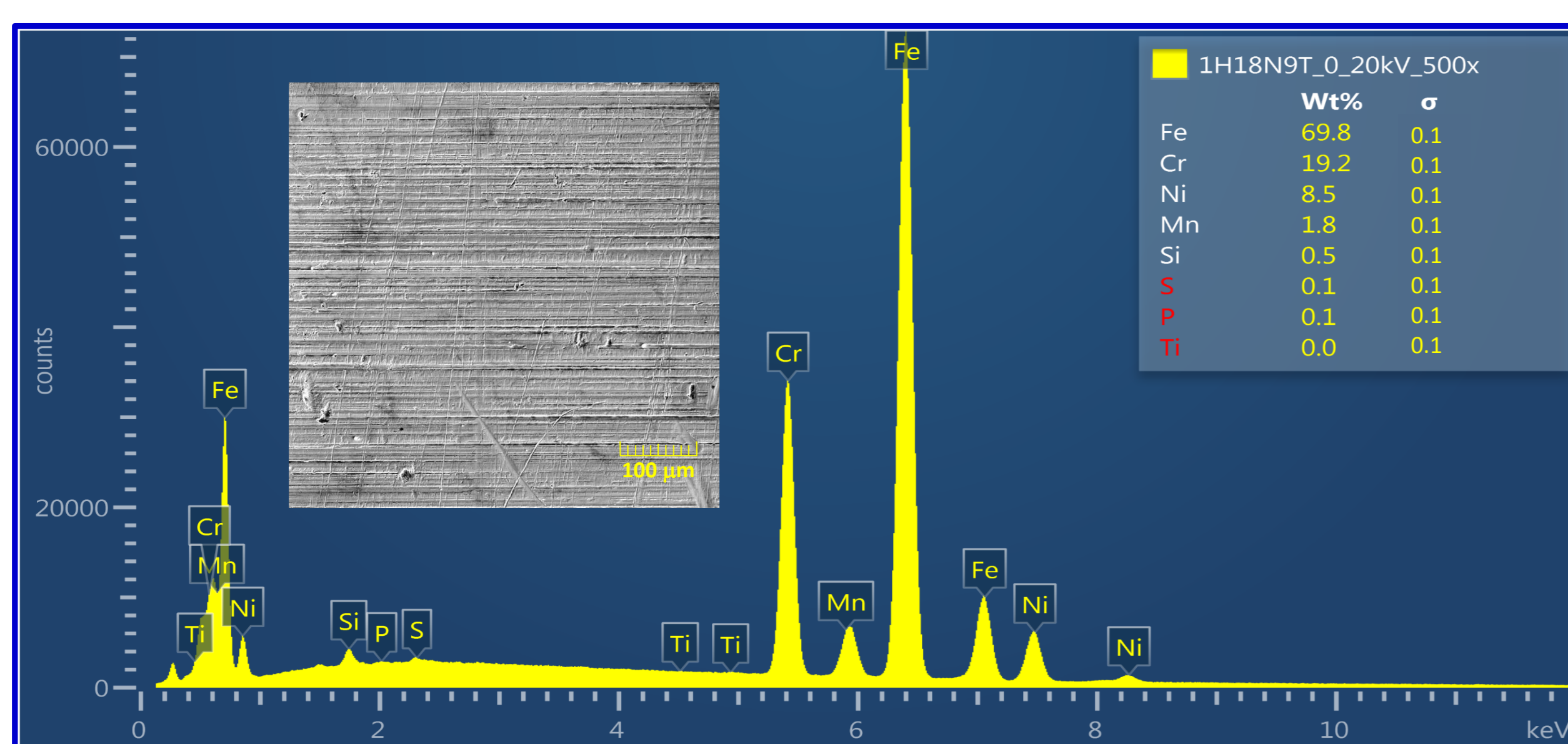
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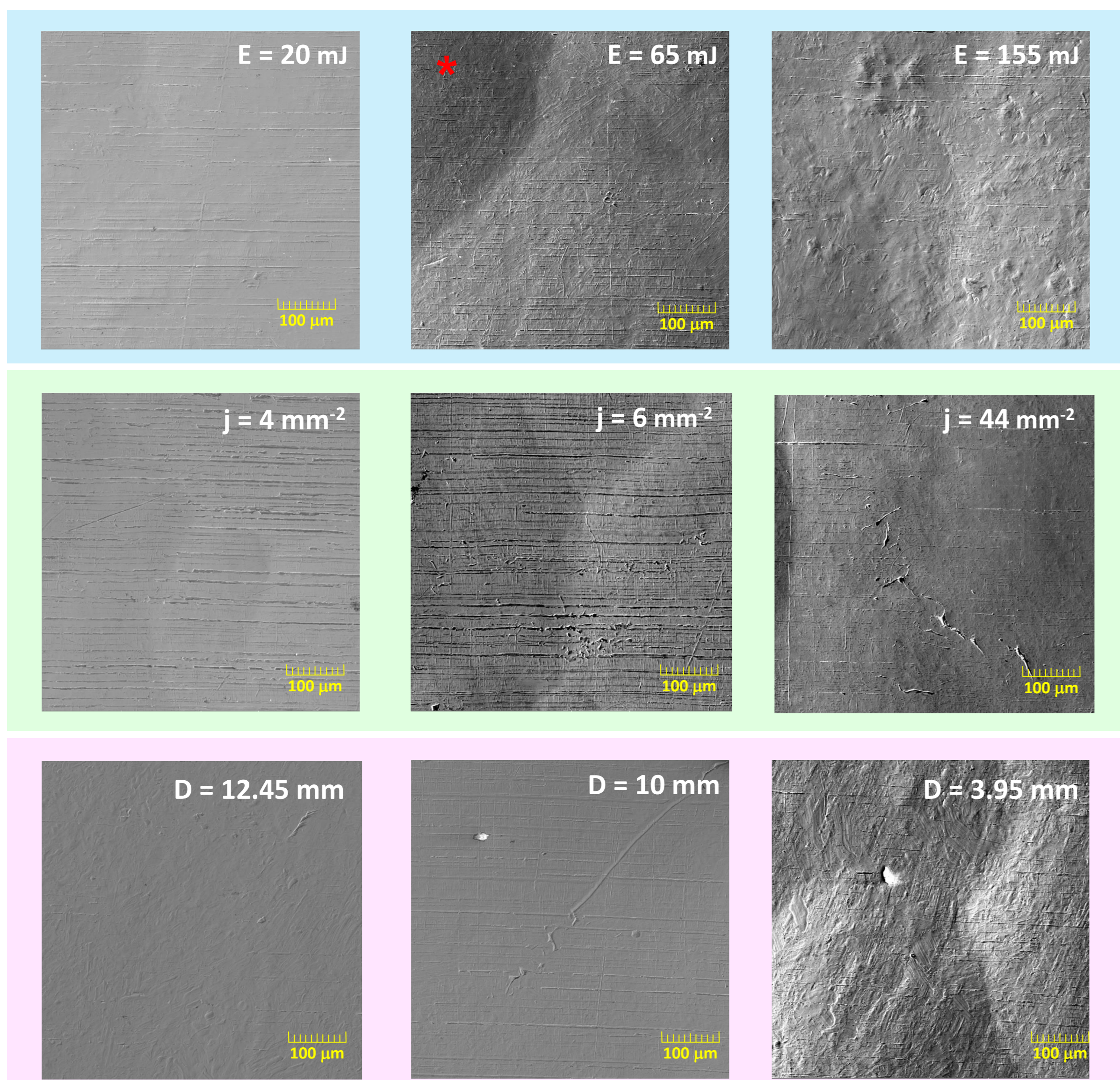
Motivation

Shot peening (SP) is one of the finishing methods of machine elements. Changes in the surface layer caused by SP result in improved performance of these components, mainly of the fatigue strength. Elements exposed to variable loads are produced, inter alia, of stainless steels, which are mainly used in corrosive environments, especially in the chemical, food, ship, aviation, and chemical industries. The nondestructive method, which allows to connect the properties of the materials with changes of the microstructure of the surface layer, is positron annihilation lifetime spectroscopy (PALS). Our previous research [1,2] has shown that unalloyed, bearing and carburizing steels, and aluminum and titanium alloys can be successfully investigated by PALS. The aim of the present work is to determine the influence of the SP parameters on both defect microstructure (studied by PALS) and properties (reflected by the surface microhardness) of the material.

SEM/EDS characterization

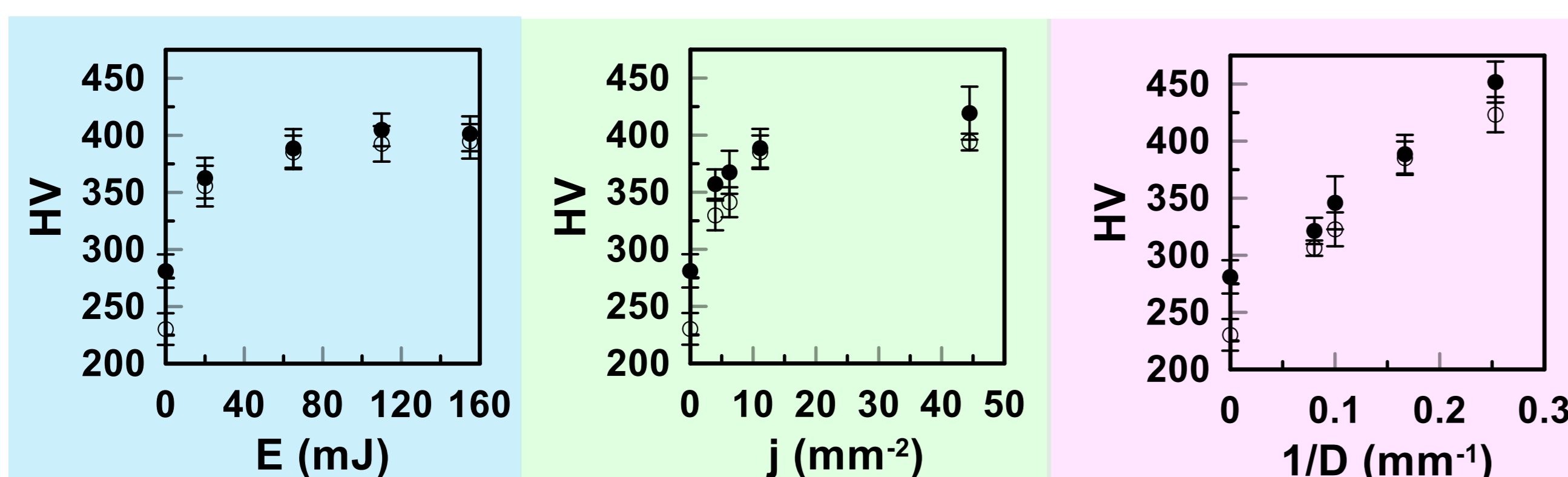


EDS spectrum and elemental composition of un-shot shot peened 1.4541 SS surface. EDS testing of the shot peened surfaces do not reveal any significant impurities.



Representative SEM micrographs for shot peened 1.4541 SS obtained at magnification of 500x, HV = 20 kV and working distance 30 mm. The SP parameters other than specified were fixed to E = 65 mJ, j = 11 mm⁻² and D = 6 mm. The sample marked by * is common for three series of measurements.

Hardness testing



Microhardness of 1.4541 SS using the force of 0.981 N (full symbols) and 4.905 N (open symbols) as a function of impact energy (E), impact density (j) and inverse of ball diameter (1/D).

Experimental

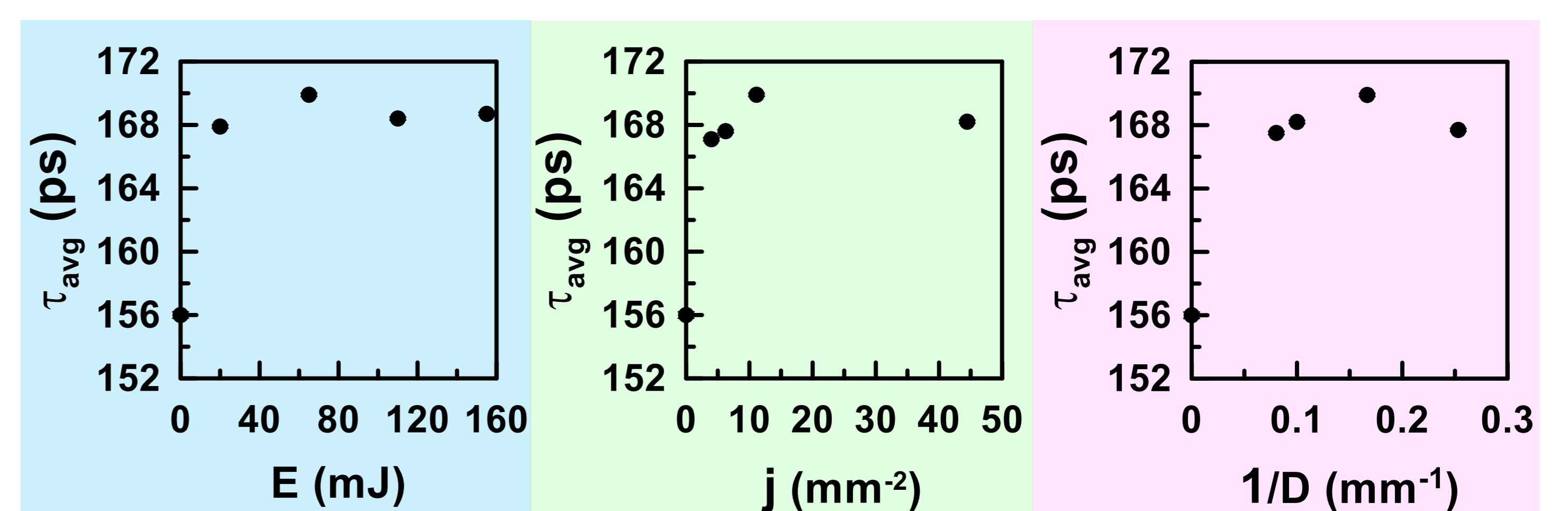
Austenitic stainless steel (SS) EN 1.4541 samples in the form of two identical 5-mm thick plates were cut from a larger piece of commercial SS. Then their surfaces were mechanically grinded. Subsequent parts of the suitable specimen surfaces were subjected to pulsed SP at various impact energies ($E = 20 \div 155$ mJ), impact densities ($j = 4 \div 44$ mm⁻²) and ball diameters ($D = 3.95 \div 12.45$ mm).

Microhardness was measured by the Vickers method on a LM700AT microhardness tester (LECO). A force of 0.981 N or 4.905 N was applied to the microindenter.

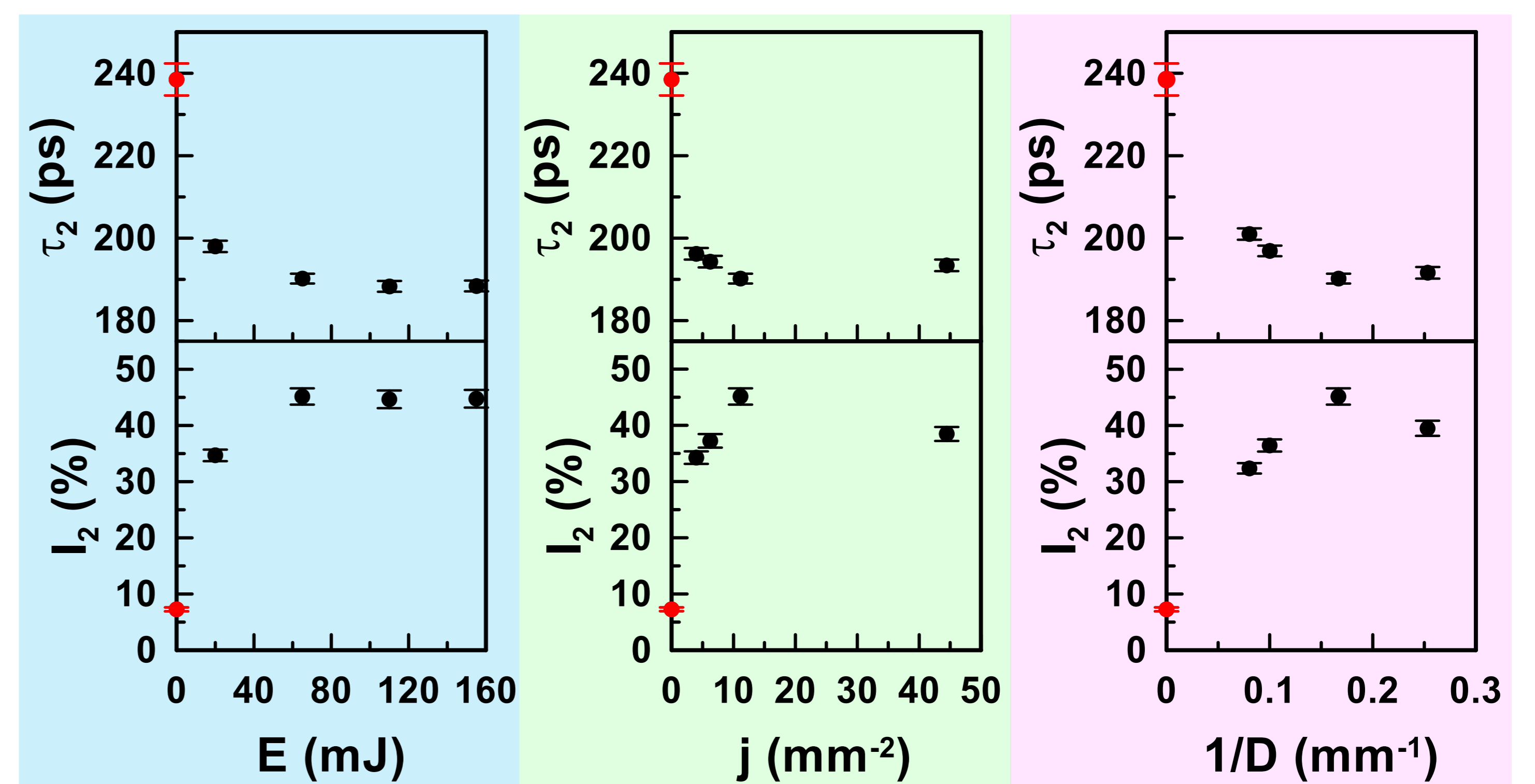
Scanning electron microscopy (SEM) observations were performed on a TECAN Vega LMU3 microscope in secondary electron mode. Oxford energy-dispersive spectrometer (EDS) attached to the microscope was used to check elemental composition of the investigated sample surface.

In PALS measurements, the ²²Na source of 60 kBq activity enclosed in a Kapton envelope was used. A digital positron lifetime spectrometer, equipped with BaF₂ scintillation detectors and U1065A Acqiris high-speed digitizers (Agilent) was employed. The sampling rate was 8 GS/s. The coincidence unit (Rehberg Electronic) served as a trigger. The software retrieving PAL spectra from digitized impulses was based on the code developed by the Prague group [3]. The time resolution of the spectrometer was about 203 ps (FWHM ²²Na). The total number of counts for each investigated sample was about 10⁷.

Positron annihilation lifetime



Average lifetime of positrons in 1.4541 SS versus impact energy (E), impact density (j) and inverse of ball diameter (1/D).



Lifetime and intensity of the second component in 1.4541 SS as a function of impact energy (E), impact density (j) and inverse of ball diameter (1/D). The first component with the lifetime of 150 ps was assumed to originate from dislocations [4].

Conclusions

- The increase of surface layer hardness with increase impact energy (E) and impact density (j) quite rapidly achieves saturation at about 400 HV0.5. The saturation for increasing inverse of ball diameter (1/D) is not observed in the investigated range.
- In the un-shot peened 1.4541 SS, two positron lifetime components: ($\tau_1 \approx 86$ ps, $I_1 \approx 88$ %) and ($\tau_2 \approx 164$ ps, $I_2 \approx 12$ %) were revealed. The former corresponds to the positron annihilation from delocalized state of positrons in bulk, shortened due to positron trapping at defect represented by the latter – probably vacancies on the edge dislocations.
- In the shot peened 1.4541 SS samples the bulk component is no longer observed. Instead, two types of defects can be identified: vacancy-like defects coupled with edge dislocations ($\tau_1 \approx 140 \div 150$ ps) and monovacancies or their small clusters ($\tau_2 \approx 180 \div 190$ ps).
- PALS and hardness testing results do not correspond very well, probably due to different depth profiles of both methods. This allows to presume that the defects, which are responsible for the increase of microhardness above 400 HV0.5 are located mostly below the surface layer penetrated by positrons.

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2. R. Zaleski, M. Gorgol and K. Zaleski. *Physics Procedia* **35**, 92-97 (2012)
3. F. Bečvář, J. Čížek, I. Procházka. *Acta Phys. Polonica A* **113**, 1279-1284 (2008)
4. J. Čížek, I. Procházka, J. Kočík and E. Keilová. *Phys. Status Solidi A* **178**, 651-662 (2000)