50 years of the Institute of High Pressure Physics Polish Academy of Sciences

Highlights in III-V semiconductors, THz physics and nanomaterials

Anniversary Symposium „Unipress 50”

High pressure application for severe plastic deformation of materials

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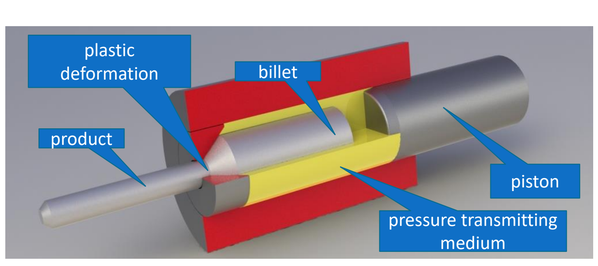
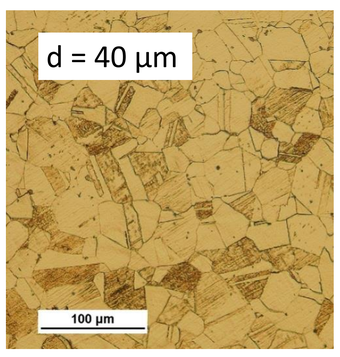
Hydrostatic extrusion (HE)

- Large plastic deformation, up to ε ~ 2.7 in one operation
- High plastic strain rate, up to $V_\varepsilon = 10^3\ s^{-1}$ (impact on the efficiency of defect generation in materials),
- High pressure (up to 2.5 GPa) leads to inhibition of the fracture process and the formation of micro cracks

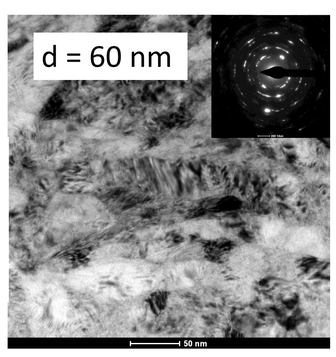


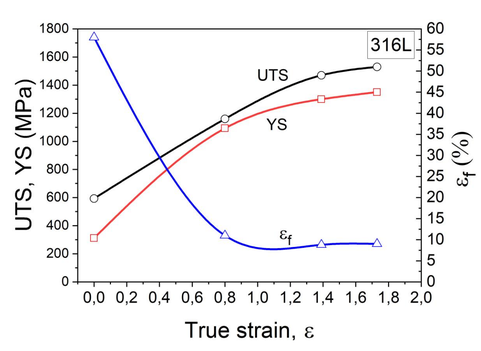
Nanocrystalline austenitic stainless steel

Plastic deformation of austenitic stainless steel with strain ε ~ 1 leads to grain refinement in nano scale.



Transformation of the microstructure during the HE process



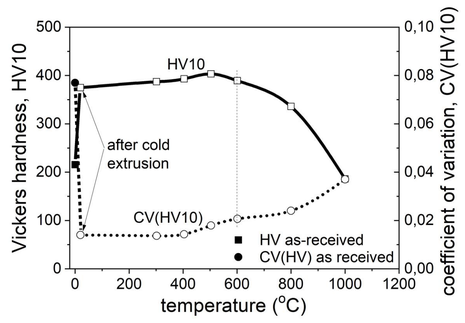


Dependence of the ultimate tensile strength UTS, yield stress YS and elongation to fracture ε_f on true strain in 316L stainless steel after cold hydrostatic extrusion [1].

two-sided pin, UTS = 1270 MPa
M20x128 A4-100 DIN 976
used at *CERN*

roundhead screw, UTS = 1150 MPa
M16x90 A4-80 DIN 912
used at *extraction platforms*

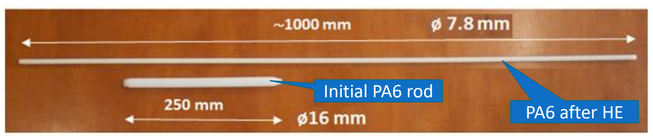
High-strength fasteners made of nanostructurized 316L stainless steel processed by cold hydro- static extrusion

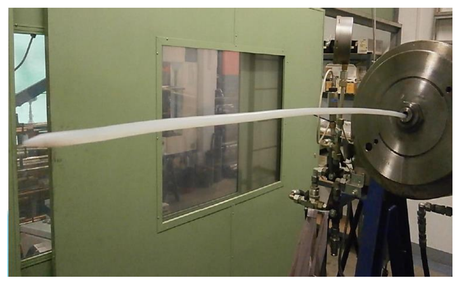


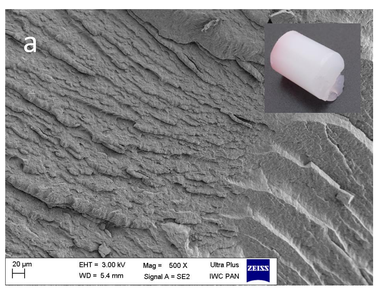
Thermal stability of 316L austenitic stainless steel after cold hydrostatic extrusion [1].

Reinforcement of polymers

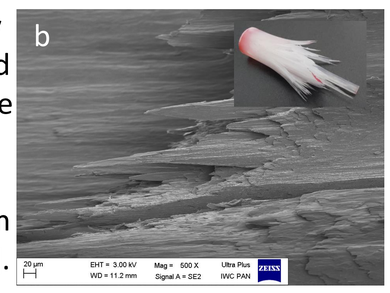
Cold hydrostatic extrusion of polyamide PA6,

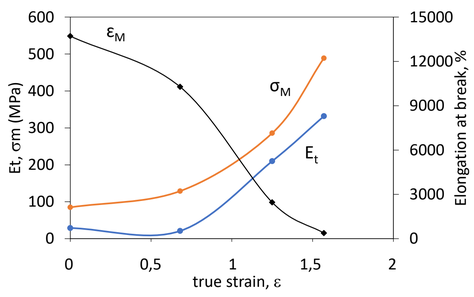




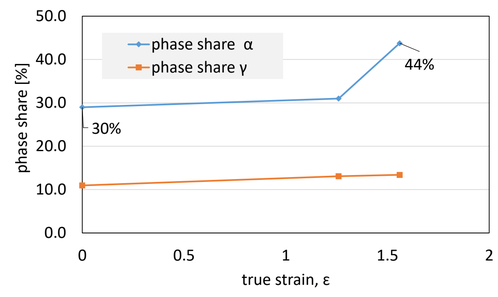


Scanning electron microscopy (SEM) images of cryo-fractured transverse cross-sections of the polyamide PA6 in (a) initial state and (b) rod after cold hydrostatic extrusion HE with true strain ε = 1.57 [2].



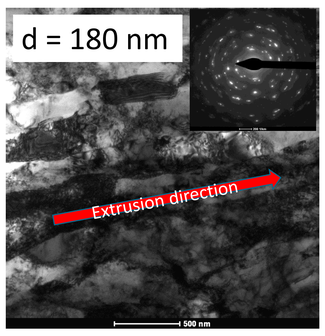


Relationship of mechanical properties determined the tensile test as a function of strain after PA6 HE. Where: tensile modulus (E_t), elongation at break (σ_M), tensile strength (ε_M) [2].

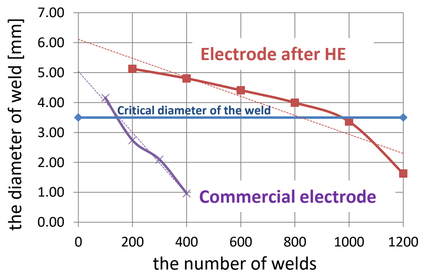


Relationship of polimer crystallinity determined FTIR-infrared spectroscopy as a function of true strain.

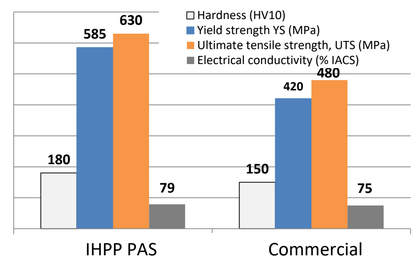
Low alloy copper CuCrZr for spot welding electrodes



Longitudinal cross-section of CuCrZr ultrafine-grained microstructure after hydrostatic extrusion and artificial aging at 480 °C for 1 h (strong anistropy).



Lifetime of the electrodes treated by HE compared with the lifetime of the reference commercial electrodes [3].



Comparison of hardness, mechanical properties and electrical conductivity between commercial CuCrZr and material after hydrostatic extrusion.

IHPP PAS electrodes

References

1. W. Pachla, J. Skiba, M. Kulczyk, S. Przybysz, M. Przybysz, M. Wróblewska, R. Diduszko, R. Stępniak, J. Bajorek, M. Radomski, W. Fąfara, Nanostructurization of 316L type austenitic stainless steels by hydrostatic extrusion, *Materials Science and Engineering: A*, 2014, 615, p. 116.
2. M. Skorupska, M. Kulczyk, S. Przybysz, J. Skiba, J. Mizeracki, J. Ryszkowska. Mechanical Reinforcement of Polyamide 6 by Cold Hydrostatic Extrusion, *Materials,* 2021, 14, 6045.
3. M. Kulczyk, W. Pachla, J. Godek, J. Smalc-Koziorowska, J. Skiba, S. Przybysz, M. Wróblewska, M. Przybysz, Improved compromise between the electrical conductivity and hardness of the thermo-mechanically treated CuCrZr alloy, Materials Science and Engineering A, *Materials Science and Engineering A*, 2018, 724, p. 45.

Summary

- The HE process is a globally unique high plastic deformation technology for modifying the structure of materials.
  - In metallic materials it causes refinement of grains on a nano-scale,
  - In plastics, it changes the degree of crystallinity and the structure of macromolecules .
- Changes in the microstructure after the HE process usually result in a significant increase in the mechanical properties of the materials.
- Optimization of the obtained properties allows for the development of unique structural solutions applicable in many branches of industry.

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