GESA

Large area pulsed electron beam facility for material surface engineering

Introduction

New methods for surface modification of materials, which are based on the use of pulsed power beams, have been developed over the last few decades. The surface modification of materials using intense pulsed electron beams exhibits essential advantages over pulsed laser and ion beams by its high efficiency, simplicity and reliability. Moreover, the electron beam, unlike the laser one, is absorbed by a target almost completely. The penetration depth of laser energy into the material surface is negligible.

The intense pulsed electron beam (Gepulste ElektronStrahl Anlage - GESA) technique proved to be an efficient method for surface modification of materials. Compared to laser surface modification, GESA technique allows the processing of larger surfaces and/or of surfaces with more complex configuration in only one pulse.

GESA technique is characterized by the formation of high-gradient temperature fields concentrated in the heat-affected zone (HAZ), and of stress fields located in the depth far beyond the HAZ in the material.

The high energy pulsed electron beam irradiation induces rapid heating and cooling (10^6 - 10^9 K/s) with high temperature gradient, leading to melting, evaporation, plasma ablation, and formation of thermal stress and shock waves. As a result, metastable and nanocrystalline structures, as well textures, may appear in the modified surface layer of the irradiated materials.

Structural and compositional modification of the materials surfaces improves the over-all performance of materials, such as corrosion resistance, microhardness, wear and fretting resistance. The process is also considered as a new potential method to polish hard steels and alloys.

GESA method, in combination with other surface techniques, can be used for micro- alloying of the surface of materials. A structural and compositional gradient could be obtained at the materials surface up to a depth of 30-50 micrometers.

Surface modification using GESA method can be applied in case of metallic materials to be used under extreme conditions, in the fields of energy production and conversion, gas and oil extraction, transport and aerospace industry, medicine (implants and tools) or defence industry.

Examples of applications:

- Increasing the life-time of hard-alloy cutting tools
- Improving endurance limit of compressor vanes of gas turbine engines made of Ti-based alloys
- Smoothing and densification of protective coatings deposed by thermal spraying of powders
- Surface alloying of metallic materials
- Improving corrosion resistance of metallic materials
- Surface hardening (e.g. in engines: valves, tapets and gears)
- Surface preparation before deposition of coatings

GESA equipment could offer to researchers the unique possibility to deepen their knowledge in the field of metastable structures generated by processes carried on under thermodynamic nonequilibrium conditions with the aim of finding solutions for materials to be used in advanced energy and transportation systems, medicine and defence industry.

Facility characteristics

The facility consists of the following main parts (Fig. 1): an electron injector of triode type with a multipoint explosive emission cathode; a transport channel; treatment chamber; magnetic focusing system; high-voltage generator; vacuum system; control rack; radiation protection unit; mechanical support.

- power density at the target 2 MW/cm^2
- current density on the target 5 - 30 A/cm^2
- pulse duration 5 - 40 us
- beam diameter on the target 4-10 cm
- max. thickness of melted layer SS 316: 25 µm; Cu: 45 µm; Al: 75 µm
- accelerating voltage 80 - 120 kV

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- beam current $\leq$ 1kA
- working pressure range $10^{-6} – 10^{-5}$ mbar
- weight of the accelerator part 1000 kg
- weight of the high voltage generator (HVG) ~800 kg
- technological area: LxWxH = 4 x 4 x 3,5 m
- radiation safety category: accelerator without electron microscope, X-ray level < 1µSv/h (§5 Abs.1RöV) http://www.bfs.de/de/bfs/recht/rsh/volltext/1A_Atomrecht/1A_14_RoeV_1011.pdf

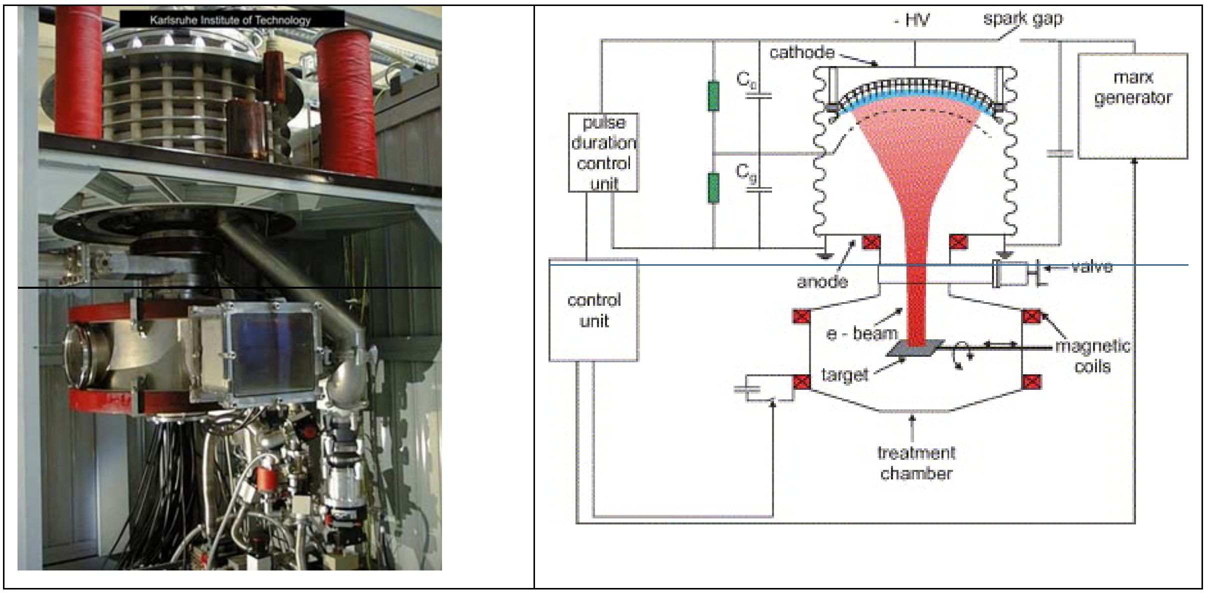

Fig. 1.(a) Intense pulsed electron beam facility at Karlsruhe Institute of Technology, Germany and (b) conceptual diagram

References:

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Patent: EP0810628 - Source for generating large surface pulsed ion and electron beams
Patent: EP0860019 – Pulsed electron beam source and use thereof

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