LASER TARGETS FROM BERYLLIUM DEUTERIDE.

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Metastable hydrides of light elements with high content of heavy isotopes of hydrogen (for example BeD_2, BeDT, $LiBeD_3$, $Li_2Be_2D_3T_3$, etc.) can be used for wall of large (reactor-scale) fusion target instead of beryllium or polyimide. The burning reactor-size targets are shown to be profitable [1] as regards energy yield. Possible methods of large fusion target fabrication for high power lasers are discussed both for direct and indirect schemes [1, 2]. These works have started a few years ago [3,4] with the view to shell application for laser targets production.

Results of irradiation of various beryllium deuteride targets by ns- and ps-lasers are discussed. The properties of fuel - materials with high content of hydrogen isotopes, which have substantial importance for large fusion target fabrication technology, are analyzed. New laser targets and its' characteristics are demonstrated.

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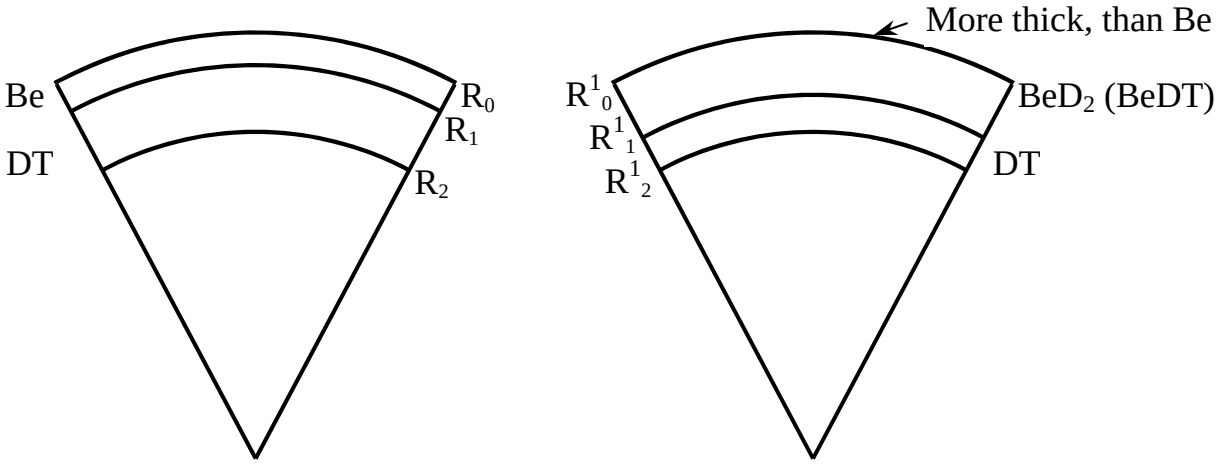
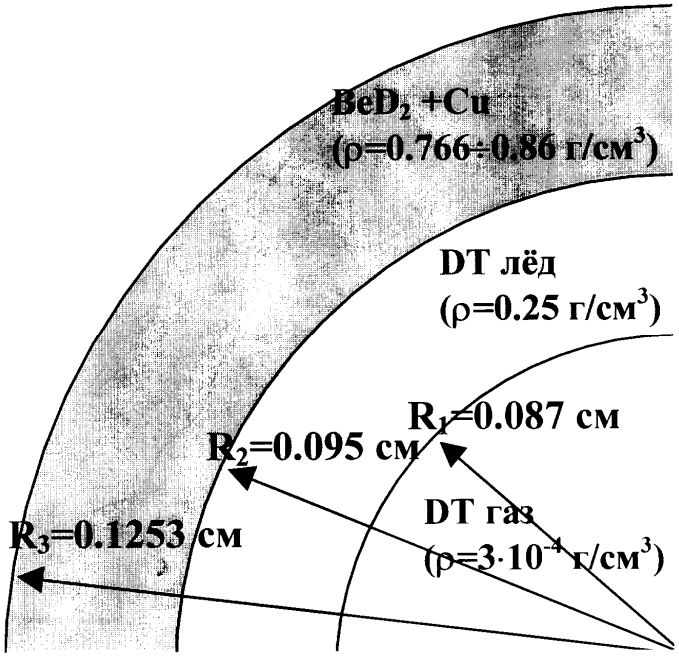
1. S.Yu. Gus'kov, N.V. Zmitrenko, Yu.E. Markushkin, Yu.A. Merkul'ev. Energetic efficiency of laser thermonuclear targets with ablators shell made of beryllium materials: a comparative analysis. // Journal of Russian Laser Research, Springer, New York, ISSN 1071-2836, 2007, V. 28, No 2, p. 148-162.
2. S.A. Bel'kov, G.V. Dolgoleva, G.G. Kochemasov, E.I. Mitrofanov. Application of beryllium deuteride as shell matter of laser x-ray targets. // Quantum electronics. (Russian), 2002, V. 32, No 1, pp. 27-32.
3. N.G.Borisenko, V.M.Dorogotovtsev, A.I.Gromov, S.Yu.Guskov, Yu.A.Merkul'ev, Yu.E.Markushkin, N.A.Chirin, A.K.Shikov, V.F.Petrunin. Laser targets of Beryllium deuteride. //Fusion Technology, V.38, No1, 2000, p.161.
4. V.M.Dorogotovtsev, N.A.Chirin, V.V.Gorlevsky, O.N.Krokhin, Yu.E.Markushkin, S.A.Startsev, A.K.Shikov, A.V.Zabrodin. Research possibility of target fabrication from beryllium deuteride (foaming technique). //Proceedings of SPIE, (2001), V.4424, p.159.

It was proved that the gain of beryllium hydride can be brought to a level of the beryllium targets due to the variations of the geometrical parameters of BeD_2 targets.

It was shown that fission of such substance – ablator as BeD_2 or BeDT in reactor-scale targets can introduce a significant contribution into the final thermonuclear yield.

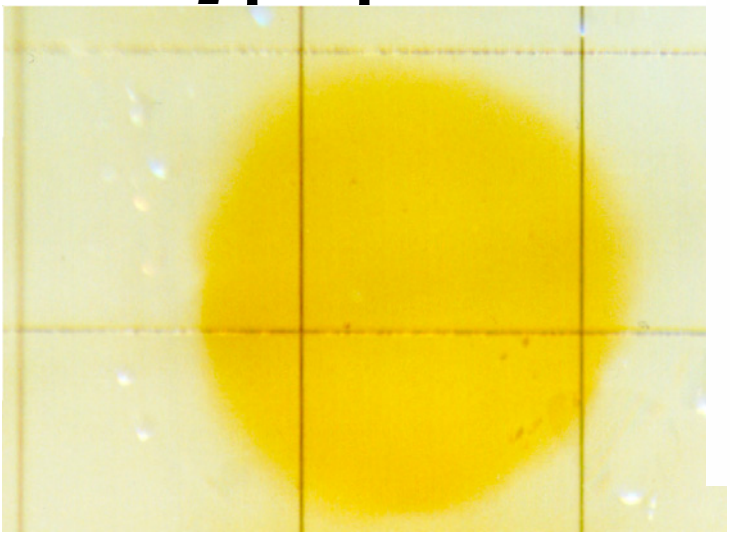


COMPARATIVE ANALYSIS OF THE ENERGETIC EFFICIENCY OF LASER THERMONUCLEAR TARGETS WITH SHELL-ABLATORS MADE OF BERYLLIUM MATERIALS. S.Yu. Gus'kov, N.V. Zmitrenko, Yu.E. Markushkin, Yu.A. Merkul'ev Preprint FIAN, 20, 2001

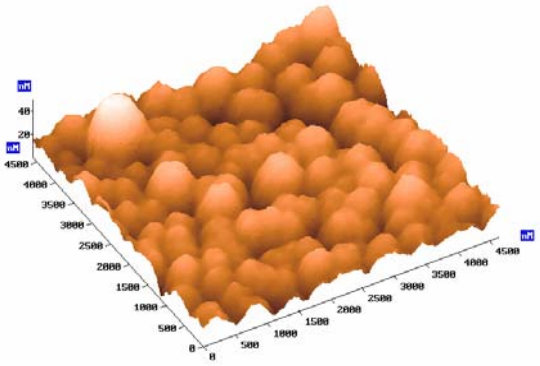


Indirect BeD_2 target for NIF by S.A. Belkov et al. Quantum Electronics (Russian) 2002, V. 32, No 1, p. 27. **Gain 17**. (Be-shell **gain – 20**).

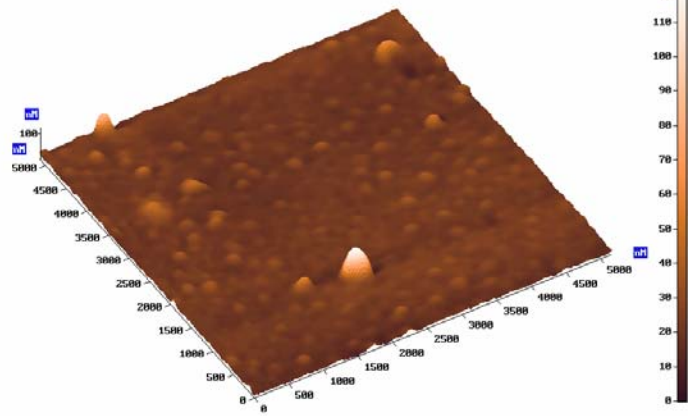
BD_2 properties

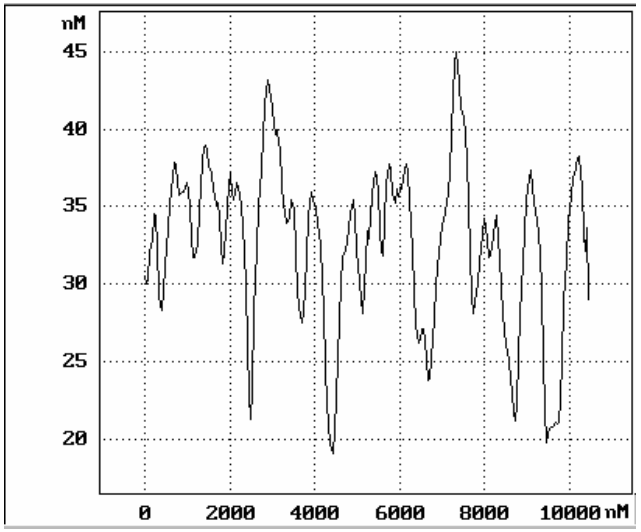


Optical transparency of beryllium hydride. 7 μm beryllium deuteride layer on 50 μm glass substrate lie glass with lines. Lines on glass can be observed vary well trough BeD_2 layer. Yellow color indicate metal beryllium in BeD_2 layer (possibility of cryogenic layer monitoring).



- amorphous structure;
- smooth surface, roughness less 10 nm .

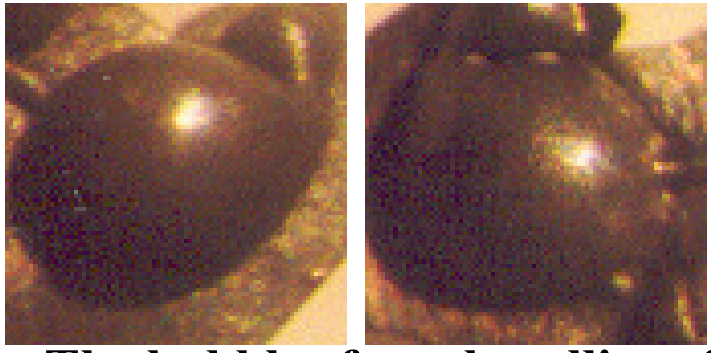




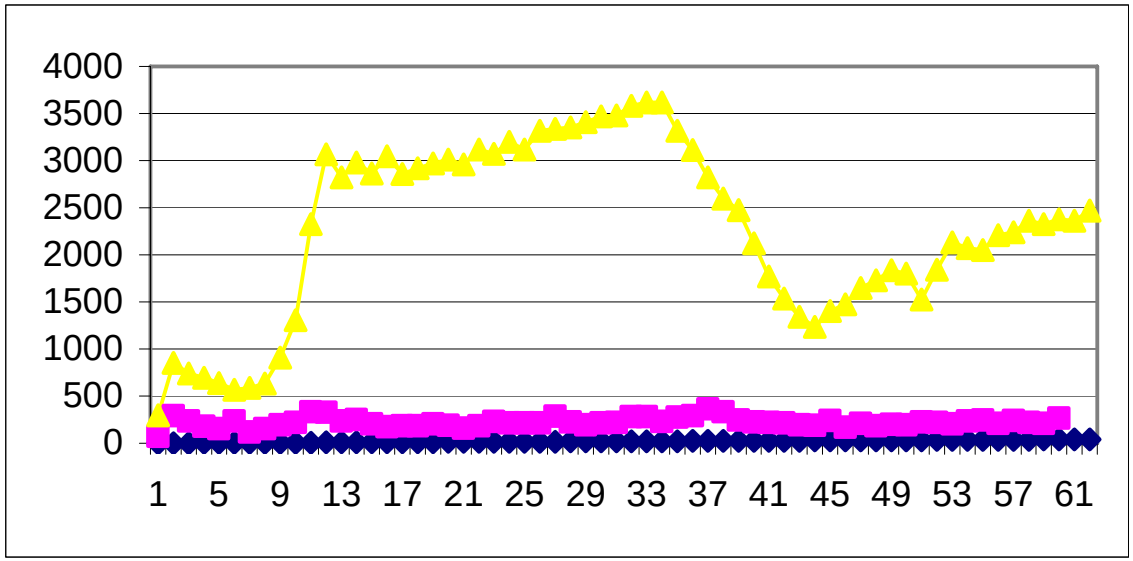
Shell wall with gradient concentration of middle Z addition

Theoretical simulations of plasma compression from large NIF targets with nonuniform Cu concentration were shown that neutron yield (or gain) from such target was higher than from the targets with uniform Cu concentration.

BeD_2 layers with gradient of Cu concentration by thickness were fabricated in joint work of LPI and Bochvar Institute of Inorganic Materials. Yu.E. Markushkin et al.

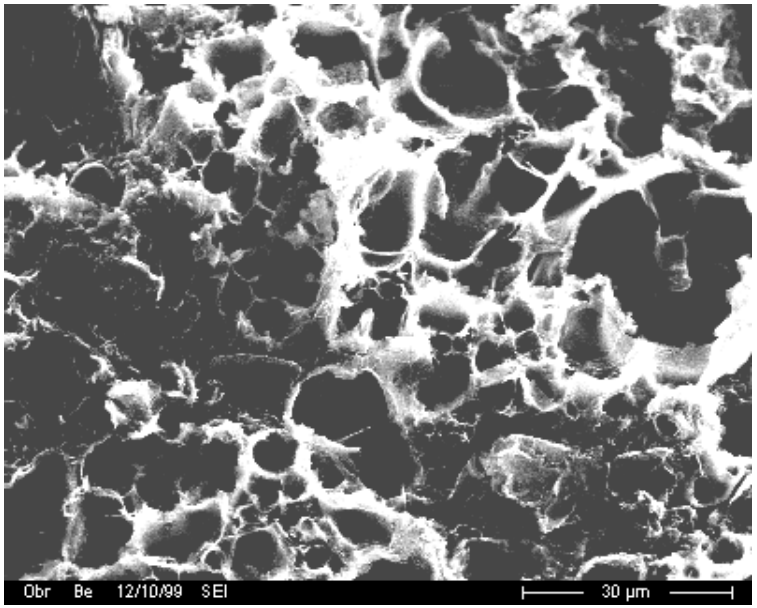


The bubbles from beryllium films.



Copper (yellow) concentration in BeD_2 layer (thickness - 12 μm). Maximum is about 36% weight.

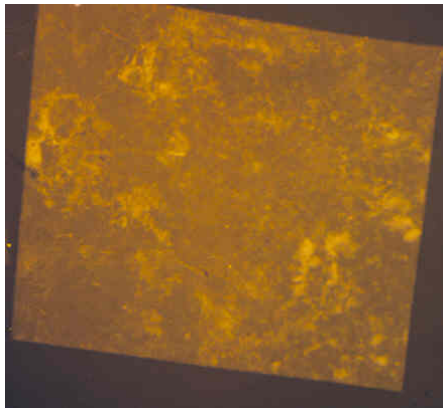
BeD_2 was transformed Be foams → at fast heating



Beryllium (deuteride) hydride is meta-stable composition, it can not be produced directly as $Be+H_2 \rightarrow BH_2$ at room temperature and at higher temperatures. BH_2 starts to decompose slowly at 50^oC and excrete intensively at 120^oC. Dr. Yu.E. Markushkin with assistants use original method of direct low-temperature syntheses [6]. The method allows to produce beryllium deuteride as thin film – coating on special substrates. BeD_2 and BeDT coating on the inner surface of copper shells (diameter of 4 mm) with holes for laser beams were applied as laser targets in experiments with the inverse corona [7]. Flat film with thickness of 5-12 microns and plate with thickness of 0.6-0.9 mm from BeD_2 were used as targets in experiments on ps-lasers "Progress-P" and "Neodim" [4].

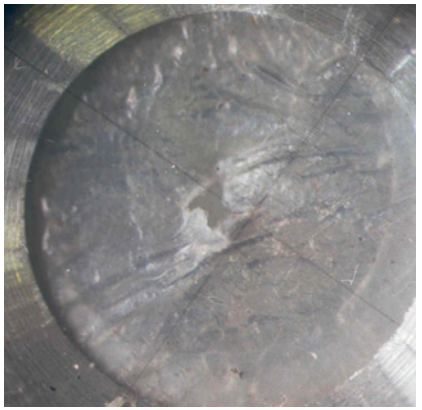
Usually beryllium hydride and beryllium deuteride does not oxidize in air at room temperature and does not interact with water and neutral solution. Pure BeD_2 is optical transparent material, but Be admixture adds color of the material.

Flat targets from deuteride polyethylene and BeD_2 with full density

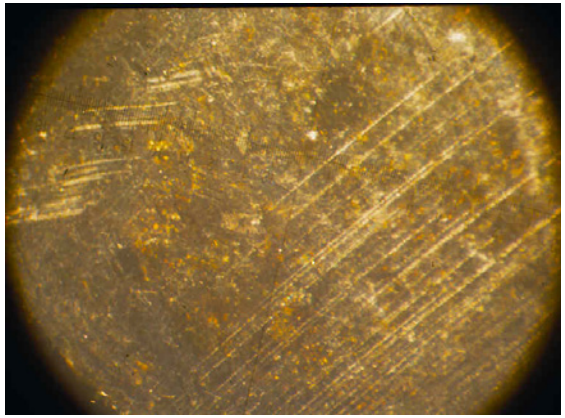


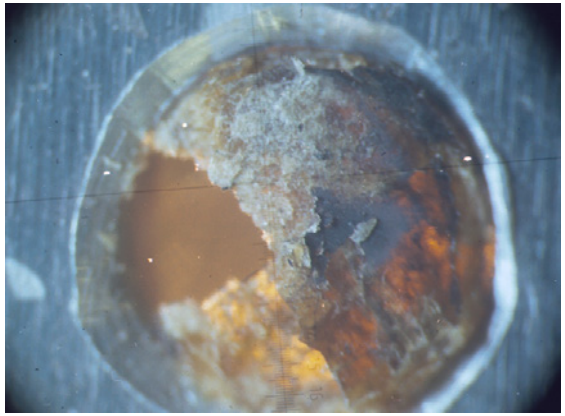
Photography of thick (350 μm) $(CD_2)_n$ layer

Craters in targets after shots of ps-laser. Left – laser incident, right – rear side.



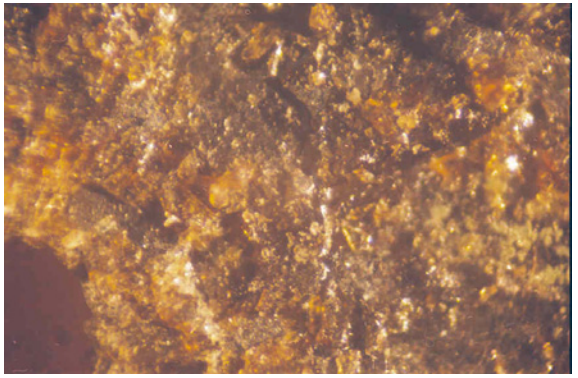
Craters in $(CD_2)_n$ multi-layers target after shots of ps-laser.





BeD_2 targets before and after shot Crater after intensive pulse and near Be-film after slow laser irradiation

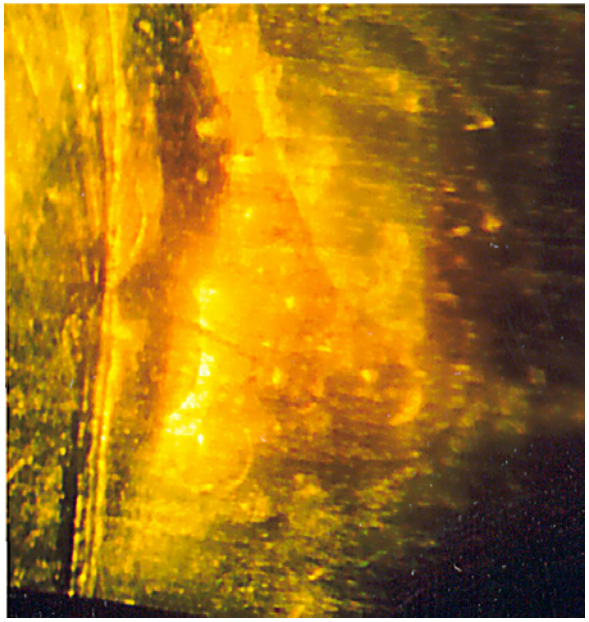
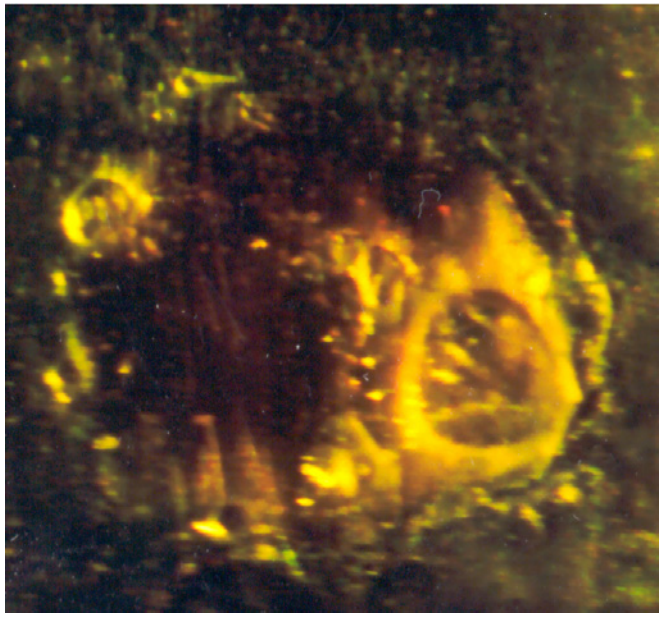
←BeD_2 targets after shots. Craters after intensive pulses and near BeD_2+Be-film after slow laser irradiation ↓



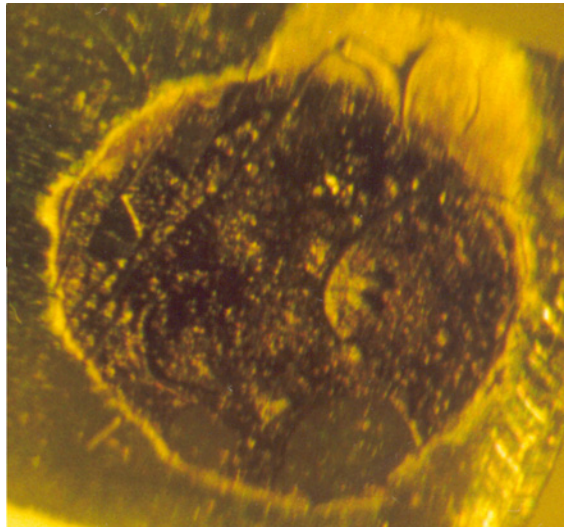
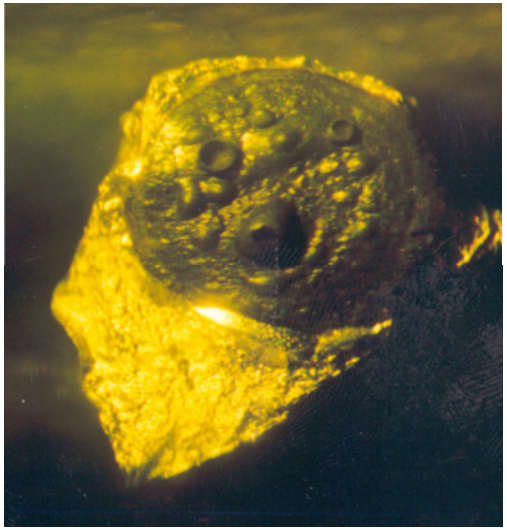
Final goal of the work is the creation of thin (with thickness about 1 micron) nanocrystalline beryllium film fabrication technology for soft x-ray windows, but not transparent in visible light, for plasma diagnostic apparatus.

Yu.E.Markushkin with assistants in Bochvar Scientific Research Institute of Inorganic Materials created production method of nanocrystalline beryllium from beryllium hydride. But micron thin beryllium film by mechanical method can not fabricate.

Thin (1 micron) beryllium hydride uniform film had been produced in Bochvar Scientific Research Institute of Inorganic Materials by original technology. Beryllium film from beryllium hydride fabricated by usual thermal method have large deformation and distorted structure. We propose to produce the thin beryllium film from beryllium hydride at interaction by short laser pulse, during pulse temperature beryllium hydride do not increase and introduced hydrogen do not deform film.

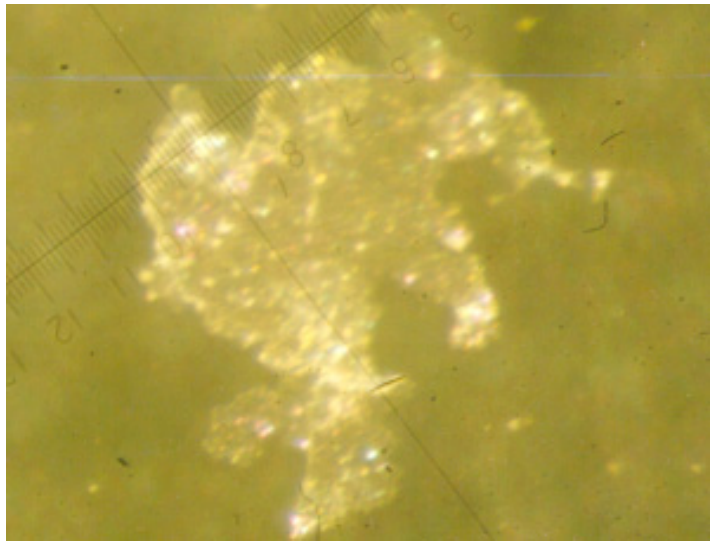



Two upper pictures show liquid of BeD_2 with bubbles at T=170^{o}C and 250^{o}C.

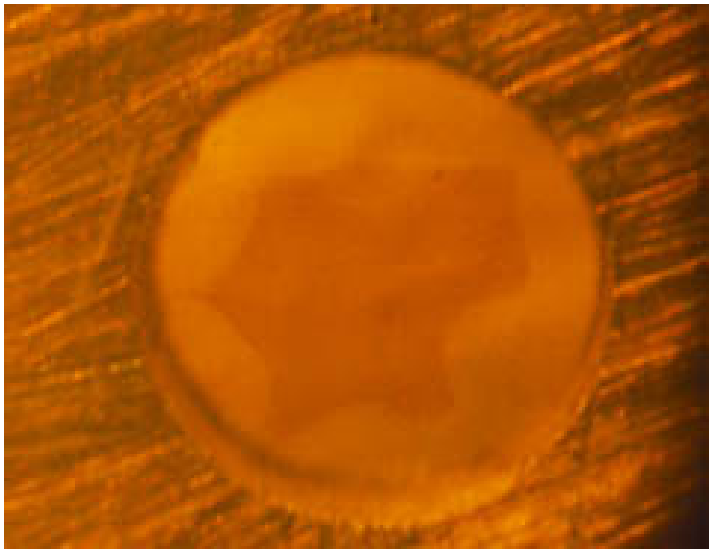




3 lower pictures show degradation of BeD_2 and forming of foam from Be.

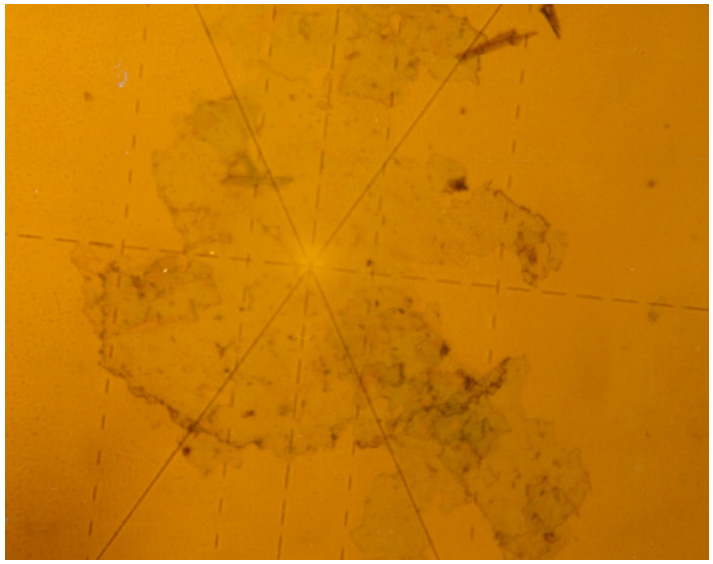
Thin BeD_2 targets on ns-(ps-)-lasers for transformation to Be.

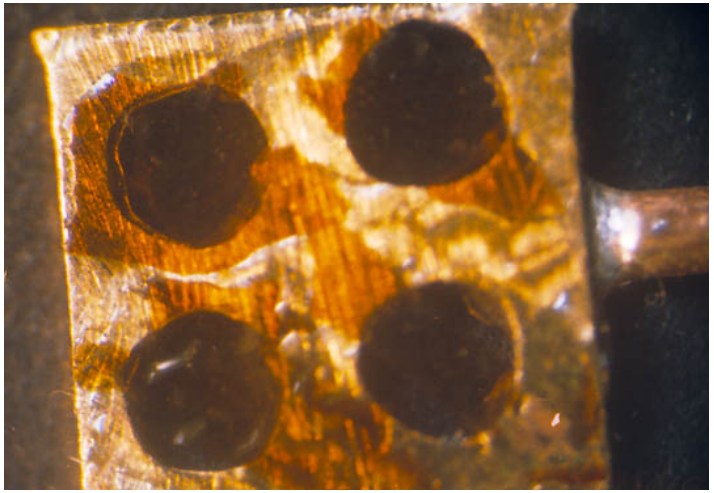


BeD_2 film with 0.3 µm thickness

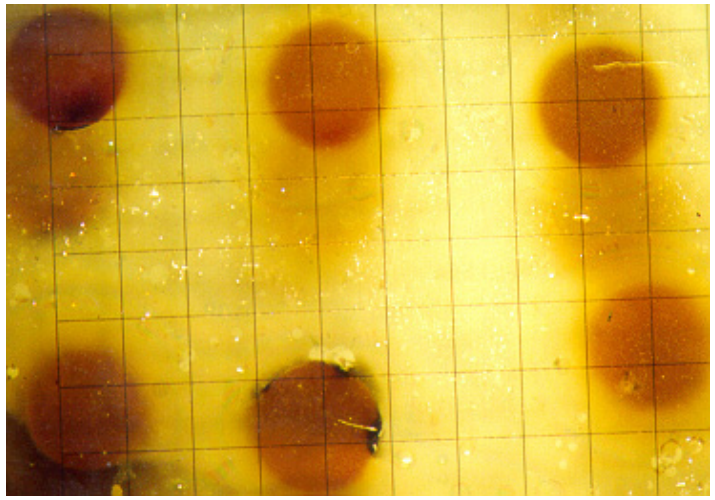


BeD_2 film with 3 µm thickness on holders

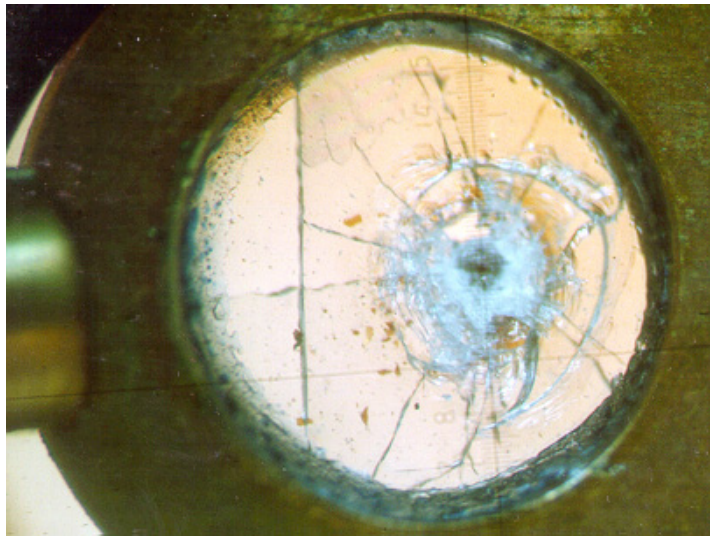




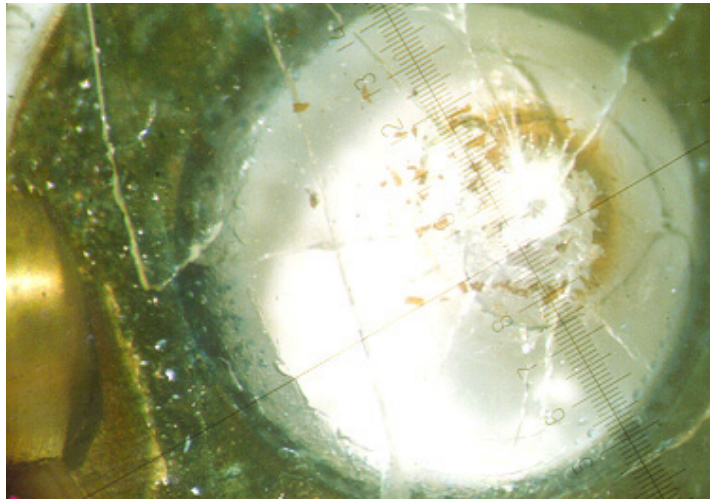
BeD2 targets after shots on “Kanal” laser (2 ns, 1,053 µm, 100 J)



BeD_2 layers with 2 mm diameter and 3 µm thickness on glass, upper optical mesh with 1 mm scale



BeD_2 layers after shots



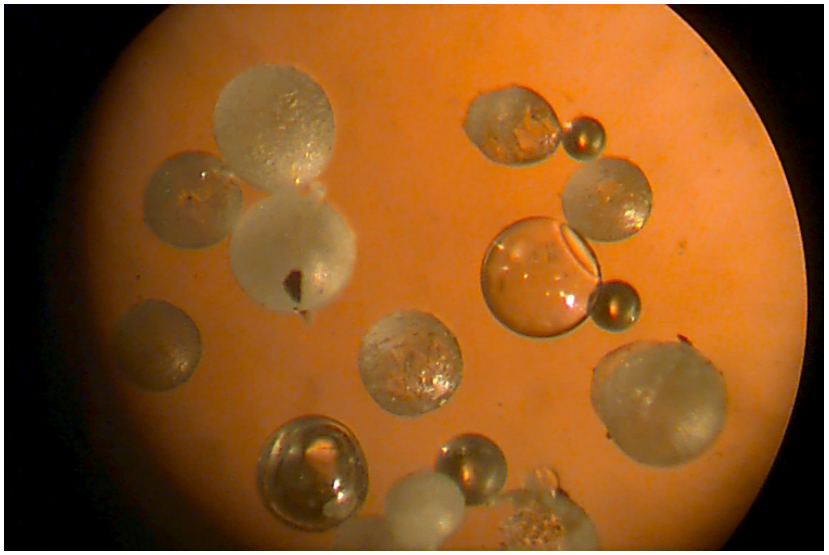
Properties of solid hydride of light elements

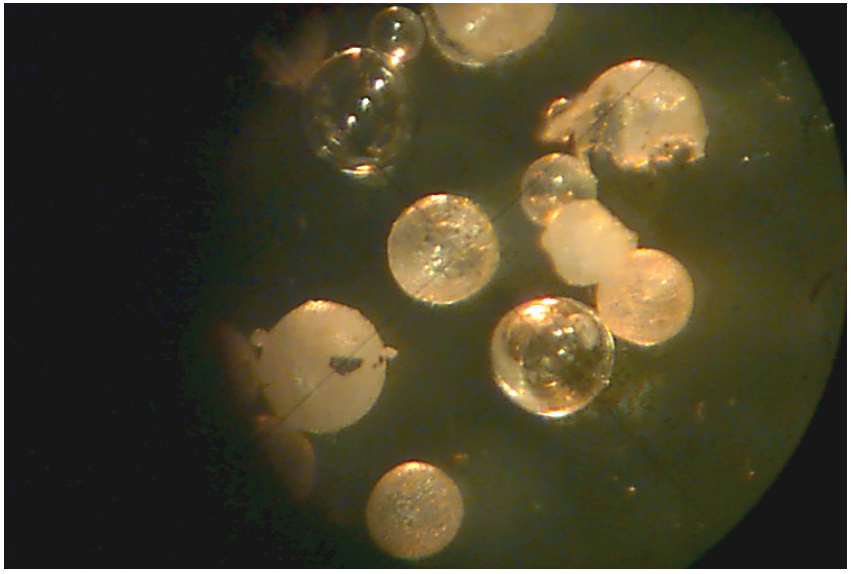
Material	$LiBeD_3$	$LiBD_4$	BeD_2	$(CD_2)_n$	ND_3BD_3
Density, g/cm3	≈0,83	≈0,86	0,765	1,10	0,92
Number Σ(Zi+1) to 4 (number D_2)	2,5	2,25	2,25	2,75	2,167
Module of e Properties of solid hydride of light elements lasticity, GPa			27,3	3,4	
Melting point, oC (Glassy temperature),			140 (134)		106
Boiling point, oC (Temperature of momentary disintegration)			(≈350)	(≈520)	(≈300)
Permeability for H_2, cm2/atm.s,			<5·10-12	10-6	≈<10-9
Optical transparency (<0,1 mm)	semi	yes	yes	yes	yes
Surface roughness, nm			<10	<60	<30
Structure (crystal, amorphous)	crys.	crys.	amor.	am-cr	crys-am

GNIIChTEOS specialists produced first 10 grams ND_3BD_3 at December 2004.
Dr. Yu.E. Markushkin with assistants fulfilled isotopes exchange in ammine-borane

Drop tower furnace for BeD_2 and ND_3BD_3 shells fabrication.

← Automatic vacuum installation with 3 hot zones for formation of BeD2 and LBeD3 shells (up to Ø 0.5 mm) with lock and vessel in which targets are transposed in vacuum to the laser chamber.
TTL of LPI, 2002.
Now installation work in Bochvar Institute Inorganic Materials.





First shells from NH3BH3 fabricated in TTL at 14.04.03.

Conclusion.

1. **New fabrication technologies of large fusion targets from light elements deuteride-tritide allow to organize the experiments with high gain by energy or the researches with imitation cryogenic targets.**
2. **Fabrication technologies of shell-targets (tritium system for DT filling shells, systems for collection and clearing DT-mixture, D↔T isotopes exchanges in polymers and hydrides, cryogenic installations with DT-mixture etc.) give possibility to design unique pulsed neutron sources using power ps-lasers with optical pumping.**
3. **Relate cheap target system from light elements deuteride-tritide with apparatus of isotopes exchange can be used in experimental installations where need to optimize targets-drivers (Z-pinches, heavy ions accelerators etc.).**
4. **Beryllium film with thickness 5-7 microns were fabricated by nanosecond laser pulse at intensity 10^{11} W/cm^2, but in several places were small bubbles.**
5. **Beryllium film with thickness 2.5 and 3.5 microns were fabricated by picosecond laser pulse at intensity 10^{12} W/cm^2.**
6. **The thin (0.5-3 microns) film of nanocrystallane beryllium can be produced from BeD_2 with using ps-(fs-)-lasers for applications as the windows in VUV- and x-ray spectroscopes.**
7. **The thin film of BeD_2 + Be composition materials are very interesting object for optical investigations and various applications.**

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