With nanoplasmonics towards fusion

NAPLIFE 2022

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Energy crisis

Summit

Specific data, available energy

J/mg = MJ/kg

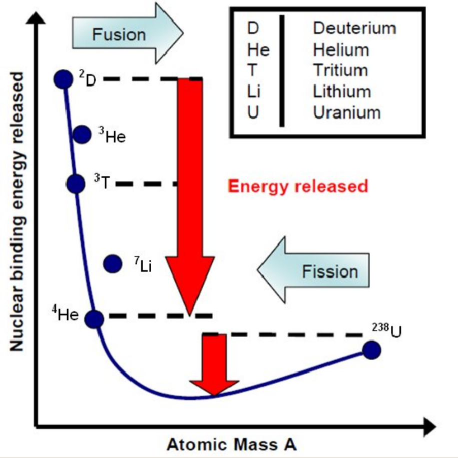
https://afdc.energy.gov/fuels/properties; https://en.wikipedia.org/wiki/energy_density

- coal 23; brown coal 18; turf 7; wood 11; biomass 10; hulladék 9; olajpala 20
- oil, PB gas 40; bio-fuel 30; waste 25
- natural gas 47; H 40; biogas 20; waste gas 15
- uranium 460.000; fusion 640.000.000

1 kg U $\approx$ 20 tons of coal $\approx$ 0.7 g fusion fuel

The ”atomic” force

nuclear techniques



Thermal and equilibrium

ITER magnetic confinement

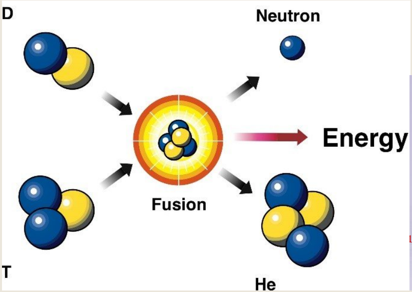
Direct and sudden

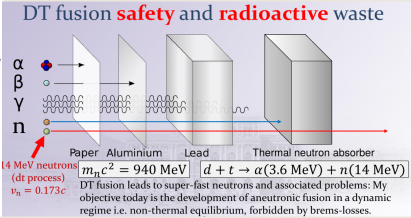
NIF laser shots

D + T fusion

why-s and problems

pictures from Rafelski





1. energetic neutrons; 2. global tritium quantity (nuclear power plants)

Neutronfree fusion

examples (wiki)

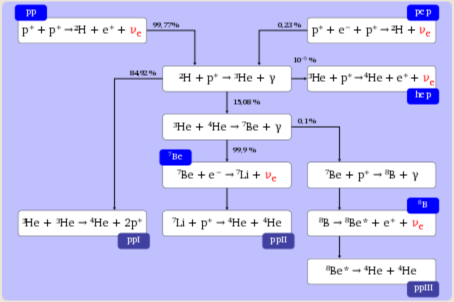
High nuclear cross section aneutronic reactions[1]

Isotopes	Reaction
Deuterium - ^{3}He	^{2}D + ^{3}He → ^{4}He + ^{1}p + 18.3 MeV
Deuterium - ^{6}lithium	^{2}D + ^{6}Li → 2 ^{4}He + 22.4 MeV
Proton - ^{6}lithium	^{1}p + ^{6}Li → ^{4}He + ^{3}He + 4.0 MeV
^{3}He – ^{6}lithium	^{3}He + ^{6}Li → 2 ^{4}He + ^{1}p + 16.9 MeV
^{3}He - ^{3}He	^{3}He + ^{3}He → ^{4}He + 2 ^{1}p + 12.86 MeV
Proton – Lithium-7	^{1}p + ^{7}Li → 2 ^{4}He + 17.2 MeV
Proton – Boron-11	^{1}p + ^{11}B → 3 ^{4}He + 8.7 MeV
Proton – Nitrogen	^{1}p + ^{15}N → ^{12}C + ^{4}He + 5.0 MeV

Electrons in the fusion

PEP process, Widom-Larsen (wiki)

$$p + e^{-} \rightarrow n + \nu_e \text{ (-1.25 MeV)}, \quad p + n \rightarrow d + \gamma \text{ (+2.22 MeV)}$$



Widom-Larsen theory

From Wikipedia, the free encyclopedia

The **Widom-Larsen theory** is a proposed explanation for supposed Low Energy Nuclear Reactions (LENR) developed in 2005 by Allan Widom and Lewis Larsen. In the paper describing the idea, they claim that ultra low momentum neutrons are produced in the cold fusion apparatuses[1] during weak interactions when protons capture "heavy" electrons from metallic hydride surfaces.[2] One source has held that it is "unlikely the electron energy threshold for neutron production can be reached in a metal lattice system without a substantial energy input".[3]

The idea was expanded by Yogendra Srivastava together with Widom and Larsen in 2014, who went on to propose that it could be an explanation for neutrons observed in exploding wire experiments, solar corona and flares, and neutron production in thunderstorms.[4] However, unrealistic concentrations of free electrons are needed for the neutron yield to be a significant component of thunderstorm neutrons, discounting the explanation.[5][6][7]

NAPLIFE individual features

Idea, plan, initial results

1. Plasmonic collectivity, energy concentration, threshold lowering, lifetime cca. $20 - 30$ fs
2. Far from equilibrium, lightspeed, simultaneous ignitions
3. Nanoantennas in target, ultrashort, high contrast laser pulses (10^6, 40 fs @ Wigner)
4. Energy balance and fusion products at low energy: microcraters, D/(2D+H)

Nanofusion

plasmons: barrier reduced, energy hot spots

Fusion cross section

when electrons screen the Coulomb barrier (Wong+Shih 2022)

Formula $\sigma(E, U_s) = \frac{S(E+U_s)}{E+U_s} \left[e^{\pi\sqrt{2.29\text{MeV}/(E+U_s)}} - 1 \right]^{-1}.$

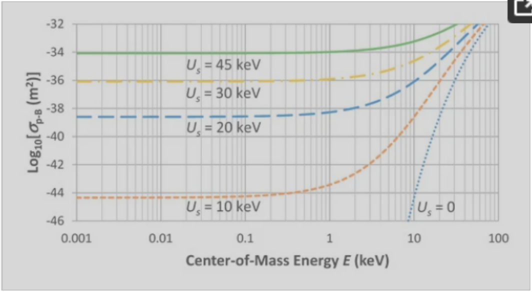
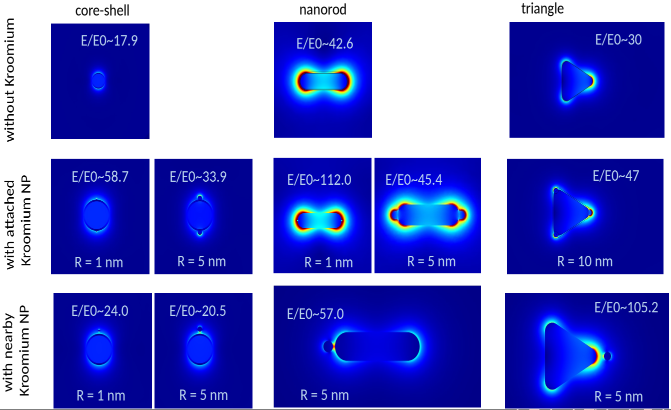


Figure 1. p-^{11}B cross section as function of particle energy for the screening electron densities up to U_s = 45 keV. The cross section below ***E*** = 1 keV grows over 10 orders of magnitude (from 10^{-44} to 10^{-34} m^2) when U_s increases from 10 to 45 keV.

Plasmonics at work

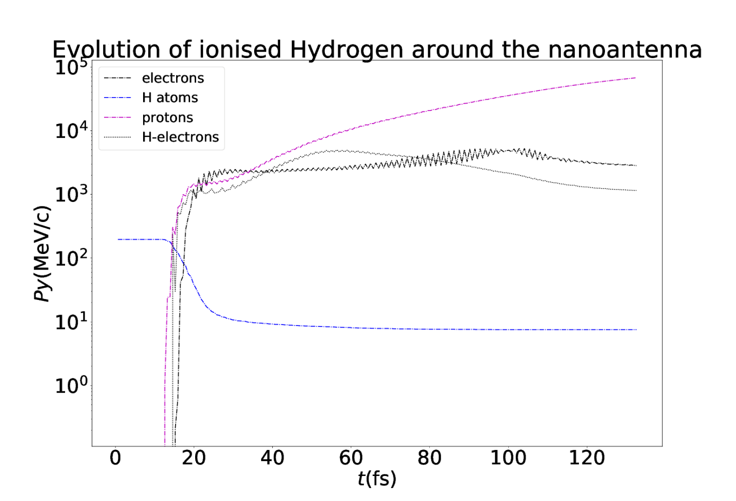
nanoantenna form variations (M. Csete)

Near-field enhancement with individual plasmonic nanoresonators & Kroomium nanoparticles



Kinetic model: PIC

Single nanorod time evolution (I. Papp)



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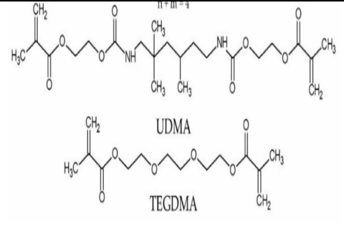
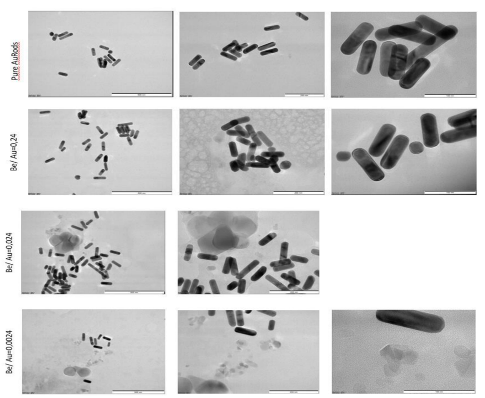
Scattered nanorod patterns (A.Bonyar, M.Veres)

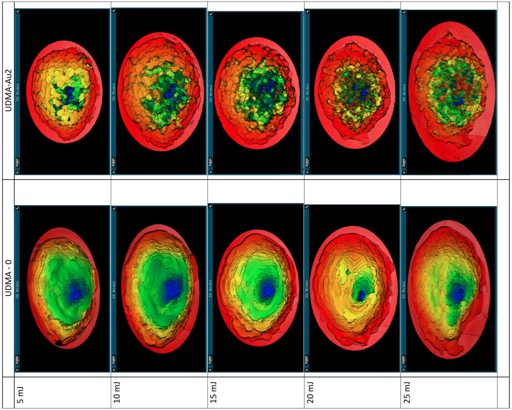




12. ábra. A különböző AuRods/ Be aránnyal rendelkező minták TEM felvételei

NAPLIFE CRATER

Craters w/o Au (J.Kaman, A.Szokol)



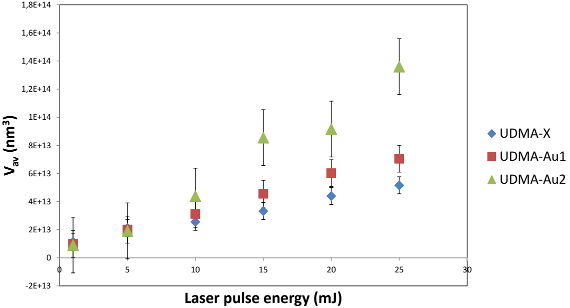
12. ábra: A Spektroszkópia csoport Zygo interferométerrel végzett mérési eredményei a belövési kráterekről UDMA-Au0, valamint UDMA-Au2 mintákról 5-25 mJ impulzusenergiák között.

NAPLIFE CRATER

crater volumes vs pulse energy

Crater volume

The analysis of the crater volumes – in 5 different points for every energy and target



ICNFP 2022 - Ágnes Nagyné Szokol - 7 September 2022

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UDMA - TEGDMA copolymer (M.Veres)

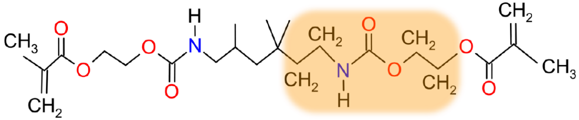


Figure 1. Chemical structure of UDMA monomer together with the selected part used for further modeling and calculations.

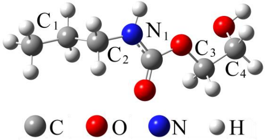
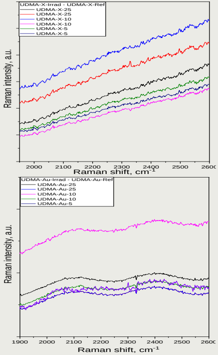
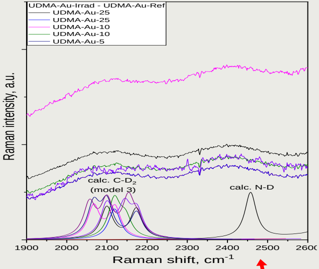


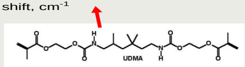
Figure 2. Optimized (B3LYP/6-311++G(d,p)) geometry of UDMA model (C_1H_2-C_2H_2 and C_3H_2-C_4H_2 groups are in anti and gauche conformational states, respectively).

NAPLIFE RAMAN

Raman signals: vibration of molecular bonds (Veres)



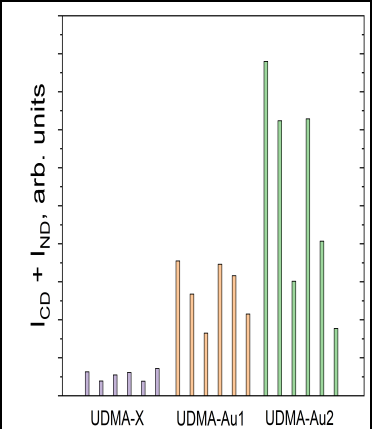


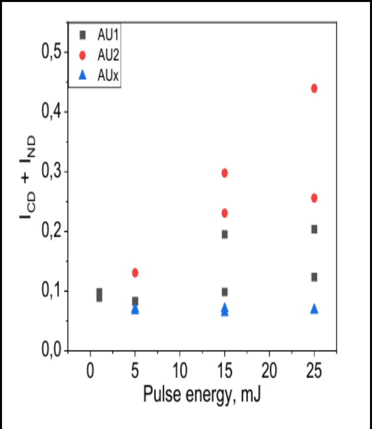


$I_{laser} > 10^{16}$

NAPLIFE RAMAN

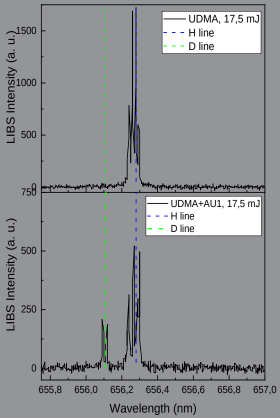
Raman signals: molecular vibrations from various spots in teh crater





NAPLIFE LIBS

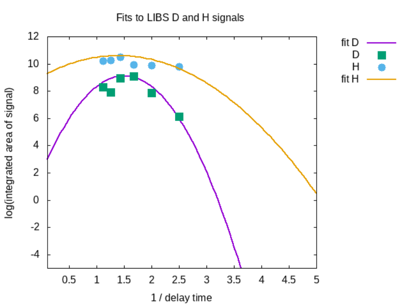
LIBS: atomic ionisation → D/H (Aladi)



NAPLIFE LIBS++

LIBS: kinetic energy estimate (Kroó, Biró)

Delay times → velocity distribution (rough proxy)



$t_{max} \approx 0.6\ \mu$ s, $t_{light} \approx 0.13$ ns, $t_{2\to 3} \approx 2$ fs.

$v_D \approx 70$ km/s, $E_{D,kin} \approx 50$ eV, $\frac{v_D}{c} \approx 2 \cdot 10^{-4}$.

NAPLIFE FUTURE

plans and suggestions

Our further plans:

- Nuclear detection (CR39)
- ELI cooperation (similar and bigger lasers)
- Variation of the shooting geometry
- Nanoparticles and medium matter variations
- energy, deuteron and α observation