V. G. Khlopin Radium Institute (KRI)

Self-glowing ceramics with Pu-238

Oksana BOGDANOVA, Boris BURAKOV

Joint ICTP-IAEA International School on Nuclear Waste Actinide Immobilization
10-14 September 2018

Development of self-glowing radionuclides-doped materials with durable crystalline matrices opens new environmentally safe applications of actinides

"Nuclear" electric batteries might be developed

Current will not be high, but enough to feed modern electronic devices during dozens and even hundreds of years under conditions of space and aggressive media

Self-glowing of highly radioactive materials is well known phenomenon

History of industrial application of natural **Ra** started in the beginning of 20th Century from the production of glowing paints.

Most of radioactive glowing sources developed in the past consist of several separate parts:

1) Non-radioactive crystalline material doped with non-radioactive luminescence ion (for example, ZnS doped with $^{3+}$Eu)

2) Highly radioactive material (for example, $^{238}PuO_2$)

3) Hermetically sealed body (made of steel and transparent glass)

G. A. Mihalchenko
“Radioluminescent emitters”, 1988

We suggest to combine all three parts in one durable crystal matrix

We have to develop durable low-radioactive ceramics with intensive self-glowing

The first stage is to define a durable crystal matrix

Why we choose cubic stabilized zirconia?

- ✓ High chemical resistance
- ✓ Mechanical durability (hardness above quartz)
- ✓ Stability under irradiation
- ✓ Becomes electrically conductive when heated
- ✓ Matrix for waste disposal
- ✓ This matrix can include different elements (actinides and non-radioactive luminescent ions) in a wide concentration range

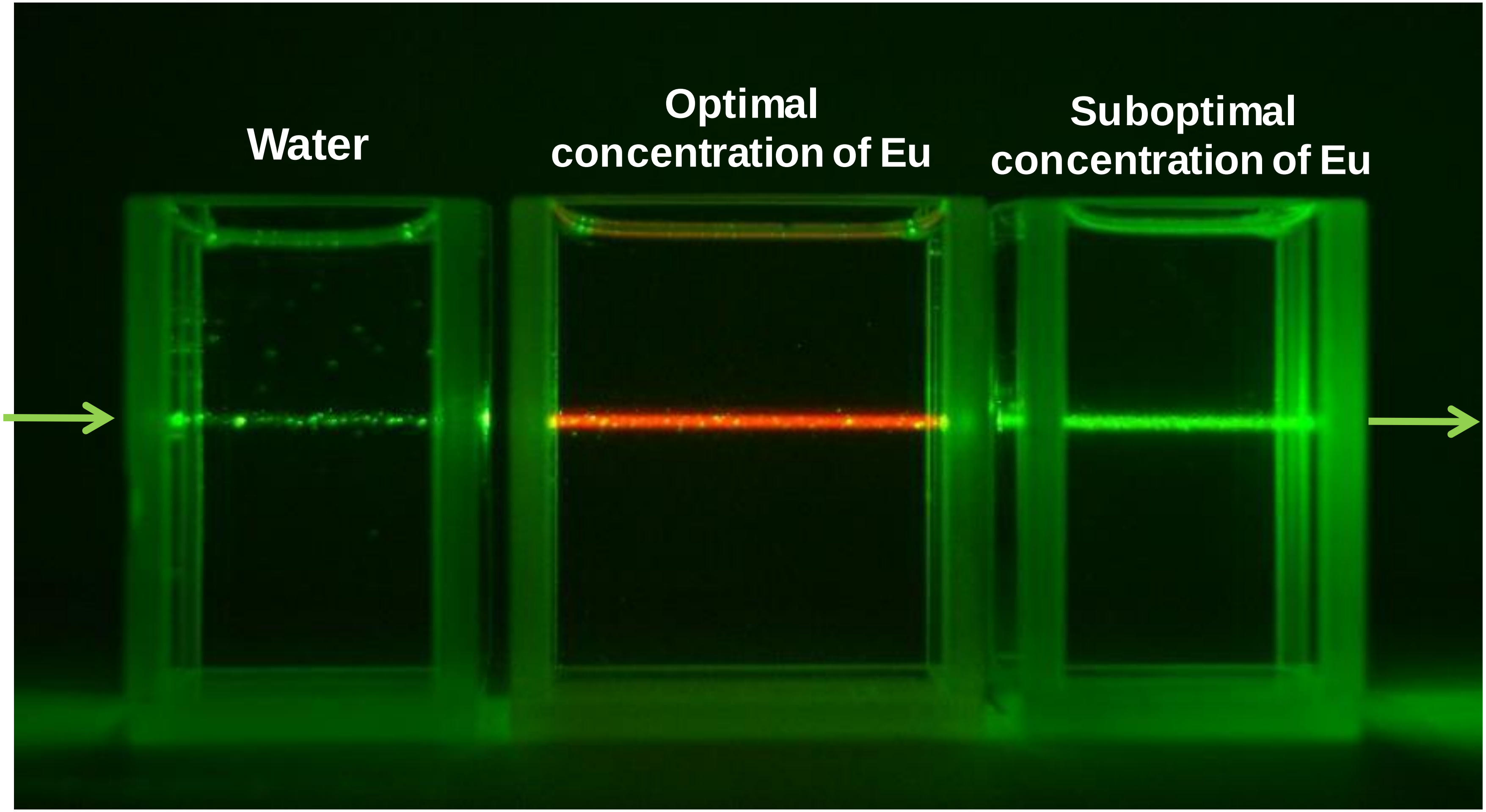
The second stage is to define the optimal concentration of luminescence ion (responsible for the highest intensity of luminescence)

Difficulties in determining the optimum concentration of luminescent ions

- ✓ Too high or too small content of luminescence ion(s) will cause weak self-glowing
- ✓ The optimal contents of luminescence ion are different for different crystalline host phase
- ✓ It is requiring multiple experiments

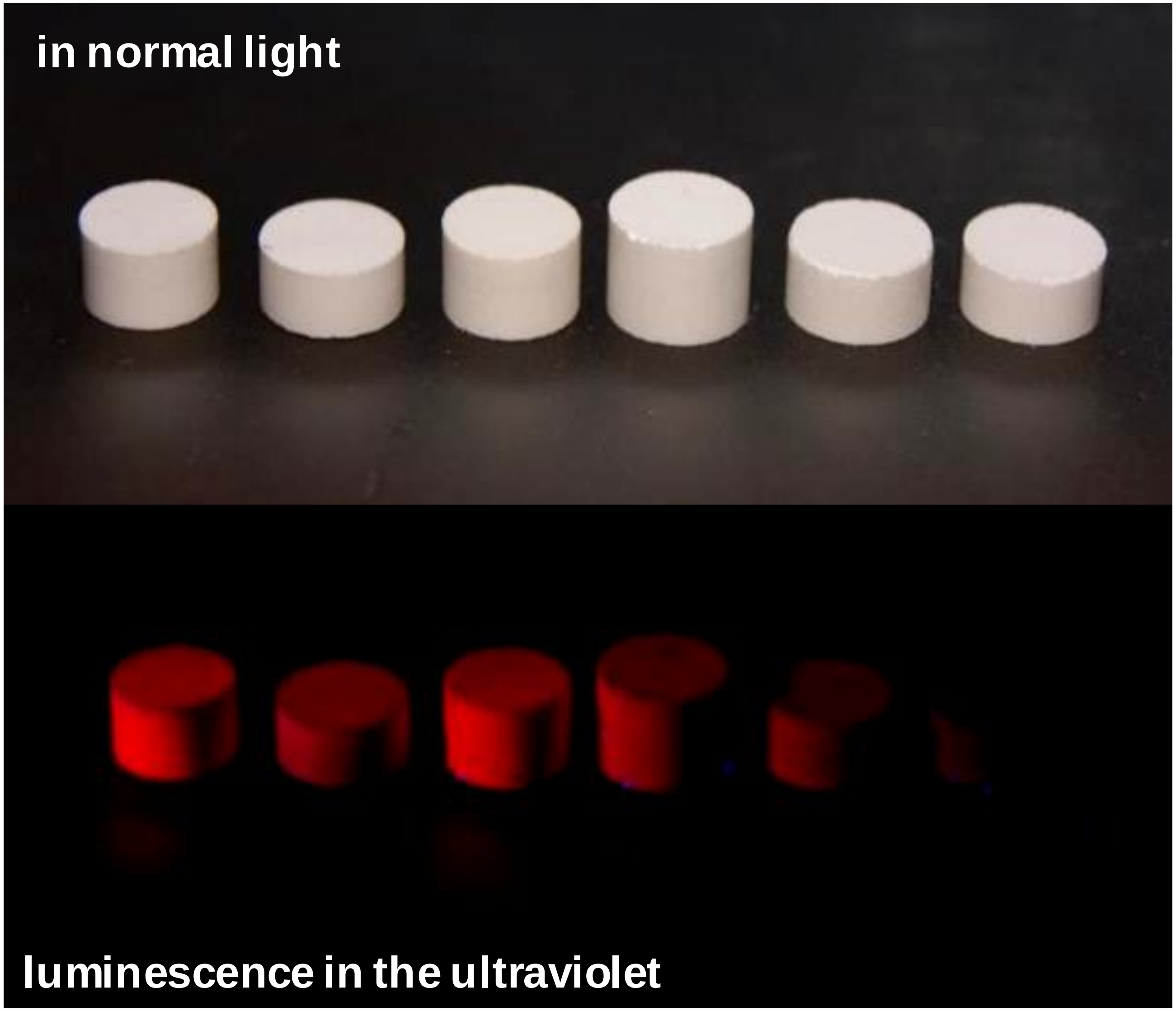
So the optimal concentrations of luminescent ions are defining for non-radioactive samples

Determination the optimal concentration of the phosphor in the solution of $Eu(NO_3)_3$



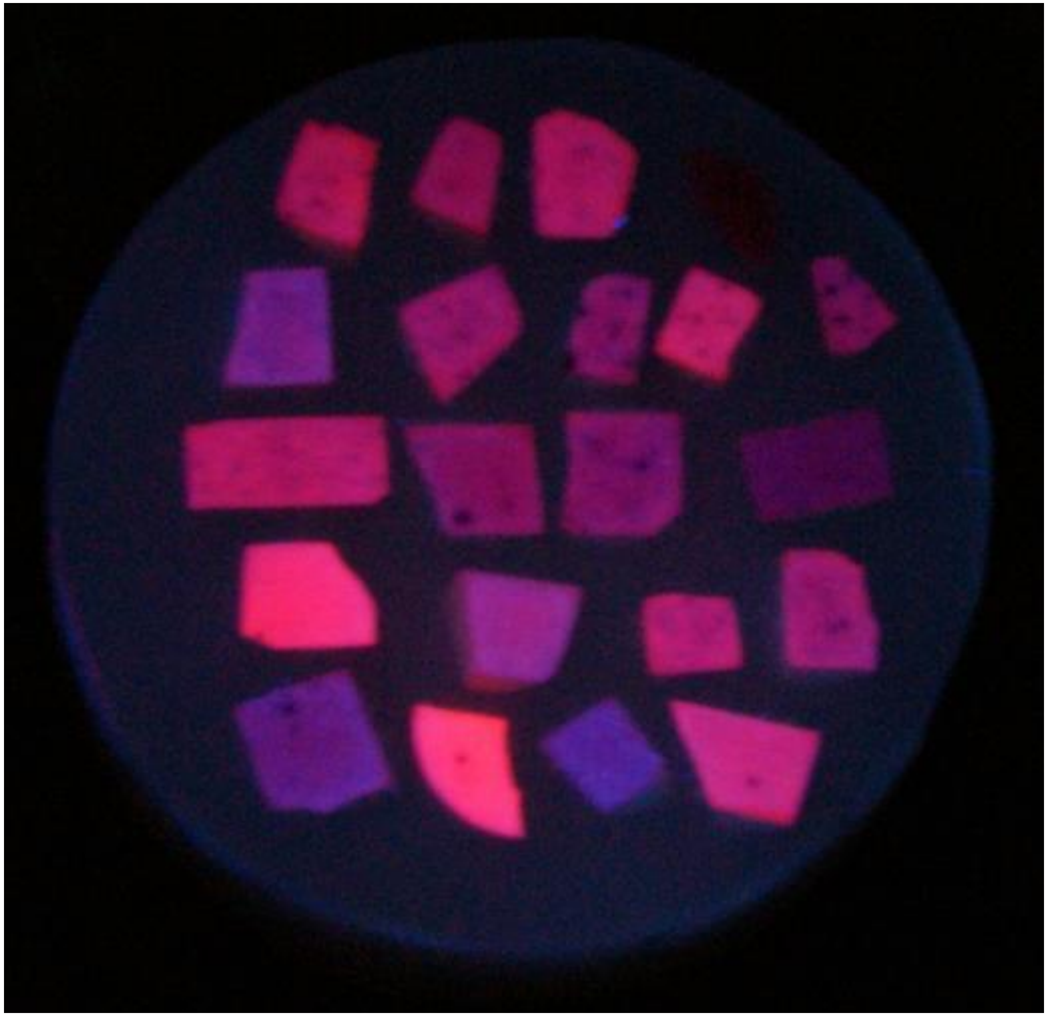
The laser beam (*532nm±10nm*) passed through the water and the solution of $Eu(NO_3)_3$

Single-phase ceramic based on $(Zr_{0.82}Y_{0.18-x}Eu_x)O_{1.91}$ (x = 0,01 - 0,10)



Single-phase ceramic based on $(Zr_{0.82}Y_{0.18-x-y}Eu_xTb_y)O_{1.91}$

(x = 0,02 – 0,10; y = 0,0005; 0,01; 0,015 и 0,02)



The third stage is to syntesize ceramic doped with a relativly small amount of actinides (up to 0.1 wt. %)

Scheme of the synthesis of ceramics

$ZrO(NO_3)_2$
$Y(NO_3)_3$
$Eu(NO_3)_3$
$Tb(NO_3)_3$

co-precipitation → filtering and drying at temperature 200˚C in air → calcination at temperature 600˚C in air → pressing of pellets → synthesis of ceramics (1500 ˚C, 3 hours)

Single-phase ceramics based on $(Zr_{0.82}Y_{0.18-x}Eu_x)O_{1.91}$ and $(Zr_{0.82}Y_{0.18-x-y}Eu_xTb_y)O_{1.91}$

Grinding the mixture into a mortar inside glove-box

Sintering in air inside glove-box at temperature 1500ºC

Glove-box

Our working group

Self-glowing ceramics based on $(Zr,Y,Eu)O_2$ and $(Zr,Y,Eu,Tb)O_2$ doped with Pu-238

Conclusions

This research can help to create environmentally friendly advanced radioactive glowing crystalline materials and improve the understanding of the behavior of actinides in ceramic matrices are promising for the disposal of radioactive waste