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Characterizations of a Hot-Pressed Polycrystalline Spinel:Ce Scintillator

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ABSTRACT

Here we report a new polycrystalline ceramic scintillator for possible use in gamma ray detection and medical imaging applications. The goal was to develop a cerium doped spinel ($MgAl_2O_4$:Ce), which can be processed utilizing ceramic forming techniques. High purity $MgAl_2O_4$ powders were used as the starting materials. Lithium fluoride (LiF) was used as a sintering aid and CeO_2 powder was used as the dopant. The mixed and dried powders were hot pressed in a vacuum environment to achieve a high density $MgAl_2O_4$:Ce. The hot pressed sample shows a transparent polycrystalline appearance. In-line transmission was measured to determine the transparency of the structure. Microstructures were characterized using x-ray diffraction and scanning electron microscopy. Fluorescence absorption and emission peaks were also measured in addition to the decay time measurement.

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Outlines

- Challenges in Special Nuclear Materials Detection
- Experimental Procedures
- Results and Discussion
- Summary

Challenges

Cargo Container

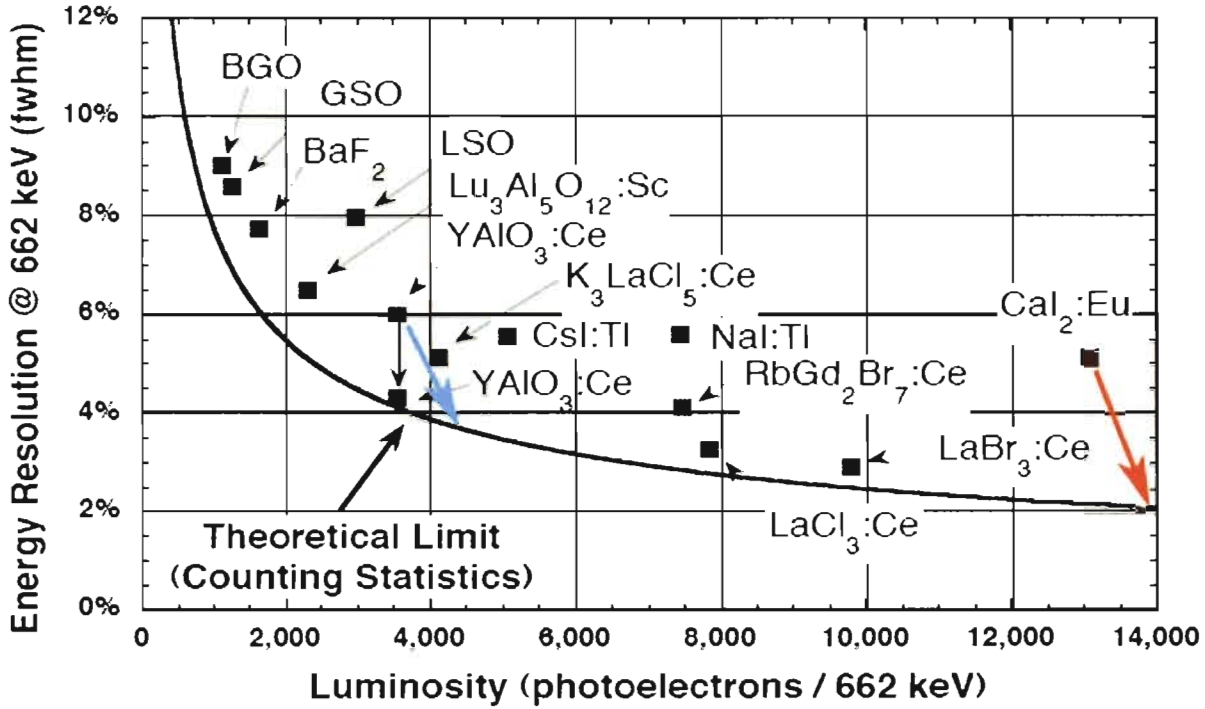
Truck Monitoring

Stand-off Detection

- Single Crystal LaBr3:Ce
  - Excellent energy resolution: 2.8%@662keV
  - High light output: 63,000Ph/MeV
  - Short decay time: 26 ns
  - High density: 5.29 g/cm^3
  - High cost ($6,000/in^3),
  - Low production rate, Small size

Polycrystalline scintillators using conventional ceramic processing techniques can be produced in large quantities, at fast rates, in large sizes, and at low cost. Oxide ceramics have high mechanical strength, good stability in air and moisture, high sinterability, and low cost.

Challenges

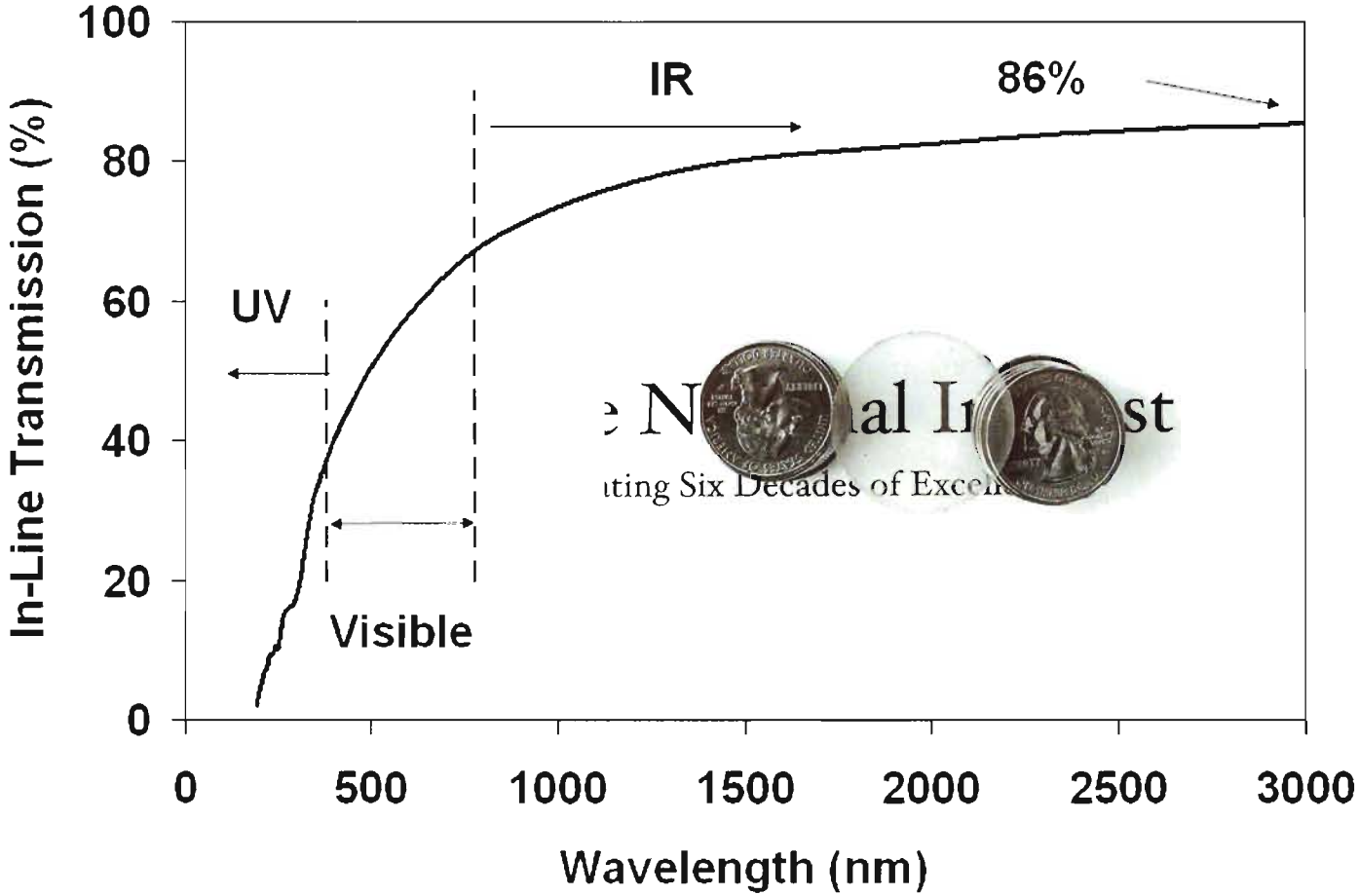

Energy Resolution @ 662 keV (fwhm)
12%
10%
8%
6%
4%
2%
0%
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Luminosity (photoelectrons / 662 keV)
BGO
GSO
BaF2
LSO
Lu3Al5O12:Sc
YAlO3:Ce
K3LaCl5:Ce
CsI:Tl
NaI:Tl
CaI2:Eu
YAlO3:Ce
RbGd2Br7:Ce
LaBr3:Ce
LaCl3:Ce
Theoretical Limit
(Counting Statistics)

Spinel:Ce^{3+} Processing

$MgAl_2O_4$ + CeO_2 + LiF ——> Ball Milling

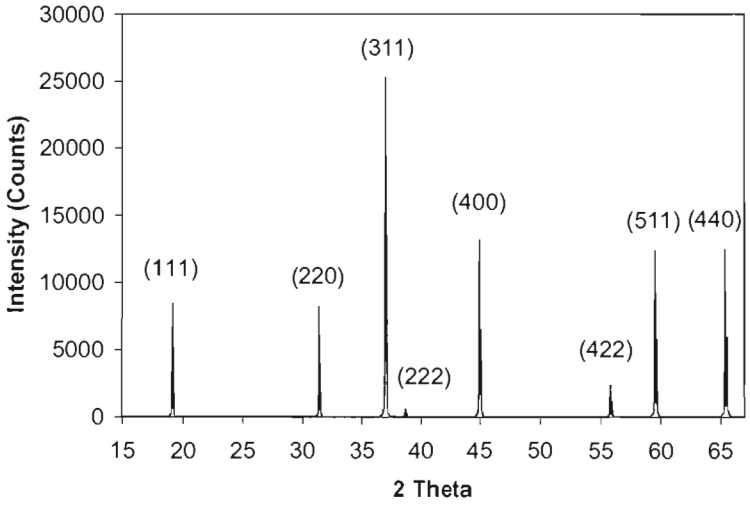
Hot-Pressed @1600°C, 2 hrs at 3 ksi.

Optical Transparency

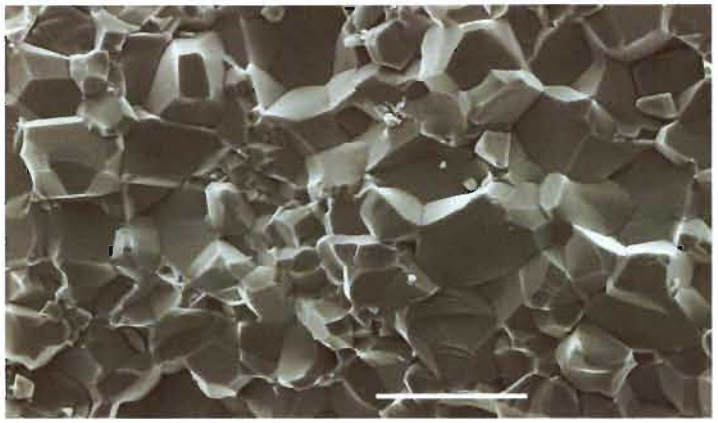


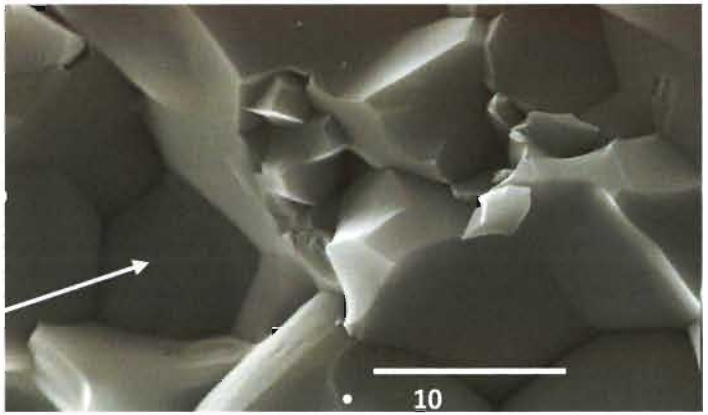
•optical transmission spectrum with 2 mm thickness. The transmittance at 3000 nm reaches about 86%. This implies that there is about 2% loss due to the imperfections of surface polishing or due to the structural defects such as residual pores or impurities.

Microstructural Characterization



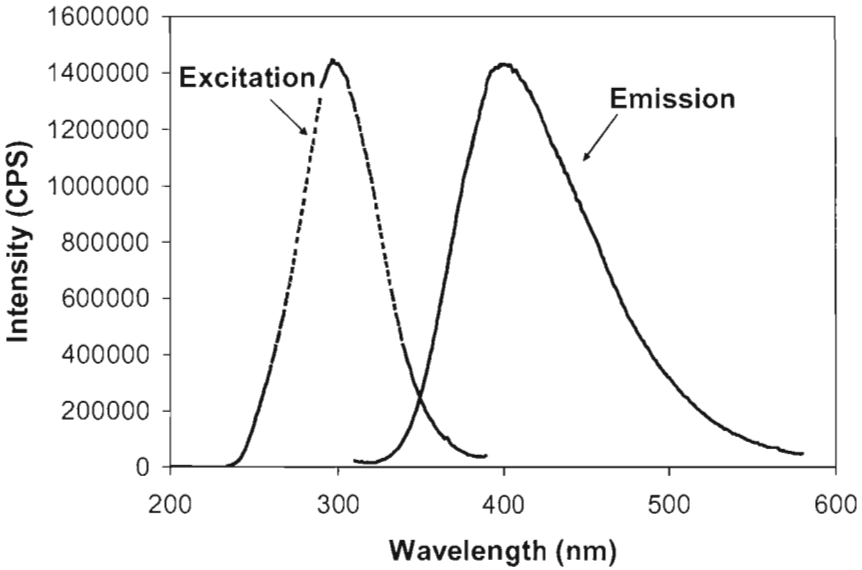
All of the observed peaks are characteristic of the spinel phase.

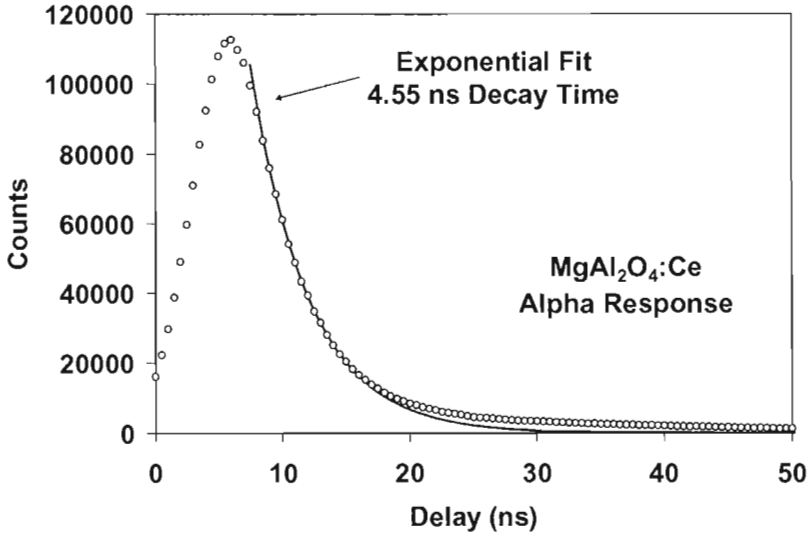




The grain size ranges from 3 to 50 microns with an average grain size estimated at 20 microns.

Scintillating Properties





- The UV excitation has the peak at 300 nm.
- The emission spectrum has the characteristic peak structure at 410 nm.

- Alpha-stimulated luminescence with a decay time of 4.55 ns.
- Very fast compared with $LaBr_3$:Ce and $LaCl_3$:Ce at 16 and 28 ns, respectively.

Summary

- A transparent single phase $MgAl_2O_4$:Ce polycrystalline scintillator has been successfully achieved.
- The microstructure shows a highly dense structure with an average grain size of about 20 microns.
- The polished sample has a high IR transmission at roughly 86%. The in-line transmission within the visible range is about 50% and about 40% at the excitation peak of 410 nm.
- The excitation and emission were centered at about 300 and 401 nm, respectively. The $MgAl_2O_4:Ce_{0.005}$ has a short decay time at 4.55 ns, which is much faster than $LaBr_3:Ce^{3+}$ and $LaCl_3:Ce^{3+}$.