Thermoluminescence (TL) is the thermally stimulated emission of light of an insulator or a semiconductor that has been exposed to ionizing radiation. During irradiation, electrons and holes are created and some of them are trapped at defect sites. The trapped charge carriers can be liberated by heating the sample and move to lower energy state with the emission of light. A glow curve is a plot of the TL intensity as a function of the sample temperature during read-out. Each trapping level in the material gives rise to an associated glow peak so a glow curve may be formed by several peaks, each related to different trapping levels.

For the purposes of personal dosimetry, a TL phosphor is expected to show certain features such as a relatively simple glow curve having ideally a single peak with its temperature at about 200°C, high sensitivity that includes both a high efficiency of light emission and a low threshold dose, good linearity of the TL signal in the specific useful range of radiation dose and low fading of TL signal. Moreover, for dosimetric purposes, the effective atomic number ($Z_{eq}$) of TL detectors close to that of the biological tissue is desired if one wants to treat it as a tissue equivalent material.

Few materials that possess all the above features have been found, and thus a search in this area is in constant progress. Tissue equivalent materials are often used for personal dosimetry.
phosphors that in general show good sensitivity to
ionizing radiation doses are, for example, LiF:Mg,Ti
(MTS-N) or MgB₄O₇. LiF materials with different
dopants characteristics were already described in
several publications because this is a material rou-
tinely used in both clinical and individual dosimetry
[1, 2], environmental dosimetry or low-dose detec-
tion (LiF:Mg,Cu,P) [3], high-dose dosimetry in
Poland [4, 5] and in the world [6, 7].
Magnesium tetraborate doped with dysprosium
(MgB₄O₇:Dy) is also recognized as a good thermo-
luminophor for personal dosimetry of gamma rays
and X-rays [8, 9]. First reports on the MgB₄O₇:Dy
came from groups in Japan and Serbia [10, 11].
Studies of TL glow curves, which are plots of TL
light vs. temperature, were used to determine the
trapping parameters. However, the TL response
strongly depends on the heating rate, an important
parameter in the TL measurements. In
fluence of the heating rate on TL glow curve has been the subject
of study by different scientists [12–15]. There are
several possibilities how to produce synthetic mag-
nesium tetraborate, for example, sol-gel method,
combustion, wet reaction synthesis, solid-state route
and precipitation (crystal growth). The most com-
monly used synthesis methods are the wet reaction
(precipitation) and solid-state synthesis, both are
described in detail in [16]. Their TL reproducibility
and sensitivity were analyzed after gamma irradiation
within doses in a range from 10 to 100 Gy. Studies
showed some advantages of solid-state synthesis, so
in this work, only pellets obtained in this route were
examined. The main goal was to test MgB₄O₇:Dy
(40% Teflon) pellets for low-dose detection and to
compare its behavior with MTS-N phosphor.

Methods
The pellets of MgB₄O₇:Dy (40% Teflon), called
MBO, were produced at the Department of Phys-
ic at the Federal University of Sergipe [16]. The
MTS-N pellets were produced by the TLD Poland
company [17]. All pellets were exposed to the air
kerma for low-dose rate equal to 100 mGy from
¹³⁷Cs source (661 keV) gamma radiation. The TL
response of pellets was acquired by a RA’04 TLD
reader system manufactured in Poland [18]. Prior
to each main read-out, the pellets were annealed
in a furnace at a temperature suitable for each ma-
terial. The schematic for pellets treatment was the
following: annealing – TL read-out for background
The following tests influencing the dosimetric
peaks of MBO detectors were performed:
1. comparison of glow curves of MBO and MTS-N;
2. annealing conditions and post-irradiation an-
nealing and their influence on the background.
There are several types of annealing for both the
materials published in the literature [19]. The
authors tested three different temperature values
for 1 h: 400, 430 and 500°C.
3. heating rate (of 2, 5 and 10°C/s) during the read-
out;
4. threshold dose, that is, the minimum detectable
dose, $D_{LD1}$, which is defined as three times the
standard deviation of the zero-dose reading [19].

Results and conclusions
Figure 1 shows typical glow curves of MBO and
MTS-N, respectively, obtained with a linear heating
rate of 5°C/s. Comparing their shape, the most strik-
ing difference is that MBO presents one main peak
whilst MTS-N presents five glow peaks, the two of
them being dosimetric (numbered 4 and 5).

Figure 2a shows the background curves of MBO
detector obtained for three annealing temperatures
(400, 450 and 500°C for 1 h). The goal of anneal-
ing study was to find the good combination of an-
nealing temperature and time to erase any effect of
previous irradiation, producing the lowest intrinsic
background. Besides to that, obtain the highest
sensitivity and reproducibility for both TL and
background signals [19]. It seems that background
for 450 and 500°C are very similar. T emperature of
450°C is advantageous because it diminishes the
total background below 230°C in comparison to
400°C and is lower than 500°C that it is clearly an
advantage for saving energy and preserve the sample.
The only concern is that the treatment above 400°C
is dangerous because the sample contains Teflon.
More tests are in progress. For MTS-N pellets, only
the standard procedure of 400°C for 1 h prior to
100°C for 2 h was applied [17].
Analysis of dosimetric peaks of MgB_4O_7:Dy (40% Teflon) versus LiF:Mg,Ti TL detectors

Figure 2a presents the behavior of the MBO glow curves obtained with three linear heating rates of 2, 5 and 10°C/s. Whilst the heating rate increases, the maximum intensity of the peak moves to higher temperatures and the duration of the read-out decreases. We chose as the best rate of 5°C/s, which gives the maximum of the main peak in 230°C and overall measurement time equal to 60 s. For MBO, the post-irradiation annealing procedure reported in literature is 5 s at 160°C in the reader [19]. The post-irradiation annealing is the thermal procedure having the aim to erase all the low temperature peaks that could be erroneous in the dose estimation because of their high fading rate. Preliminary tests performed in this work showed that this procedure has very little influence on the main result obtained; thus, it was not necessary to perform.

The threshold dose for MBO was calculated according to \( D_{LDL} = 3 \cdot \sigma_0 \cdot K \), where \( K \) is the calibration coefficient and \( \sigma_0 \) is the standard deviation of the zero-dose reading [19]. It was equal to 50 mGy (see Table 1). More tests are planned to improve this value because the detection limit obtained for MBO detectors is much higher than the one for MTS-N using the same TL reader.

The main features of the detectors are summarized in Table 1. The attractive dosimetric characteristics of magnesium borate solid thermoluminescence dosimeters (TLDs), such as near-tissue equivalence (\( Z_{eff} = 8.4 \)), sensitivity sufficient for clinical dosimetry purposes and other similar features to MTS-N, make this material a good detector for radiation protection dosimetry.

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Table 1. A comparison of main characteristics of MBO and MTS-N [17, 19]

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MgB_4O_7:Dy (40% Teflon)</td>
</tr>
<tr>
<td>Annealing procedure</td>
<td>Pre-irradiation: 450°C for 1 h</td>
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<tr>
<td></td>
<td>Post-irradiation: 160°C for 5 s</td>
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<tr>
<td>Form</td>
<td>Solid disc 6 mm diameter</td>
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<tr>
<td>TL emission spectrum [nm]</td>
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<td>Effective atomic number Z</td>
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<td>Main peak temperature [°C]</td>
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<td>for the heating rate of 5°C/s</td>
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<tr>
<td>Thermal fading [% at room temp.]</td>
<td>&lt;20%/year</td>
</tr>
<tr>
<td>Detection threshold [mGy]</td>
<td>50</td>
</tr>
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</table>

References