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High-Efficiency Heater for a Thermoluminescence Apparatus

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Abstract. — The paper reports on the optimization of a heater used in a Thermoluminescence glow curve apparatus. Two variants of the heater, planchet system and block system, are described. Both variants performed by a cheap material as graphite and designed following cryogenic principles, are very simple constructively, ensure minimum heat losses and require lower power.

1. Introduction

The most critical part of a TL apparatus is the heater [1]. Several methods exist by which the temperature of the sample can be raised in a controlled fashion and the most common of these implies a passing of current through a planchet or a coil (i.e. resistive heating). The use of a planchet is probably the most popular [2–4]. The planchet itself is usually a thin metal (e.g. tantalum or nickel-chrome) strip, with typical dimensions of about 0.025 cm x (1-2) cm x (4-5) cm [1]. The advantage of the planchet system over other arrangements is the low thermal mass of the heater. A disadvantage is that the planchet can often buckle and warp at high temperatures, sometimes resulting in permanent distortion. An alternative to the planchet arrangement is a heater block, usually of copper [5] which itself is heated by a resistance. The heater block design is especially useful for low-temperature cryostats wherein the block can be maintained at low temperatures. Because of the large thermal inertia of such devices fast heating and cooling rate are not possible [1].

The present contribution reports on the optimization of a heater used in a home-made TL glow curve apparatus and formerly equipped with a planchet graphite heater having the following dimensions: 0.25 cm x 1.5 cm x 6 cm and a mass of about 5 g. The maximum current required by this heater was higher than 150 A.

The new heating element is made up also in graphite, a cheap material and easy to process mechanically. It is designed to heat thin (ca. 10 mm diameter) aluminium discs on which a layer of thermoluminescent grains is placed. We have used cryogenic principles to minimize heat losses.
loss, to ensure maximum temperature uniformity over heated area. This gives the advantage of lower power requirements and a more linear temperature response at high temperature end. We worked out two variants of the heating element: planchet system and block system.

2. Results and Discussions

A top view and a longitudinal section of the heater in the planchet system are shown in Figure 1. The heating element is supported on a stainless steel pieces which conduct the electric heating current but diminish the heat losses. The central hole for sample and its longitudinal ditches for disc manipulation assure a higher heating in the centre of the planchet and a higher temperature uniformity over the sample. The heating element mass is 1.55 g. A copper disc placed between the heating element and the sample ensures a correct functionment of the heater.

An axial section of the heater block system is shown in Figure 2. The graphite heater, performed in a cylindrical geometry, is fastened to thin stainless steel arms that conduct the electrical current but minimize heat losses. The heat is generated mainly by the lower part of the graphite block. Its upper part serves as disc holder and provides uniform temperature over the sample. Owing to the upper stainless steel arm the photomultiplier sees only the heated sample and a small circular rim from the graphite block. This experimental approach is simpler than the technical solution presented in reference [5]. An advantage of the coaxial current flow by graphite block is that external magnetic fields are decreased an unlikely to upset the photomultiplier. The mass of the graphite block is 0.76 g.

We studied comparatively the natural glow curves for the same materials with the two heaters placed in the same TL apparatus. The materials (about 2 mg in weight) were in powder form.

Fig. 1. — A top view a) and a longitudinal section b) of the planchet system heater (S: Sample, H: graphite heating element, SS: Stainless Steel pieces, Cu: Copper disc).
Fig. 2. — An axial section of the heater block system. (S: Sample, H: graphite heating element, SS: Stainless Steel arms).

Fig. 3. — Natural glow curves of a ceramic sample from Tell Afis (Syria) obtained with a graphite planchet heater without copper disc a) and a graphite block heater b).
Fig. 4. — Natural glow curves of an Antarctica sediment sample obtained with a graphite planchet heater, without copper disc a) a graphite planchet heater with copper disc a’) and a graphite block heater b).

with dimensions in the range of 1 – 8 μm or 90 – 120 μm. The glow oven was first evacuated at 10⁻³ Torr and N₂ of high purity was left to flow during the readout. The light emission was detected by an RCA 4900 photomultiplier tube. The measuring geometry was practically the same for both heaters. The glow curves were stored in a computer via a NIM module operating in the multiscalning mode. The TL curves were obtained in the following temperature range: 28 °C(±1°) – 510 °C(±5°) with a ramp temperature controller. The rise in temperature was linear with a chosen rate of 4 °C/s. The heating current is delivered by a low voltage power supply with output currents up to 150 A. The maximum currents required by the heaters are 105 A for planchet heater and 40 A for block heater. A low heating power for block heater reduces cooling requirements and facilitates the fast cooling rates. About twelve minutes are
necessary to cool the sample from 510 °C to room temperature instead of thirtyfive minutes for the planchet heater at nitrogen cooling jet of 0.8 l/hour. Water cooling can be removed when block heater is used.

Glow curves of a sample with a low intensity TL signals are presented in Figure 3. There are not practical differences concerning the amplitudes and shapes of the TL curves. The area of the curves and the amplitude of the black-body signal at the highest temperatures tend to be greater for the block heater.

The glow curves for a sample with a high intensity TL signal are presented in Figure 4. In this case there are significant differences between them. The area of the curve obtained with the block heater is practically twice in comparison with those obtained with the planchet heater. In the curves obtained at the beginning (Fig. 4a) with the last heater there are some small peaks superimposed over the large curve. These peaks have note a physical meaning. The most probable explanation consists in the possibility of the electrical current to pass also by the aluminium disc and by Thermoluminescence grains, inducing local heating in the sample volume, in the case of planchet heater. The small peaks disappeared by using substances, with a very good thermal conductivity and higher dielectric rigidity, as silicone oils [4], between aluminium disc and graphite heater. Such substances have stable characteristics at temperature up to roughly 300 °C and are expensive. The non-physical spikes can be removed successfully also by two less expensive means: using a copper disc placed in central hole between the heating element and the sample or by coating the central hole for sample with silver lacquer. In this way, for a correct functioning of the planchet heater, it is not necessary to use expensive silicon oils. We used a copper disc and its effect is shown in Figure 4a'. Owing to geometry and mounting of the block heater, the aluminium disc is placed on a equipotential surface and therefore the electrical current does not pass by it. So, for the block heater there is not imperative to use a method to stop the passing of the current by the sample in order to obtain a correct TL glow.

3. Conclusions

Two variants of heater for a TL glow curve apparatus are described. The heaters made of cheap materials as graphite and stainless steel, are designed using cryogenic principles and they are simple constructively. The block heater, simpler than those presented in reference [5] has better performances than planchet heater. Its thermal inertia is smaller than that of the planchet heater.

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