Networked Learning Physics of Semiconductors through a Virtual Laboratory Environment

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INTRODUCTION

Virtual laboratory tools have been introduced a long time ago. Initially, they were designed to increase the flexibility of controlling hardware and run experiments (i.e. Labview, Vee, etc). Gradually such tools have been introduced into the learning procedure in order to help students to increase their performance through a user-friendly tool that stimulates them on their study. Additionally, when the high cost of hardware replacement and maintenance is put in contrast to the flexibility of adding new subjects on a laboratory course, the virtual laboratory environment tools render a power tool for educational purposes. Such new tools have been proposed by several researchers (Stavrakas et al., 2005; Cheng, Y.K. et al., 2004; Hudgins, J.L et al., 2002). The effects of these tools in the performance of the students are still under investigation (D. Triantis et al., 2004; K.A. DeBord et al., 2004; J. Epstein et al., 2001; Ali, N.S. et al., 2004). The Technological Educational Institution of Athens in the Framework of Education and Initial Vocational Training Program – "Upgrading of Undergraduate Curricula of the Technological Educational Institution of Athens" has developed several platforms that constitute novel tools in the educational processes (P. Tsiakas et al., 2005). Specifically, e-examination methodologies have been adopted and evaluated regarding their impact on the students' performance.

DISCUSSING THE NEED

Statistics prove that students do not spend adequate time of study on a laboratory module. 45% of the students actually do not spend any time to prepare for a laboratory module and become familiar with the terms and the concept of the exercise. Corresponding measurements show that only 25% have previously spent sufficient time in order to get prepared for the module. This observation was a motivation towards a new way of conducting laboratory experiments in order to attract the students' interest and increase their performance.

DESCRIPTION OF THE SYSTEM

A virtual laboratory environment was built in order to teach Physics of semiconductors. The system has been developed through Java programming environment and consists of a server and a client application in order to become network enabled. The student designs the experimental circuit through a user friendly interface, sets all the experimental variables, evaluates the build model and finally runs the experiment. After the experimental procedure is completed the student has the option to plot the experimental results and to export the dataset in .xls format. Several laboratory exercises have been incorporated in this software. The most important ones deal with the I-V characteristics of non-linear electronic devices and the calculation of the energy gap of Ge crystals.

CALCULATING THE ENERGY GAP OF Ge CRYSTALS : A CASE STUDY

A case study will be described here and specifically the experiment that deals with the calculation of the energy gap of Ge crystals. To calculate the energy gap the student must measure the resistance of the sample and its dependence on temperature changes. To conduct the experiment the student must use a Ge sample mounted on a resistor which acts as a heater, connect an ohmmeter and a thermocouple to measure resistance and temperature and a controllable voltage source that will feed the heating resistor and increase the temperature of the sample. Figure 1 shows a representative circuit that the user should be able to build in order to measure the energy gap. After designing the circuit, the software validates the model and if no validation error occurs, the experiment starts. The student sets a voltage to feed the heating resistor and observes the development of the transient phenomenon of temperature increase and the corresponding change of the resistance (Ω) of the Ge crystal.
The software using the appropriate formalisms (that are shown in a textbox) converts the measured resistance of the sample into conductivity (σ) using its geometric dimensions, measured in S/m.
Consequently, a plot like the one of Figure 2 gradually forms and at the end of the experiment its slope is calculated and presented. Using this slope, the software calculates the energy gap Eg through: $\text{slope} = -\frac{1}{1000}\cdot\frac{E_g}{2k}$ where, k is Boltzmann's constant, equal to $k = 8.6\cdot 10^{-5}\,\frac{\text{eV}}{\text{K}}$ In this case Eg = 0.65 eV.

ISBN No: 978-1-86220-206-1

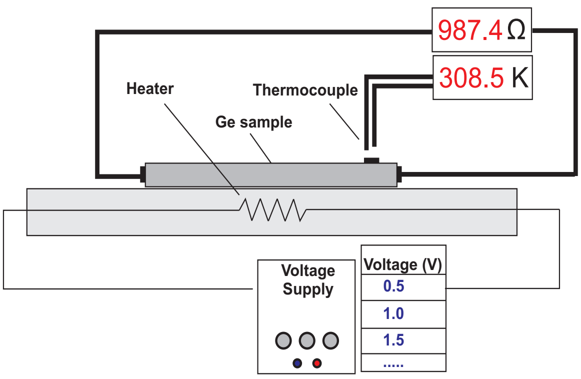

Figure 1: Typical circuit with a Ge crystal

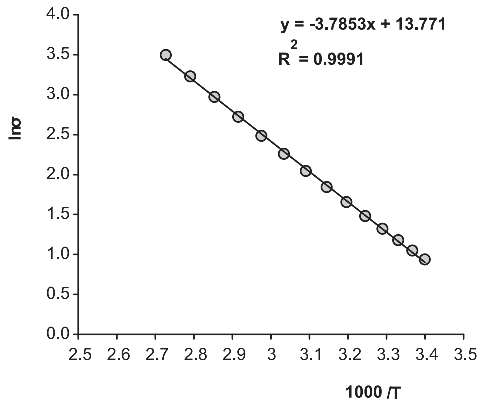

Figure 2: Experimental results for the calculation of the energy gap of Ge crystals

RESULTS

The software was distributed to a number of students as a preparation guide for the laboratory (open virtual laboratory). Preliminary tests on the module topic were given to students just before conducting the laboratory experiment. Two sets of students participated in the tests; students that had no access to the software and had to prepare for the laboratory via the traditional way and students that had the software prior to the experiment and prepared themselves for the laboratory by using it. It was seen that the software affected the results since the number of the students that successfully completed the tests (grade > 5.0) and belonged to the set that had used the software was larger than the corresponding ones of the set that had never used the software.

Consequently, the laboratory experiment was conducted using two methodologies. Some students used hardware devices and manual controls and others used the software to conduct the measurements (close virtual laboratory). After the experimental procedure, the students handed in an assignment. It was seen that the students that conducted the experiment using the software achieved higher scores in the assignments. Another important observation is that the students that achieve high scores (>8.4) are not significantly affected by any of the evaluation processes, preliminary test, or final assignment.

CONCLUSIONS

The main factor that motivated this work was the fact that students have been observed to lack preparation prior to lab sessions. It was concluded that a software tool provided to the students before taking the laboratory increased their performance. It was also observed that this tool mainly serves the weaker students since, according to the evaluation tests, they are mainly helped to achieve a pass score.

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