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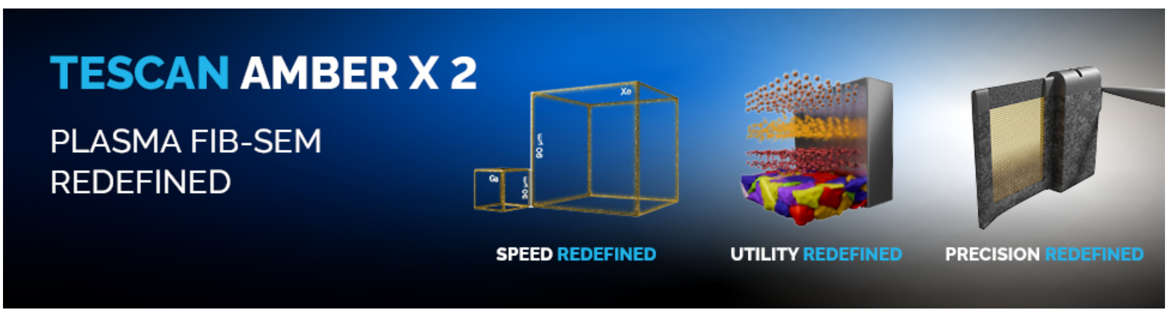

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Meeting-report

Cathodoluminescence Thermometry for Accurate Temperature Measurements in In Situ TEM

Pavel K. Olshin[1,3], Won-Woo Park[1], Ye-Jin Kim[1,4], Hak-Won Nho[1], Daria V. Mamonova[2], Ilya E. Kolesnikov[2], Vassily A. Medvedev[2], and Oh-Hoon Kwon[1]

[1]*Ulsan National Institute of Science and Technology, Ulsan, South Korea*
[2]*Saint Petersburg State University, St. Petersburg, Russia*
[3]*Present address: Chan Zuckerberg Institute for Advanced Biological Imaging, Redwood City, CA, United States*
[4]*Present address: California Institute of Technology, Pasadena, CA, United States*

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In situ transmission electron microscopy (TEM) becomes increasingly popular, as it allows studying the behavior of nanoscale materials under various stimuli, such as high or low temperature, light irradiation, electrical biasing, mechanical stresses, or at various environments. In many cases, the temperature of the sample changes, either from the direct heating, or light absorption, Joule heating, as the result of a chemical reaction. In some cases, the actual temperature of the specimen is not known, whereas in other, the temperature of the entire TEM grid is detected. But the local temperature may significantly deviate from that of the reading, for example, during the laser heating of samples at room temperature [1]. Therefore, a precise and accurate method for the local temperature determination is required.

Temperature affects the properties of materials in many ways, from changing the distances between atoms to altering their electronic and chemical properties. These properties have been demonstrated to be useful for the local temperature reading in the TEM. However, the methods lack precision, as the uncertainty may reach tens of Kelvin [2]. Optical methods may also be successfully used for the temperature determination, particularly, the luminescence thermometry, which is based on the monitoring the changes in the luminescence characteristics with temperature, is able to deliver sub-degree accuracy in the temperature determination [3]. However, the spatial resolution of these methods is limited by the size of the optical probe. We decided to combine the high spatial resolution of the electron microscopy methods with the high accuracy of optical methods via studying the response of the cathodoluminescence spectra on temperature and its applicability for use in in situ TEM.

Temperature may affect the luminescence of materials in many different ways, from changing its absolute intensity to changing its kinetics. Many different types of materials have been demonstrated as suitable for optical thermometry, but some of them, for example, organic dyes, or semiconductor crystals, suffer from the electron beam induced damage, which causes degradation of the luminescence signal. Metal oxides doped with rare earth ions (REI), on the other hand, demonstrate high stability under electron beams. Here, we studied the luminescence of Gd_2O_3 particles doped with various REI in the range from cryogenic to room temperature (Figure 1) and checked the suitability of this material for the temperature measurements [4]. We found that some luminescence bands, which correspond to the emission from different excited levels, demonstrate various trends with the temperature due to the complex energy transfer processes between the excited levels of the REI and the matrix. These differences in the behavior were used to establish the calibration between the intensity ratio between these CL bands and the temperature. Beside this we found that the electron dose significantly affects the energy redistribution in the system, and, therefore, should be thoroughly controlled during the experiments. We also demonstrate that the proposed approach may be successfully used for the temperature determination with an accuracy of ~5 K degree, which outperforms many other methods for the in situ TEM temperature measurements [2].

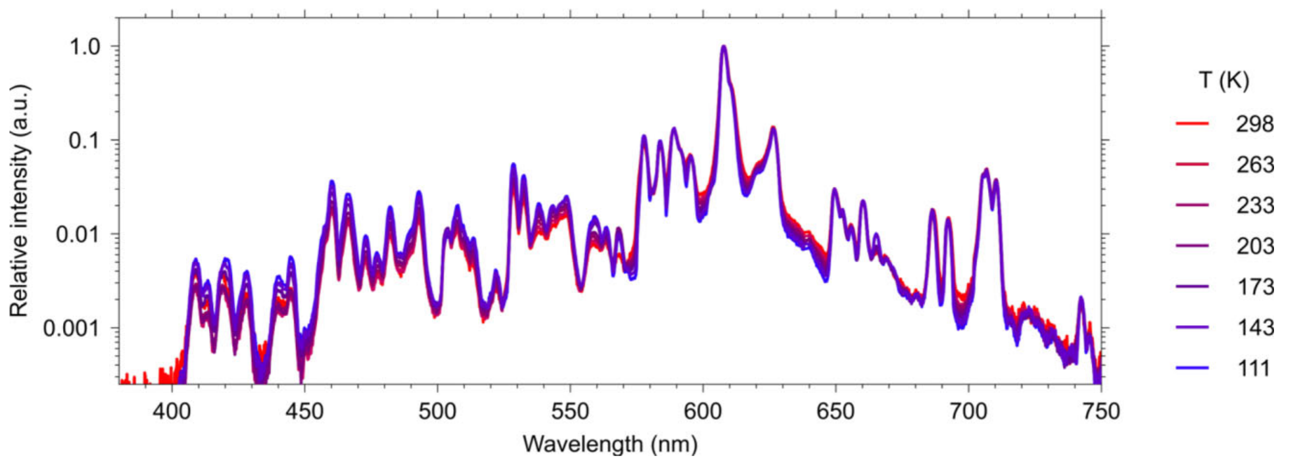

Fig. 1. Demonstrative image of cathodoluminescence spectra of Gd_2O_3:Eu3+ at different temperatures.

References

1. N Uemura *et al.*, *Micron* **157** (2022), p. 103244. https://doi.org/10.1016/j.micron.2022.103244
2. F Gaulandris *et al.*, *Microsc Microanal* **26** (1) (2020), p. 3 https://doi.org/10.1017/S1431927619015344
3. WM Piotrowski *et al.*, *Advanced Optical Materials* **11** (3) (2023), p. 2202366. https://doi.org/10.1002/adom.202202366
4. W-W Park *et al.*, *ACS Nano* **18** (6) (2024), p. 4911. https://doi.org/10.1021/acsnano.3c10020

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