

Contributors:

, Anna Carroll¹, Kevin Cheng¹, Roman Kapur¹, Patrick Kulaga¹, Karisa Liaw¹, Imaan Niazi¹, Tim Park¹, Volker Rose², Katherine Seguino¹, Nozomi Shirato², and Sarah Weighold²

Contributing Institutions:

¹ Naperville Central High School, Naperville, IL 60540

² Advanced Photon Source Beamline 9, Argonne National Laboratory, Argonne, IL 60439

ABSTRACT

Perovskite solar cells are an emerging photovoltaic technology that have become more relevant as their efficiencies have increased throughout the years. However, despite the jump in efficiency from about 3% in 2006 to over 25% today, perovskite solar cells still must overcome many challenges before they can be commercially adopted. One of the major issues facing perovskite solar cells is their high instability compared to other photovoltaic technology. Using the XTIP, a beamline dedicated to SX-STM (synchrotron x-ray scanning tunneling microscopy), nanoscale chemical characterization of perovskite solar cells can be revealed, and analysis of the spectra can offer views into voltage-induced charges in the atomic coordination. This information can aid in understanding the degradation and stability of perovskite material at the atomic scale, present possible paths forward to overcoming these challenges, and create more stable cells. Similar data was reviewed last year and characteristic comparisons will be made between the two data sets to reveal any changes in stability.

EXPERIMENT OVERVIEW

In this experiment, we examined the emission of electrons on a perovskite cell as a voltage bias was applied to the sample. This process was conducted at five locations on the same sample to examine the difference in how the surface reacts to an outside electric field across a sample. To do so, we utilized Argonne's Advanced Photon Source to produce high-energy x-rays and synchrotron x-ray scanning tunneling microscopy to measure the current produced. By comparing the resulting current from each location, a better understanding of how potential imperfections across a perovskite sample affect its properties.

IODINE MOBILITY

If iodine was always in its proper location, perovskite would have a more predictable longevity and usage. Additionally, iodine mobility is significant as it grants the ability to determine where the element migrates to throughout the data collection process. In the data collection process, chemical characteristics can be used to determine what kind of material is possessed. The intensity of absorption can also help identify the characteristics for each type of iodine. Moreover, the lack of uniformity in our recorded data indicates that iodine mobility is taking place.

REFERENCES

Wieghold, S., Shirato, N., Rose, V., Nienhaus, L., (2020). Investigating the effect of electric fields on lead halide perovskites by scanning tunneling microscopy. *Journal of Applied Physics* 128, 125303

Rose, V., Shirato, N., Bartlein, M., Deriy, A., Ajayi, T., Rosenmann, D., Hla, S., Fisher, M., & Reininger, R. (2020). XTIP – the world's first beamline dedicated to the synchrotron. X-ray scanning tunneling microscopy technique. *Journal of Synchrotron Radiation*. 27, 836-843

MOTIVATION

With a rapidly increasing world population, our planet desperately seeks new and improved energy sources, as energy propels our quality of life and global development forward. That's where solar power and specifically perovskite solar cells come in! With an abundance of supply worldwide and growing efficacy as research in perovskite progresses, solar power offers accessible, renewable, pollution-free, and non-greenhouse gas emitting characteristics that show promise for a future major energy source. We've focused on solar cells made of a perovskite structure because it is known to have a balance of being cost-effective, energy-efficient, physically flexible, easy to fabricate, has an adjustable band gap, and is solution-processable. However, faults have been found within perovskite, such as the movement of the iodine structure, which causes the electromagnetic field to be less effective. This loss in effectiveness leads to the 1 year lifetime of perovskite solar cells. Without solutions to this lifespan, perovskite might not be a feasible long-term source of energy.

DATA ANALYSIS

The data was plotted with the x-axis representing the photon energy in electron volts and the y-axis representing the strength of the signal, an intensity dependent on the number of photons absorbed. Ideally, the graphs would have similar shapes with two significant peaks near 640 eV and 653 eV. This would indicate that iodine was properly ordered within the structure of the perovskite. However, only the graph from location 2 (Figure 3) had both the expected shape and location of peaks. This means that the iodine was not distributed identically throughout the sample. In different locations the iodine was oriented around nearby ions in different ways, leading to different absorption spectra.

FUTURE DIRECTIONS

In this experiment, graphs of current vs energy for five different locations on the perovskite material were obtained. However, the period of time over which we recorded this data was relatively short compared to the usual lifespan of a solar cell. Therefore in the future, in order to study the true efficiency and efficacy of perovskite solar cells and perovskite materials in general, similar experiments would need to be conducted over much longer timescales, ideally on the order of the solar cell lifespan. Additionally, conducting experiments on different-aged perovskite material would supplement our understanding of perovskite behavior. Perovskite materials have potential power conversion efficiencies greater than 30%, so they would be very applicable for energy conversion purposes (such as solar cell technology and laser systems), especially since they are relatively cheap to produce and more eco-friendly than traditional solar cells.

ACKNOWLEDGEMENTS

Thank you to Dr Rose, Dr. Shirato, & Dr. Weighold for their time and guidance through this project.

Thank you to Argonne National Laboratory and the U.S. Department of Energy for the opportunity to participate in this project.

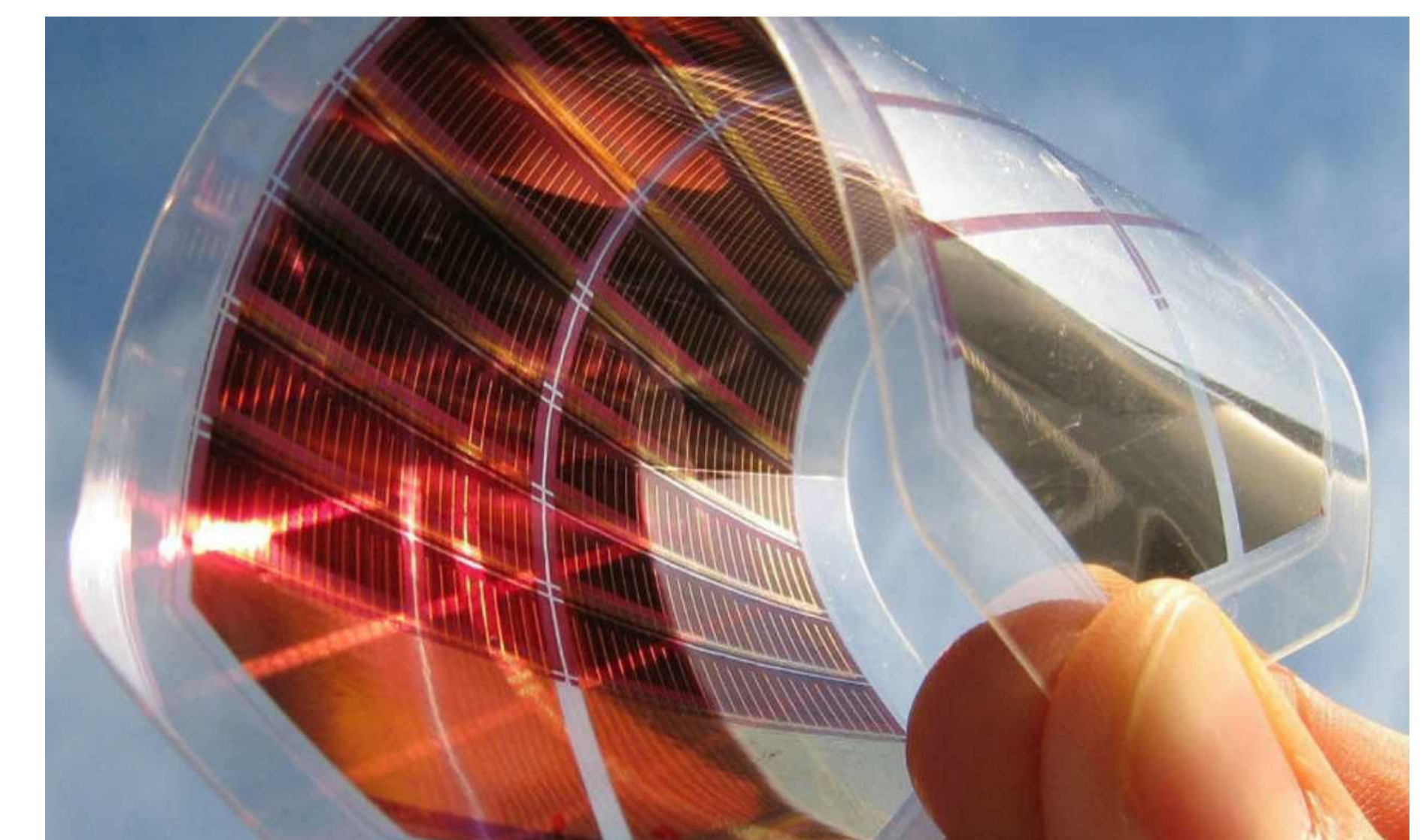


Figure 1: Flexibility of Perovskite materials is one of its key beneficial features. Image source: <https://medium.com/@sabeehassany/perovskite-solar-cells-the-future-of-energy-75e8c1f9488a>

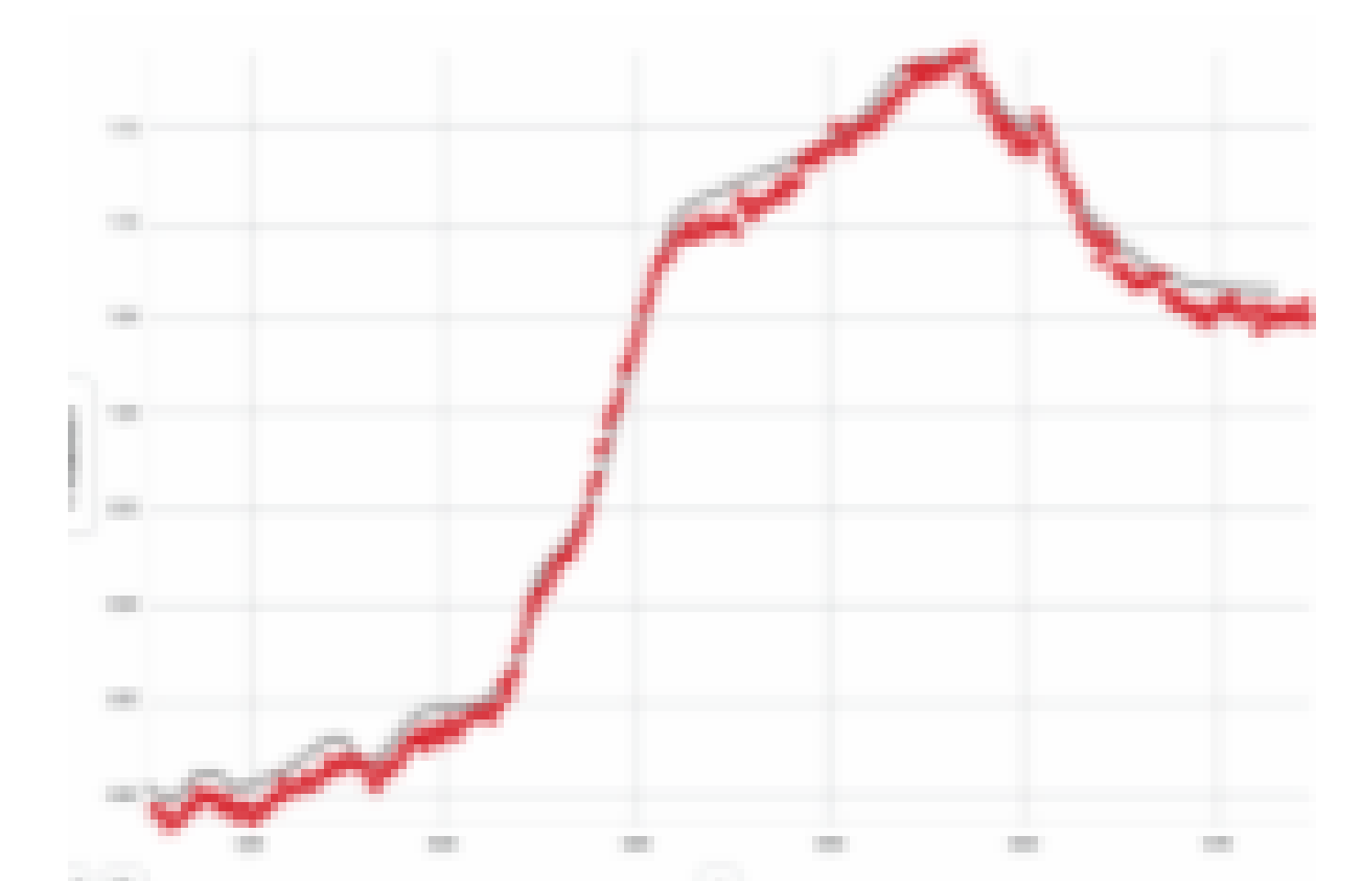


Figure 2: Location 1, peak at 657 eV

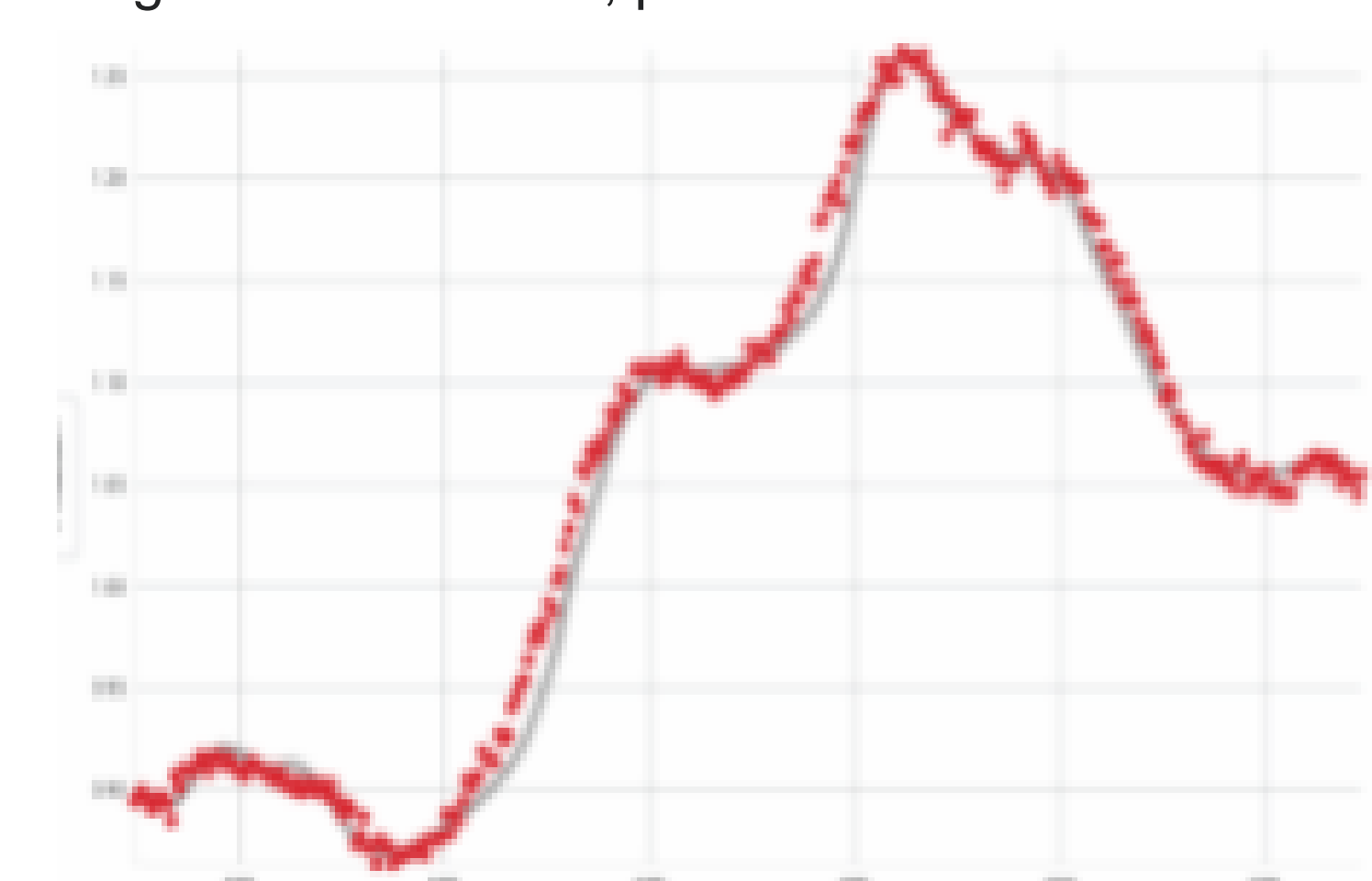


Figure 3: Location 2, peaks at 640 eV and 652 eV

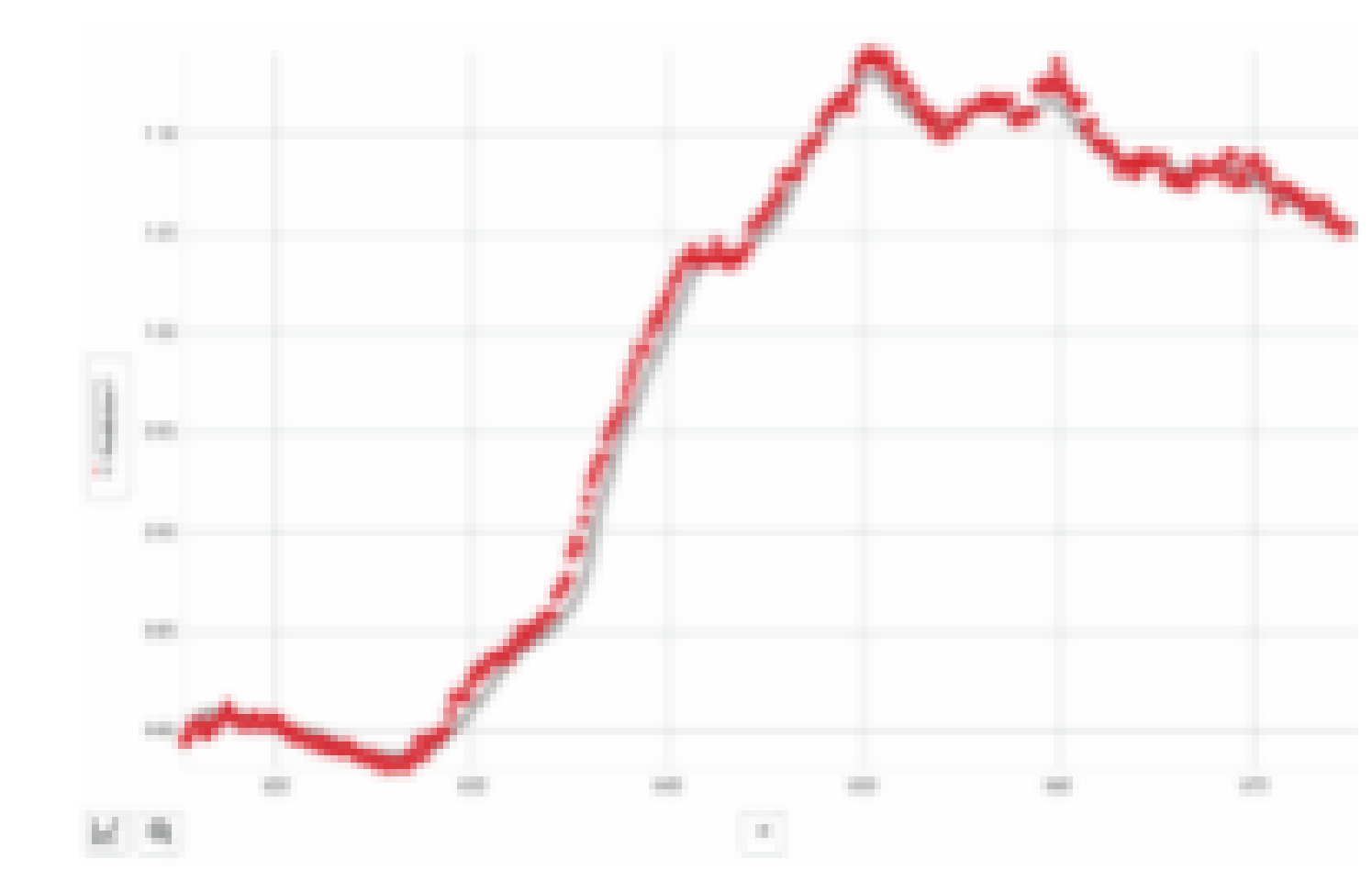


Figure 4: Location 3, peaks at 650 eV and 660 eV.

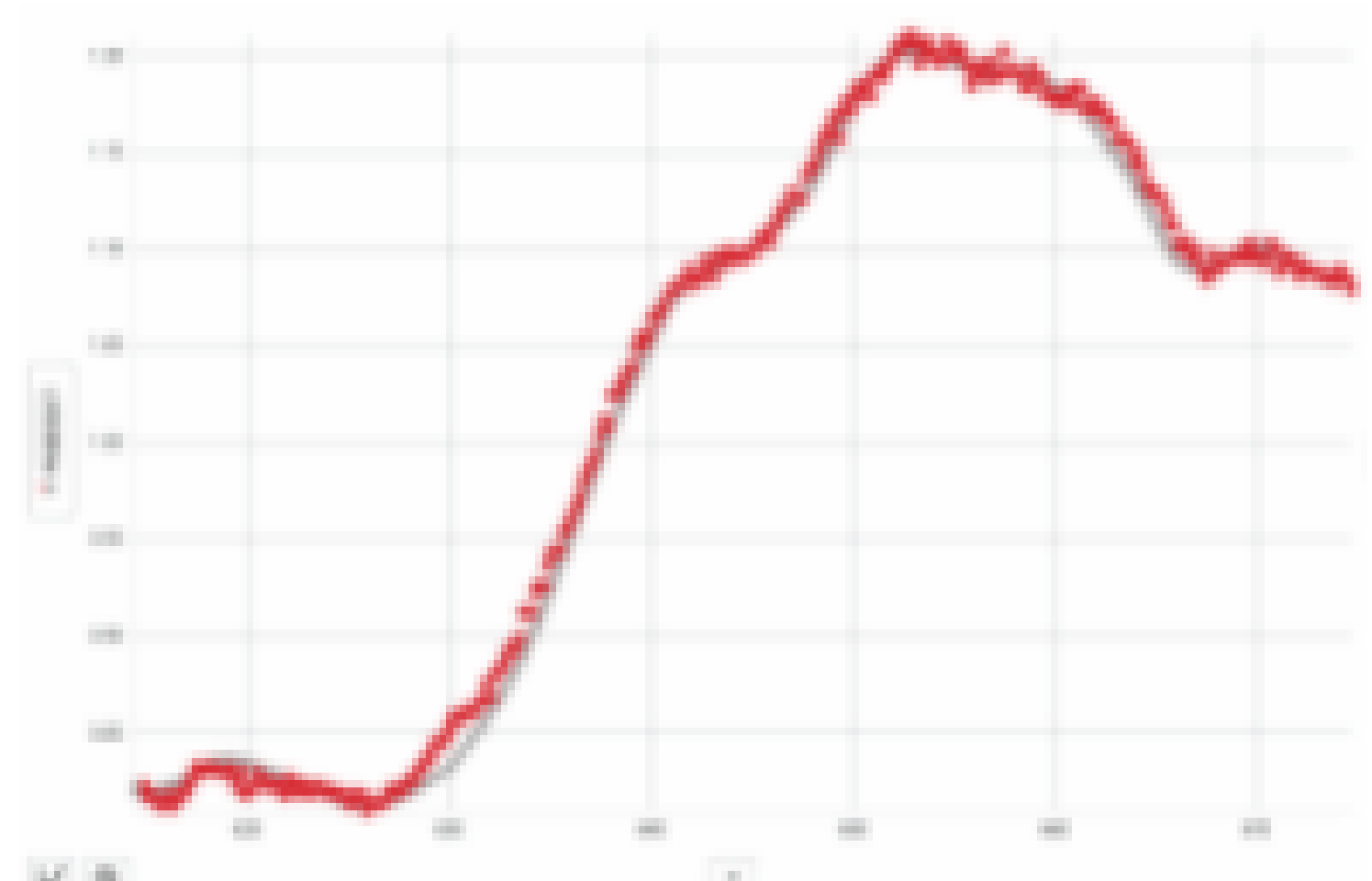


Figure 5: Location 4, peak at 653 eV

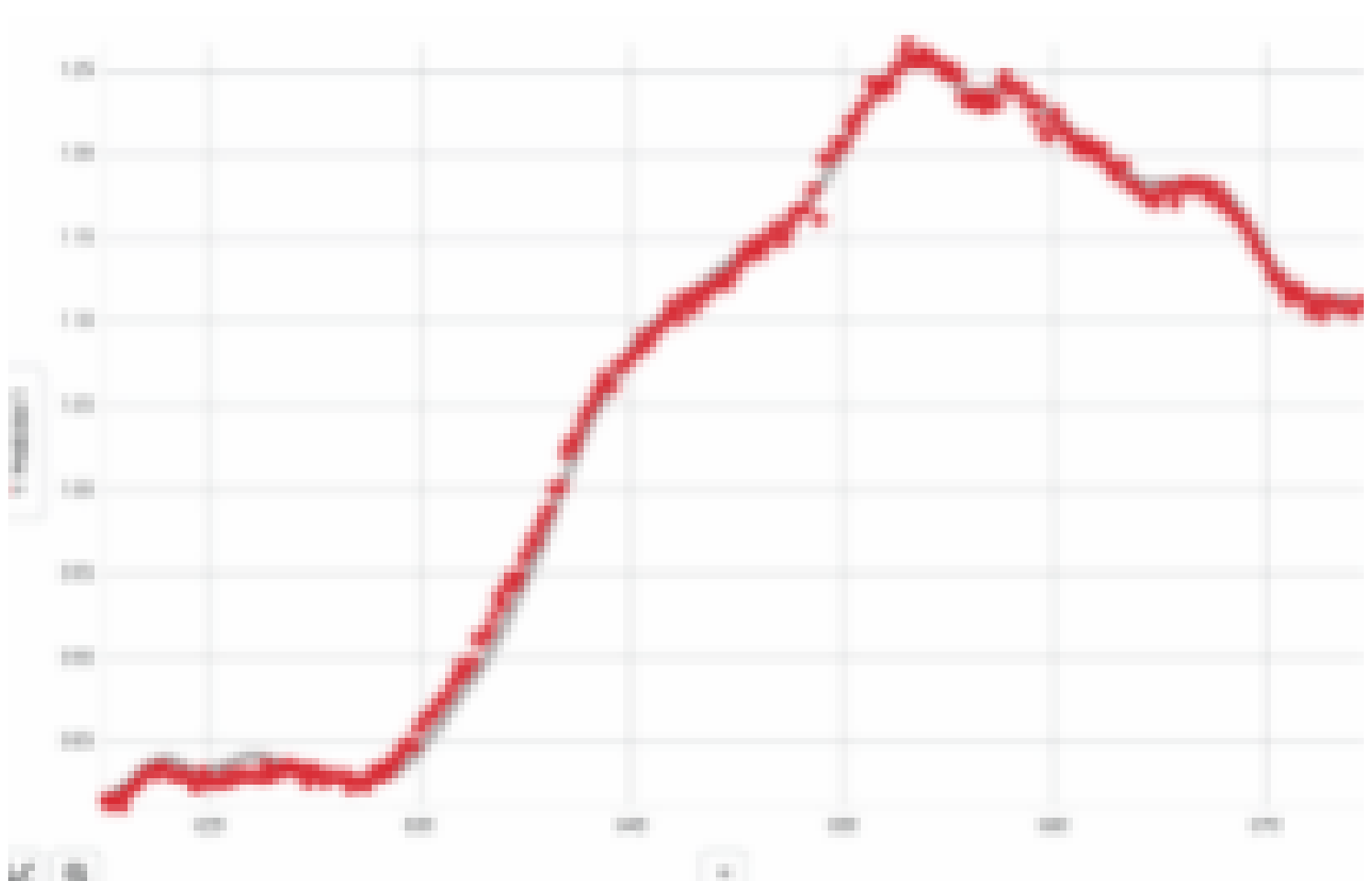


Figure 6: Location 5, peak at 653 eV