The project goal: The aim of the project is to investigate the fundamental properties of **ZnCdO and ZnMgO alloys produced by molecular beam epitaxy**, as well as to develop **photodetectors based on these materials**. In such devices, the alloys are intended to form a semiconductor junction with the substrate and transmit incident light to the junction region. The project focuses on studying how technological parameters and the introduction of foreign elements into ZnO affect the structural properties of the resulting alloys and the electrical properties of the junctions.

Description of research: Incorporating Cd and Mg into ZnO is meant to manipulate the bandgap – a parameter that determines the maximum photon energy that can be transmitted through the material. This parameter will be determined using reflectance measurements and confirmed by micro-photoluminescence. **The introduction of dopants – in this case, europium** – aims to provide additional carriers and improve the electrical performance of the alloy. Raman spectroscopy will be used to examine how the presence of foreign atoms influences the vibrational properties of the ZnO crystal lattice, and consequently its structural quality and strain. Additionally, current-voltage measurements will help identify current transport mechanisms in the samples and determine the electrical parameters of the junctions.

The potential of these samples to convert light into electricity, i.e., to generate photocurrent depending on the wavelength of the incident light, in a self-powered mode, will be examined. The final part of the project will focus on the application of these alloys in **ultrafast photodetection** employing the **pyro-phototronic effect**. When light irradiates the photodetector, the ZnO layer heats up (Fig. 1a). Due to the crystal structure of ZnO and its alloys, a change in temperature induces an internal electric field. In a photodetector, this field facilitates the separation of photogenerated charges, thus significantly reducing the response time (Fig. 1b). However, an excessive concentration of Cd or Mg can alter the crystal structure, suppressing this effect.

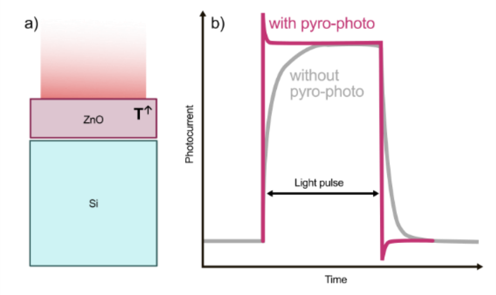

Fig. 1. a) Incident light increases the temperature of the ZnO layer, generating an additional electric field.

b) Schematic comparison of photodetector response with and without the pyro-phototronic effect.

In addition to random ternary alloys, the project will also explore the use of so-called **quasi-alloys** in the form of **superlattices** — i.e., periodic structure consisting of thin layers of material with nanometer-scale thickness. Even a slight change in the thickness of one of these layers can modify the bandgap, making it easy to tailor the material to absorb light within a specific spectral range. Moreover, the superlattice structure addresses the issue of compositional inhomogeneity found in random alloys.

Reasons for attempting the research topic: In recent years, the number of electronic devices utilizing light detectors (photodetectors) has been steadily increasing — from smartwatches to smoke detectors. As a result, a rise in energy consumption is inevitable. Therefore, the development of **innovative semiconductor materials** enabling the fabrication of fast and efficient photodetectors operating without external power supply is becoming crucial in the context of technology development aligned with climate neutrality goals. This project is fully in line with this trend. **Research on the application of ZnCdO- and ZnMgO-based superlattices and random alloys in self-powered ultrafast broadband photodetectors remains scarce, which is the main reason for attempting this study.**

Substantial results expected: The results of our research will provide technologists with valuable insights necessary for **optimizing the fabrication process** of ternary Eu-doped ZnCdO and ZnMgO alloys, aiming to obtain **fast and efficient photodetectors** with a **strong pyro-phototronic effect** that enhances charge separation. We will also determine the extent to which the **bandgap of the alloys can be modified without suppressing the pyro-photoelectric effect**.

Investigation of materials for low-power and self-powered devices is currently supported by the European Union. Given its objectives, the proposed project is well aligned with **global trends in scientific research**, development, and innovation, as well as with key societal challenges defined in the EU's 'Horizon Europe' programme, particularly those concerning resource-efficient industry and sustainable energy use.