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The RAMSES-4-CE project – developing a smart sensor network for e-waste characterisation

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The steeply increasing demand for electronic devices and fast innovation cycles, combined with the recent political and societal orientations towards e-mobility and energy transition leads to vast amounts of e-wastes (i.e. Waste of Electrical and Electronic Equipment – WEEE). Most of the million tons of WEEE generated annually are only partially recycled up to now. This impedes dramatically EU goals towards Circular Economy. In order to improve recycling efficiency and thus minimize our environmental footprint, modern recycling plants need multi-component sensors that can identify complex materials rapidly and accurately. We address this challenge by using a combination of imaging sensors to identify key chemical compounds in material streams. Our main objective is the rapid mapping of the critical compounds in unknown, variable WEEE material streams. Such digital information is then immediately available for an adequate sorting and inherently adapted recycling that will enable Circular Economy. In this context, the RAMSES-4-CE project, which is funded by EIT innovates optical spectroscopy-based multi-sensor systems for the recycling industry. By means of hyperspectral (HSI) reflectance spectroscopy in the near- and mid-infrared range certain alloys, ceramics, and plastics can be identified and classified. Laser-induced fluorescence (LiF) spectroscopy enables the detection of rare earth elements (REEs) and low-reflective black plastics among others. In order to expand the range of WEEE classes which can be identified by our system, we propose to add a rapid, non-destructive and cost-efficient Raman sensor.

To achieve the required innovation towards an efficient and smart sensor network, we focus on three major aspects: (1) developing a Raman sensor, (2) its integration in an existing LiF-HSI system (EIT inSPECtor project), (3) advanced multi-source data fusion via a rapid machine learning-based data integration. The combination of fast imaging sensors with a precise point validation sensor addresses the need for the identification of shredded recycling materials at high measurement speeds (up to 1 m/s) as well at high spatial resolution (about 2 mm) in industrial applications of sensor-based sorting. In this contribution, we present the RAMSES-4-CE sensor network concept of two integrated line-scan sensors (HSI, LiF) for rapid mapping combined with an adapted Raman

point-sensor. The sensor network is mounted on top of a conveyor belt of about 50 cm width and can be adapted for the characterization of minerals/rocks in exploration and mining applications as well. Component identification is based on the comprehensive work on spectral fingerprints for plastics, semiconductors, REE and other critical WEEE components. In addition, we present our concept for a time-efficient data processing workflow to enable sensor communication and accordingly, allow for selected validation analysis to update the mapping results. The temporally and spatially resolved information enables then subsequent decision making in recycling processes.