International Conference on Advanced Optical Technologies
University Erlangen-Nürnberg, March 13th – 15th 2019

The Optical Properties of Copper - Analysis of the Wavelength and Temperature Dependence and their Impact on Laser Material Processing

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Laser material processing of copper, especially welding, has always been challenging due to its low absorptivity and excessive spattering, resulting in low reproducibility [1]. The ongoing trend towards electromobility increases the demand for precise and reproducible copper joints. However, current state-of-the-art process management and system technology using infrared lasers do not always ensure sufficient quality of the welding process and the resulting processing results [2]. The low absorptivity of copper at the solid state leads to the need of comparably high laser powers to ensure sufficient energy input, which in combination with the increase in absorptivity at the liquid state, leads to a prompt onset of evaporation and therefore to spattering and low reproducibility.
In this context, the development of novel laser sources at different wavelengths and several beam shaping technologies promise to meet this challenge successfully. It is known that the absorptivity of solid copper increases drastically from the infrared to the visible wavelength range [3]. However, the wavelength as well as the temperature dependence of the absorptivity needs to be analyzed more thoroughly to be able to assess advantageous wavelengths and their influence not only towards an increase in absorptivity, but also towards an increase in stability of the process.
For the analysis, data from ellipsometric measurements from literature and calculations based on the Drude model were used [4–11]. First results indicate that while for infrared, there is a sudden increase in absorptivity from solid to liquid copper, for visible wavelengths liquid copper does not absorb better than solid copper. Further analysis based on energy balances shows that this behavior improves the stability of laser material processing.
These results contribute to an increase in process understanding of laser-based copper processing. Thus, this study helps to ensure that laser material processing of copper becomes more reproducible and robust for the cost-efficient production of electromobility components.

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