Contribution ID: **190** Type: **Oral Presentation**

Quantification of Pore Diameter in Solder Joints of Printed Circuit Boards Based on Super-Resolution Microcomputed Tomography

Tuesday, 20 May 2025 12:20 (15 minutes)

Non-destructive characterization of printed circuit boards (PCBs) is crucial for ensuring the reliability of electronic components. Defects like cracks and pores in solder joints significantly influence the performance of PCBs. Microcomputed tomography (µCT) has proven effective in detecting such pores and quantifying relevant characteristics like diameter, volume, and shape. The current study expands on these findings by introducing super-resolution (SR) µCT, utilizing a novel approach that integrates µCT imaging with convolutional neural networks (CNN) for resolution enhancement. Using SR µCT and a pre-trained CNN, it is possible to generate high-resolution (HiRes) image data from low-resolution (LowRes) input data that was not part of the training cohort. This methodology bridges the gap between high-throughput imaging and detailed pore characterization, since LowRes µCT scans can be carried out several times faster.
In this contribution, 18 PCB samples featuring a total of 432 solder joints were scanned at a voxel size of 8 µm to create a high-resolution (HiRes) reference dataset using a Nanotom 180 system. Voltage was set to 140 kV using an integration time of 650ms and 1800 projections resulting in a total scan time of 19min per sample. We focus on developing a methodology to generate correponding LowRes datasets directly from HiRes scans using different downsampling approaches, e.g. topology-guided downsampling and edge-preserving downsampling, followed by image filtering approaches like Gaussian blur. Our goal is to generate realistic LowRes image data that resembles actual LowRes µCT data. In order to check the feasability of artificially generated LowRes data for training, downsampled data was compared with actual LowRes µCT scans (voxel size: 40 µm) of the same sample using structural similarity index (SSIM) and feature similarity index (FSIM). Preliminary results show a high SSIM of 0.91 between the compared data sets.
Artificially downsampled and filtered data was subsequently used in our SR approach that employs a U-Net 3D architecture augmented with LossNet [2]. The model was trained using paired HiRes and LowRes datasets to predict high-fidelity 3D pore maps from LowRes inputs. Evaluation metrics included SSIM and peak signal-to-noise ratio (PSNR).
At 8 µm voxel size, diameters of detected pores in HiRes data vary between 27µm and 235µm. Preliminary results show that SR images provide a more precise estimation of maximal pore diameter compared to LowRes data. However, small pores with a diameter below ca. 60 µm are not detected. Nevertheless, since the smallest pores detected in LowRes data have a diameter larger than 120 µm, this is a significant improvement in defect detectability. One advantage is the increase in scan speed, since LowRes scans were carried out in 5 min compared to 19 min total scan time of the respective HiRes scans. Our work focuses on the determination of the optimal downsampling approach and the effect of the choice of training samples on the prediction probability. In future, we will diversify the training sample for a generalized model for various porous media.

Acknowledgements
This work is funded by the IBW/EFRE & JTF project "HyperMAT"(Österreich 2012-2027) and the FFG project "sustaiNDT"(909801).

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Session Classification: MS15

Track Classification: (MS15) Machine Learning and Big Data in Porous Media