Selective leaching of electronic waste for valuable metal recovery based on particle size

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Abstract:
Electronic waste (e-waste) recycling for recovery of valuable metals reduces the need for extracting virgin ores and extending the life of the resources. Hydrometallurgical recovery of valuable metals from e-waste, e.g., printed circuit boards (PCBs), is widely used by industry and consists of at least leaching and recovery. Mechanical size reduction (milling) of e-waste after disassembly/sorting is essential before leaching to facilitate liberation and dissolution of valuable metals in the leachate. The methods that the recycling industry currently uses to improve leaching efficiency include leaching the streams of e-waste containing similar compositions, e.g., only CPUs or GPUs. However, particle size variability in milled e-waste has been underexplored. For example, larger particles (e.g., > 1 mm) contain primarily base metals such as Al and Cu, making it uneconomical to leach them with smaller particles (e.g., < 0.5 mm), which have a much higher mass concentration of valuable metals. If particle size can be used as a key performance indicator to identify particles that potentially have a high mass content of valuable metals and a low mass content of base metals, there will be an opportunity to optimize the leachate for leaching only select milled particles based on size and scale-up the throughput for leaching. Therefore, this study proposes investigating the feasibility of selective leaching based on milled e-waste particle size. To begin with, a two-step milling method is used for preparing leaching-ready PCB feedstock with a shredder for coarse milling and a cryogenic mill for fine milling. The cryogenic mill uses a novel configuration for retention of fines and any hazardous airborne materials, and calibration of processing parameters, achieving mass retention above 98%. The milled particles are then sieved for size-graded sampling (> 4, > 2.36, > 1, > 0.425, > 0.25, > 0.106, and 0.045 mm) and analyzed using the scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS) to determine the mass distribution of valuable metals over sieve size, with an example shown in the figure. Finally, inductively coupled plasma (ICP) spectroscopy analysis is used to detect target metal elements and cross-examine the SEM-EDS results. The potential correlation between ICP and EDS test data in relation to particle size is critical for leaching process optimization. Full results will be detailed in the manuscript upon acceptance.

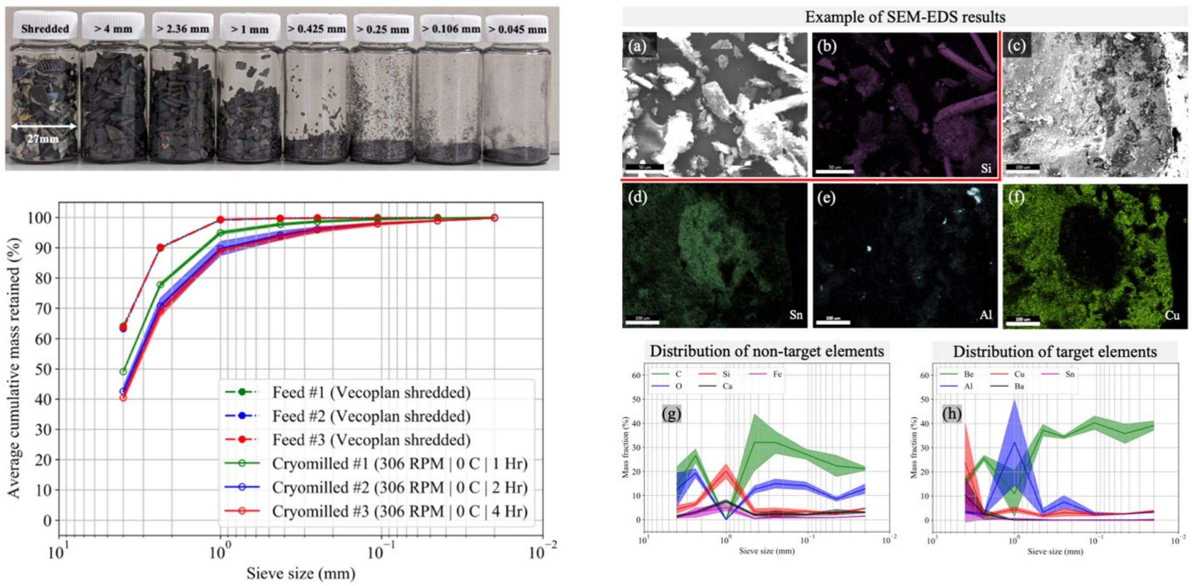

Figure: (Left-upper) After milling, samples are sieved and separated into 8 size classes. (Left-lower) Average PSDs are shown for the shredded and cryo-milled particles, with the shaded area indicating the uncertainty range of cyro-milled PSDs. This was obtained in the proposal's recent study on the step-2 milling method. (Right-upper) SEM and EDS imaging of the milled particle size fractions: SEM image (a) and corresponding EDS scan (b) of the fine particles show large aspect ratio silicon structures, as expected from the fiberglass base of PCBs, while SEM image (c) and EDS scan of the largest particles exhibit many of the expected metallic elements, such as tin (d) from the solder joints, aluminum fragments (e), and copper (f) from the PCB conducting layer. (Right-lower) Base metal and non-metal element mass fractions(g) and valuable element mass fractions (h) are plotted with shaded regions showing the error percentage.