Size Effects on Melting of Silver Nanoparticles: In-situ TEM Observations

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The melting temperature (T_m) of a material is crucial for many applications. In bulk systems, the surface-to-volume ratio is small and the curvature of the surface is negligible. Thus, surface effects on T_m can be disregarded. However, for the case of nanoparticles, for which the surface-to-volume ratio is large and the surface curvature is high, T_m is size dependent.

In this work, in-situ heating experiments on silver nanoparticles, ranging from 5nm to 25nm, were performed in a JEOL 2010F transmission electron microscope (TEM) to determine the effect of size on T_m. The in-situ heating experiments were conducted with an Aduro^{TM} heating stage designed by Protochips Inc. The heating stage is a MEMS design that exhibits an extremely low drift even at high temperatures due to its low thermal mass. The temperature is controlled by a power source supplying current to a thin film that contains the silver NPs and that is heated resistively, allowing very fast heating rates (10^6 ℃/s) without sample drift. Starting from room temperature, the samples were heated in-situ in the TEM in increments of 25℃ until all the nanoparticles melted and vaporized.

A sequence of TEM images showing the melting and vaporization of silver nanoparticles at various temperatures is shown in Fig. 1. As expected, T_m decreases with decreasing particle size. However, significant differences between T_m predicted from thermodynamics and the experimentally measured T_m were found. This seems to be due to changes in the solid-liquid interfacial energy with size.

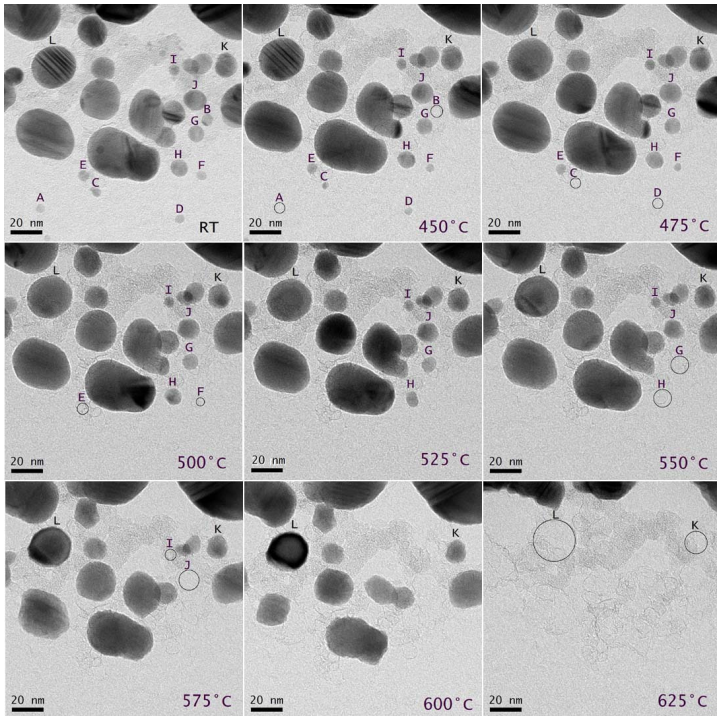

Figure 1: A sequence of TEM images showing melting and vaporization of silver nanoparticles.