Looking at Solar and Interstellar Dust in the Laboratory: The NanoSIMS Facility at the ASIAA

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NanoSIMS, a 3-million-euro worth of Secondary Ion Mass Spectrometer (SIMS) featuring submicron spatial resolution, was purchased in December 2011 and installed in Academia Sinica in July 2013. Since its debut in academia in 1998, NanoSIMS has been proven to be an extremely powerful tool in a wide range of research fields, including astrophysics and cosmochemistry, geochemistry, cellular biology and material science. At IAA, this instrument will be applied to the study of meteorites, in hopes of better understand the origin and evolution of the Solar System as well as the chemical history of the Galaxy.

One important research topic is to study the isotopic compositions of the oldest Solar System solids, namely Ca-Al-rich Inclusions (CAIs). These inclusions, with absolute radiometric ages of 4.568 billion years, formed at the very beginning of the Solar System history and therefore witnessed the earliest evolution of the Solar System. CAIs are known to have preserved fossil records of some short-lived radionuclides (half-life < 3 Myr). Such radioactivities could have originated from a specific stellar source (supernova, asymptotic giant branch star, or Wolf-Rayet star) and/or been produced by nuclear reactions between nebular dust and solar energetic charged particles. If the initial abundances and distributions of, and the relationships amongst, different short-lived radionuclides in the solar nebula can be quantitatively constrained, a clearer picture regarding the Solar System formation can be obtained.

The chemical evolution history of the Galaxy can also be studied with NanoSIMS through the isotopic analysis of “true stardust” or “presolar grains”. These dust particles are condensates in the outflows of evolved stars so that they sample material directly produced by stellar nucleosynthesis. Some presolar grains survived their interstellar passage and destructive processes in the early Solar System and then were incorporated into meteorite parent bodies. In the laboratory, these grains can be identified by their extremely anomalous isotopic compositions (far different from the average solar ratios) in many elements, such as C, N, O and Si, and then can be analyzed for other isotopic systems for other purposes. One topic that has been of interest to IAA researchers is the residence time of presolar grains in the interstellar medium. This problem can be constrained by analyzing the isotopic compositions of purely spallogenic elements, such as Li-Be-B, in the presolar grains. These elements are destroyed by stellar nucleosynthesis, therefore, any Li-Be-B seen in presolar grains must be due to spallation by Galactic Cosmic Rays (GCRs) when grains resided in the interstellar medium. Therefore, combined with theoretical modeling, the results of Li-Be-B measurements will not only tell us the residence time of stardust in the interstellar medium, but also constrain the paleo-flux and compositions of GCRs.