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”Astromineralogy” as mineralogy: until now and from now

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Small solid-state grains called ”dust”, which are ubiquitously present in a variety of astronomical environments, control thermal balance in astronomical processes by absorbing the radiation of high-energy and radiating in the infrared region. They are also raw materials that form solids in the solar system. Since recent development of infrared astronomical observation reveled presence of minerals as dust, which has been once considered to be amorphous state, a field between astronomy and mineralogy called ”astromineralogy” has been developed [1]. In circumstellar regions of evolved and young stars, ˜15% of crystalline silicates (mainly Mg-rich olivine and pyroxene) has been observed as well as amorphous silicate as sub-micron dust. In interstellar regions, in contrast, any crystalline silicates have not been observed [2]. It is accepted that crystalline dust becomes amorphous by cosmic ray irradiation. If such interstellar dust is incorporated in a molecular cloud, ice condensed onto the amorphous silicate dust, and organic materials form from the ice. This composite dust called Greenburg particles [3] are considered as a solid raw material in the solar system. In a high-temperature region of a protoplanetary disk, crystallization of amorphous silicate and evaporation and recondensation should occur.

Astromineralogy has been developed mainly as a branch of astronomy. From the standpoint of material science, formation and evolution of dust has been discussed by considering infrared spectrum features, which are controlled by intrinsic properties (crystal structure, chemical composition and temperature) and extrinsic properties (particle size, morphology, anisotropy, lattice defects and aggregate form) of minerals (e.g., [4]). Based on the intrinsic properties, minerals in circumstellar regions have been identified and their chemical compositions have been estimated by comparing observed infrared spectrum. Researches based on extrinsic properties are now developing, and it is important in the future to promote mineralogical researches in addition to observation and theoretical researches.

Important issues for future studies are follows. (i) Origin of crystalline circumstellar dust: crystallization of amorphous silicate [5,6] or direct condensation from high-temperature gas [7]? Is there any possibility of impact fragments of larger crystals [8]? (ii) Behaviors of Fe and S. (iii) Relation with extra solar materials (presolar grains) [7] and the candidates (GEMS) [9]. (iv) Farther understanding physics of infrared absorption spectrum of minerals.

Finally, a following working hypothesis for a series of processes of dust formation and evolution is proposed here based on previous studies. (1) Mass loss from an evolved star. (2) Condensation of refractory minerals, such as corundum [7], followed by condensation of spherical particles of amorphous silicate [5] with an metallic iron nano-particle inside [9]. (3) Partially crystallization of the amorphous silicate [6]. (4) Transportation to interstellar region and amorphization [2]. (5) Incorporation into a molecular cloud, condensation of ice and formation of organic materials [3]. (6) Incorporation into a protoplanetary disc and sintering of spherical amorphous silicate particles (GEMS formation) [9]. (7) Crystallization in a high-temperature region near the central star. (8) Evaporation and recondensation of silicates in a higher-temperature region and recycling of the high-temperature materials.

References: [1] Henning (2010) ”Astromineralogy” Springer-Verlag. [2] Kemper et al. (2004) ApJ 609: 826. [3] Greenburg (1998) A&A 330: 375. [4] Chihara et al. (2006) Planetary People 15: 44. [5] Koike et al. (2010) ApJ 709: 983. [6] Murata et al. (2009) ApJ 697:836. [7] Takigawa et al. (2009) MAPS, 44: A200. [8] Imai et al. (2009) A&A 507: 277. [9] Matsuno et al. (2012) JGU Meeting, abstract, this volume.

Keywords: circumstellar dust, interstellar dust, amorphous silicate, crystalline silicates, infrared spectrum, condensation