

Formation and evolution of cores in asteroids: clues from iron meteorites

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In 12 out of 14 groups of iron meteorites, chemical variations are consistent with fractional crystallization of single pools of molten Fe-Ni-S (e.g., Ir is inversely correlated with Ni and varies by factors of 10^{1-4}) [1]. These irons have W isotopic compositions indicating they were isolated from Hf-bearing rock <1 Myr after CAI formation [2]. By contrast, irons in groups IAB and IIE do not show fractional crystallization trends (e.g. Ir is uniform), they contain abundant silicate inclusions including chondritic fragments, and their W isotopic compositions indicate more recent metal-silicate exchange. This suggests that most irons come from cores of asteroids that accreted <1 Myr after CAIs when ^{26}Al was abundant enough to form molten cores. Irons in groups IAB and IIE probably come from bodies that accreted later when there was insufficient ^{26}Al to allow metallic pools to form cores.

Irons from cores of differentiated asteroids should have cooled more slowly than irons from metallic pools. However, fractionally crystallized irons show fast cooling rates, e.g., 60-300 °C/Myr for IIIAB irons, 100-6600 °C/Myr for IVA irons, and 500-5000 °C/Myr for IVB irons [3-5]. These cooling rates are incompatible with cooling in cores of asteroids that were melted by ^{26}Al for two reasons. 1) Each group has a wide range of cooling rates whereas metallic cores should have cooled almost isothermally as metal conducts heat much more rapidly than silicate. 2) Bodies that were small enough to have cooled at these rates would have had radii of <10 km and could not have been melted by ^{26}Al . In addition, the 4565 Myr Pb-Pb age of a IVA iron [6] is incompatible with conventional models for fully differentiated asteroids which require cooling over tens to hundreds of Myr. The metallic cores supplying most iron meteorites must have cooled rapidly with little or no insulating mantle.

Impacts between asteroids at current impact velocities of ~5 km/s cannot efficiently remove silicate mantles from cores. However, impacts at lower speeds during accretion can disrupt projectiles impacting at grazing angles and speeds comparable to mutual escape velocities [7]. Repeated collisions under these conditions may have allowed core material to cool with little or no silicate insulation. Low-velocity collisions during accretion may also explain the presence of rock fragments in the IAB and IIE iron meteorites.

The diversity of melted and unmelted asteroids and meteorites may result from formation of iron meteorites and achondrites from planetesimals that accreted near the terrestrial planets whereas chondrites accreted later in the asteroid belt [8]. Grazing impacts eviscerated differentiated asteroids so that fragments were lofted into the asteroid belt. Planetary accretion may have been a very inefficient process so that the differentiated asteroids represent the construction debris [7].

[1] Goldstein et al. (2009) *Chemie der Erde* **69**, 293-325. [2] Kleine et al. (2009) *GCA* **73**, 5150-5188. [3] Yang & Goldstein (2006) *GCA* **70**, 3197-3215. [4] Yang et al. (2008) *GCA* **72**, 3043-3061. [5] Yang et al. (2010) *GCA* **74**, 4493-4506. [6] Blichert-Toft et al. (2010) *EPSL* **296**, 469-480. [7] Asphaug (2010) *Chemie der Erde* **70**, 199-219. [8] Bottke et al. (2006) *Nature* **439**, 81-824.

Microscopy based detection and analysis of carbon nanocomposites in commercially available baseball bats

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The number of consumer products incorporating polymer nanocomposites has rapidly increased in recent years [1]. Especially in sport equipment, the enhanced material properties such as high strength, high toughness and low density of these nanocomposites are effectively translated into a lighter equipment with improved performance characteristics. Although much work has been done in developing and characterizing these nanocomposite materials and nanofillers (nano-tubes, -particles, -fibers, etc.), characterization and lifecycle studies of nanocomposites in their product condition have been lacking. However, several recent studies have examined nanocomposite degradation and disposal products and explored their environmental impacts. Nguyen et al. have shown that surface exposure of carbon nanotube (CNT) network can result from the photodegradation of polymer matrix under UV exposure of CNT-polymer nanocomposites [2]. Wohlleben et al. have evaluated nanocomposite fragments for the nanofiller release and their in-vivo toxicity [3].

In this study, we examined two different types of commercially available baseball bats that incorporate CNT-polymer nanocomposites into their structures. Several different microscopy techniques were used to identify and analyze the CNTs in the bat and in the release fragments from two different use scenarios (normal and recycle/disposal). The normal use scenario included abrasion of the bat surface with different grades of polishing cloth and sand paper, simulating normal wear and tear. The recycle/disposal scenario included sawing and ripping the bat pieces. The cross-sectional samples of the bats were used to identify the locations of CNT nanocomposites and confirm the presence of CNTs in these materials. The bat surfaces and the release fragments from the two use scenarios are examined for the particle size distribution, release particle morphology and presence of loose or exposed CNTs. The preliminary results from the normal use scenario showed no loose or exposed CNTs in the wear particles or the abraded bat surfaces. The bulk of the release fragments from the sawing and ripping operation were mm to μm sized fragments. However, albeit in very low level, several types of nano-sized particles and fibers, including some that showed morphology consistent with polymer coated CNTs, were also detected in the release fragments. Additional work is in progress to characterize and quantify the nano-sized debris from the disposal scenario.

[1] <http://www.nanotechproject.org/inventories/consumer/>

[2] Nguyen et al. (2009) *Proc. Eur. Weathering Symposium* **11**, 149-161.

[3] Wohlleben et al. (2011) *Small* **7**, 2384-2395.