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Microstructural Characterization of Automotive Materials

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Implementation of new materials or processes in the automotive industry are typically driven by the desire to improving fuel economy and customer satisfaction while reducing cost. Microstructural characterization is typically employed to assist in failure analysis of proto-type components or to evaluate the effect of process changes on microstructure. The types of materials under investigation include steels, aluminum, magnesium and polymers used primarily in body panel applications, steels and cast aluminum for powertrain components, and ceramics utilized in exhaust gas catalysts and various sensors. Three examples of materials characterization are presented below.

Aging studies of three-way exhaust gas catalysts.
Automotive three-way catalysts (TWCs) are most often comprised of a cordierite monolith coated with a washcoat containing Al_2O_3, CeO_2 and ZrO_2 which is impregnated with finely dispersed noble metal particles. Thermal aging and chemical poisoning are two of the primary deactivation mechanisms in TWCs. Post-mortem studies on aged catalysts can assist in understanding these failure mechanisms. Figure 1 shows WDS elemental maps of a cross section of a catalyst that was vehicle aged for 50k miles. Decomposition products of the oil additive zinc dialkyldithiophosphate (ZDDP) have deposited on the surface of the washcoat. The maps show that zinc and calcium are localized on the surface of the washcoat, while the phosphorus has migrated into the washcoat. The contamination layer on the surface blocks the washcoat pores and prevents the exhaust gas from reaching the catalytic material. TEM analysis has identified regions of $AlPO_4$ formed in the washcoat which can also block pores and cause a loss of surface area necessary for catalytic activity.

Development of polyolefin-based nanocomposites.
The development of a new generation of polyolefin-silicate clay nanocomposites requires a compatibilization process that can effectively disperse the clay throughout the polypropylene (PP) matrix in an economical way for large-scale automotive applications. Both supercritical fluid (SCF) processing and ultrasonic melt processing are currently being investigated to improve the dispersion, exfoliation and intercalation of the clay platelets. Figure 2a shows a bright-field (BF) TEM micrograph of a conventionally processed silicate-clay nanocomposite showing tightly layered tactoids. Clay platelets in materials which have been SCF processed (Figure 2b) show evidence of increased intercalation, while ultrasonication of the clay-PP mixtures during the melt state shows an increasing amount of dispersion and exfoliation (Figure 2c).

Heat-treatment optimization of a cast 319 aluminum (Al) alloy.
The substitution of 319 Al for cast iron in engine block and cylinder head applications results in significant weight savings. Since this alloy is heat-treatable (primary age hardening precipitate is θ-Al_2Cu), care must be taken to insure that material properties do not degrade during the life of the vehicle. This requires a thorough knowledge of temperatures encountered during operation and precipitation kinetics. The "as-cast" 319 alloy consist of aluminum dendrites surrounded by Si eutectic which also contains θ-Al_2Cu particles (Figure 3a). The remaining Cu in the Al dendrites is concentrated near the eutectic due to coring (Figure 3b). Solution treatment at 495°C for 1hr significantly increases and homogenizes the Cu in solid solution. Natural aging of solution treated

material for approximately 24hr increases the hardness of the alloy due to the formation of G.P. zones (Figure 3c). However, the alloy undergoes significant volume changes during aging until the G.P. zones are replaced by the metastable θ'-Al_2Cu (Figure 3d). θ'-Al_2Cu remain the predominate precipitate for agings of at least 1000h at 305°C.

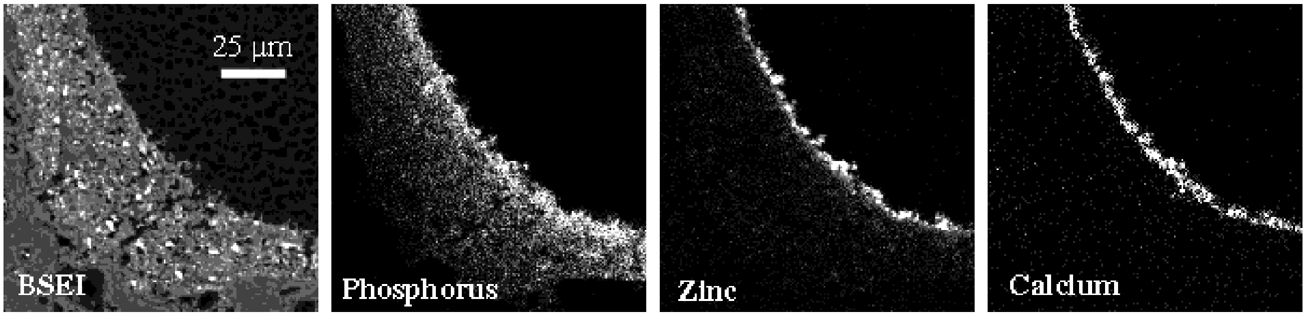

Figure 1. Electron probe micro-analyzer (EPMA) images of exhaust catalysts after 50,000 mi. aging. The presence of phosphorus throughout the washcoat and zinc and calcium on surface are due to the oil additive zinc dialkyldithiophosphate (ZDDP).

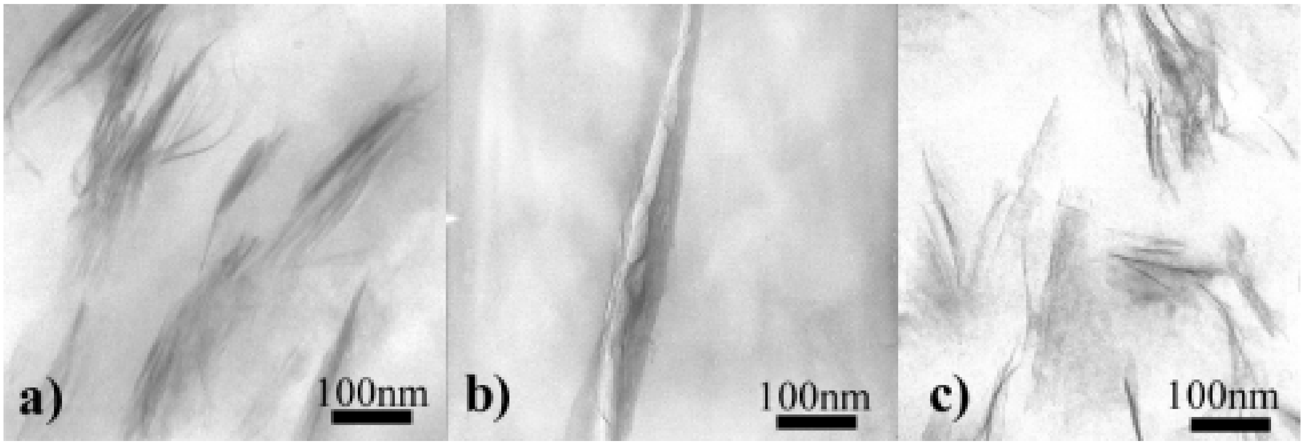

Figure 2. BF micrographs of clay nano-particles in a polypropylene (PP) matrix following; (a) conventional processing, (b) SCF processing, and (c) ultrasonic processing. Samples were cryo-microtomed and subsequently stained with ruthenium tetraoxide vapor.

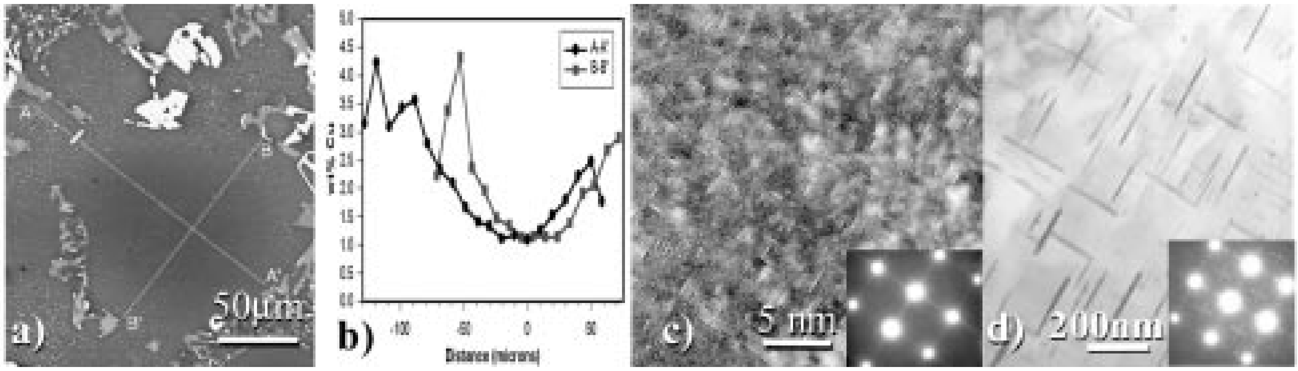

Figure 3. (a) BSEI of a dendrite in "as-cast" 319 Al. (b) wt% Cu determined by EPMA along the lines A-A' and B-B' shown in 3a. (c) BF micrograph of solution treated and naturally aged 319 Al. (d) BF micrograph of 319Al aged to a T7 condition (solution treated and aged for 5h at 260°C).