"*Nano-Springs* " for Elastomer Reinforcement

G. Beaucage[*, a], S. E. Pratsinis[b], J. E. Mark[c]

[a]*Department of Materials Science and Engineering*
[b] *Chemical Engineering Department*
[c] *Chemistry Department*
University of Cincinnati,
Cincinnati, OH, 45221-0012

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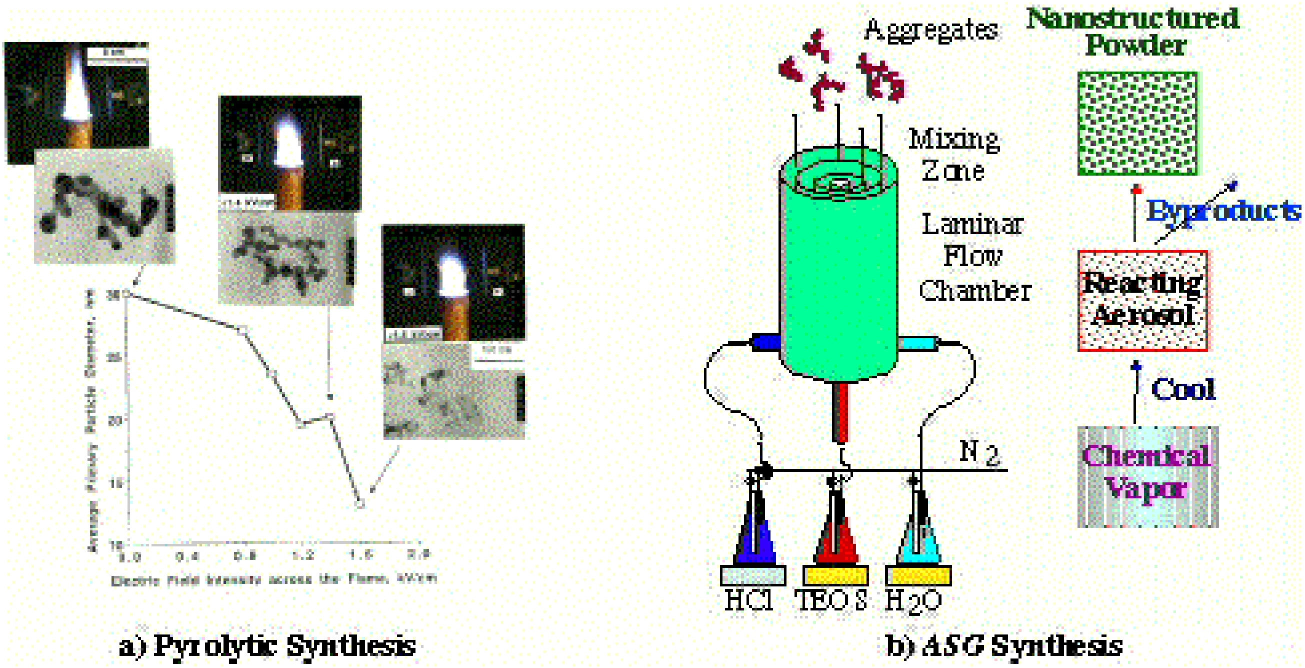
There will be a link from here to the full article when it is available on the web.

The recent discovery for synthesis of nanoparticles with closely controlled size and structure using flame to room temperature processes at the *University of Cincinnati* [Beaucage, et al. 1998; Fotou, et al. 1994; Hyeon-Lee, et al. 1997 and 1998; Kusters, et al. 1995; Pratsinis, et al. 1996 a and b; Spicer, et al. 1996; Vemury, et al. 1995 a-c, 1996] have made available, for the first time, nanostructured materials with tunable Hookean elastic characteristics [Friedlander, et al. 1998] and interfacial chemistries. These *nano-springs* display complimentary dynamic elastic behavior to organic elastomers [Friedlander, et al. 1998, Treloar 1975]. This presentation will discuss recent efforts at understanding the physical basis of elastomer reinforcement by Hookean nano-particles using the framework of mass-fractal theories [Beaucage 1995, 1996; Heinrich, et al. 1995; Huber, et al. 1996; Witten, et al. 1993, 1987]. The work highlights a university team with expertise in particle synthesis (Pratsinis, Beaucage), aggregate characterization (Beaucage), elastomers (Mark) and simulation of molecular (Mark [Mark 1996 a-c]) and aggregate nanoparticle (Pratsinis) dynamics that is coupled with experts from leading industries in elastomer manufacture of silicones (GE Silicones), tires (Goodyear) and precipitated silicas (PPG). Our collaborative research aims at understanding the role of nanoscale Hookean fillers (silica) in elastomers that are used for instance in tires, seals, and electronics.

A process has been developed for synthesis of silica by scaling-up electrically-assisted flame aerosol and aero-sol-gel (*ASG*) reactors so large quantities of nanoparticles with precisely controlled characteristics can be readily made. The design and operation of these reactors are guided by state of the art simulators relying on computational fluid and particle dynamics that detail the effect of process conditions on product nanoparticle characteristics. This process is used to make pristine fumed silica as well as carbon and organically coated silica particles. State of the art diagnostics are used relying on recent developments from other closely related ongoing projects in our laboratories (in-situ FT-IR sizing and thermophoretic sampling, small-angle x-ray scattering). Special emphasis is placed in characterizing the surface of these silica particles and understanding the role of process variables on the specific surface area, porosity and even the number of hydroxyl group surface concentration by vacuum IR and proton NMR.



Two synthetic processes used at the University of Cincinnati for the synthesis of nano-aggregates for elastomer reinforcement.

These base nanoparticles are used as fillers in natural rubber (NR) and styrene-butadiene (SBR) and poly dimethyl siloxane (PDMS) gums with non-interacting cure systems. Elastomer samples with variable filler weight fraction have been made using a Banbury mixer, an extruder and hot press. These samples have been mechanically characterized both statically and dynamically to rigorously test the predictions of existing theories and proposed simulations for elastomer reinforcement using fillers of closely controlled primary and aggregate size for the first time. Elastomer molecular-dynamics simulations incorporating filler dynamics (recently observed [Friedlander, et al. 1998]) are being used to develop a basis for dynamic mechanical properties in nano-composites.

A fundamental understanding of structure/property relationships in these nano-systems may lead to development of new applications using nanoparticles. In the past few years, for example, European elastomer and inorganic oxide producers have teamed to produce, using an empirical approach, the *green tire* which is based on nano-structured silica reinforced hydrocarbon elastomers. The green tire dramatically improves fuel economy and overall performance over conventional tires, leading to a projected fuel savings of 11 billion gallons per year!

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*Corresponding Address:
Gregory Beaucage, Assistant Professor, Department of Materials Science and Engineering, University of Cincinnati, 45221-0012, (513) 556-3063, fax: -3773, gbeaucag@uceng.uc.edu

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