

“Synthesis and Characterization of highly uniform Palladium nanoparticles”**Yisrael Herzberg and Yonatan Schwab, Rambam Mesivta High School, Lawrence, NY – 2004-05 National Finalists**

Abstract: Palladium nanoparticles are of interest because of their catalytic properties and affinity for hydrogen. Nanoparticles synthesized by functionalizing with long-chain carbon-thiol groups may not be useful catalysts since the sulfur groups coating the particle can poison reactions.

We synthesized hydrophilic Pd citrate-coated nanoparticles using an emulsion method. TEM analysis showed highly crystalline particles with a mean size of 11 nm +/- 1.6 corresponding to only a 1.7% deviation. Conventional Pd-thiol nanoparticles produced 5nm and 2nm particles with larger % deviations and diffuse electron diffractions rings, indicating greater disorder. EXAFS analysis confirmed that the Pd-Pd spacing in all three Pd nanoparticle types was equivalent to bulk values but that the Pd-coating/Pd-Pd ratio was 10⁶-fold less for the PdCitrate particles than the Pd-thiols. EPR indicated little or no magnetism for the Pd-thiols while the citrate particles had a large moment, nearly half that of the Fe₂O₃ standard. We hypothesize our nanoparticles are composed of single magnetic domains of one or two hundred atoms, rendering them magnetic. The Pd-thiols have their magnetism quenched by the surface thiol impurities.

Porosity was introduced to the citrate particles encased in PEO using supercritical CO₂, making them ideal catalyst particles with large surface to volume ratio without sulfur impurities. Their magnetism permits remote positioning and removal at reaction completion. Hydrogen storage with these particles is now being studied.

Mentor: Dr. Miriam Rafailovich

"The Effects of Nanoparticles on Selective Gas Permeability of Thin Film Membranes Using Supercritical Fluid"**Allyson Ho, William P. Clements High School, Sugar Land, TX and Alex Thachara, The Wheatley School, Old Westbury, NY – 2004-05 National Finalists**

Abstract: The addition of inorganic nanoparticles to polymer thin films can be highly beneficial to their lubrication, strength, and UV resistance. Since nanoparticles are rigid, they do not conform to the molecular order of the film, producing nano-scale voids. Consequently, the introduction of nanoparticles into polymer films alters their porosity; this phenomenon may be exploited to engineer selectively permeable membranes.

Assorted nanoparticles were added to polystyrene and poly (methyl methacrylate) solutions to observe this change in porosity and to analyze its dependence on polymer structure and on polymer-nanoparticle interactions. We monitored the effects of various nanoparticles (gold-0.5%, clay-10%, 20% of solute mass) on the permeability of O₂ gas. We then exposed the nanocomposites to supercritical CO₂ (36°C, 1200psi and 50°C, 1450psi), finding that membrane permeability is dependent on two factors: rigidity of the polymer and absorption of scCO₂ through the nanocomposite membrane.

By controlling permeability, we may engineer materials that better suit their functions. For example, a gas mask can be improved by allowing more O₂ penetration while impeding pollutants and bacteria. In the food packaging industry, such materials could be produced inexpensively to create packets that restrict air flow and preserve food for longer time periods.

“Using Nanoparticles to Enhance Polymer Properties for Improved Commercial Applications: Space Lubricants to Nanolithography”

Jeffrey Reitman and Sean Mehra, Jericho High School, Jericho, NY – 2003-04 National Team Finalists

Abstract: High performance polymers are in increasing demand by industry. Dewetting is a major problem for space lubricants. We propose that nanoparticles might be able to stabilize lubricants, such as PDMS based silicone oil. We tested this hypothesis by spincoating various nanocomposite solutions and observing dewetting. In each instance, nanoparticles reduced lubricant dewetting. We then analyzed evaporation rates, interfacial tensions, and viscosities for each solution. We showed that nanoparticles can both increase and decrease these properties. The data was incorporated into a model to predict the stabilization of lubricants by specific nanoparticles.

In nanolithography, polymer masks will soon approach molecular scales. When they do, the glass transition and modulus are expected to decrease, degrading resolution of the features. Using our derived model, we incorporated ODT/Au nanoparticles into monodisperse PS films. Nanopillars were patterned in polymer matrices, with and without filler, using contact printing. Shear modulation force microscopy revealed an increase of modulus and TG.

Our research serves as a foundation for future work regarding the stabilization of industrial polymers and will help create a general model of the effect of nanoparticles on polymers.

Mentor: Dr. Miriam Rafailovich

“Optimization of Biomimetic Osteoblast Response on Phospholipid-Modified Implant Surface for Bone Regeneration”

Arpan Satsangi, Health Careers High School, San Antonio, TX – 2003-04 National Individual Finalist

Abstract: Significant numbers of metallic bone implants fail due to lack of host tissue attachments. Therefore, implant metals must be coated with natural, bone growth-accelerating substances. Research indicates that phospholipid calcium-phosphate complexes (Ca-PL-PO₄) enhance biological hydroxyapatite deposition, and thus, biomimetically enhance osteogenic activities. This research attempts to optimize the phospholipid structure, at positions-1, 2 and 3, relative to bone cell response on coated Titanium surfaces.

Titanium discs were coated with select Ca-PL-PO₄s. Osteoblast progenitor cells were cultured on these coated discs for differentiation into osteoblasts, as measured by expression of alkaline phosphatase specific activity and total protein production. The polar-head group in the phospholipid part of Ca-PL-PO₄ prominently effected osteoblasts, and the phosphatidylserine-complex performed the best. Further evaluation of biochemical structures at positions-1 & -2 of phosphatidylserines showed that unsaturation in fatty ester groups is preferred by osteoblasts, and that the 1,2-dilinoleoyl phosphatidylserine exhibited the best combination of osteoblast activities.

Mentor: Dr. Joo Ong

“A Viscometer for Ultra Thin Films”

Shira Billet and Dora Sosnowik, Stella K. Abraham School for Girls, Hewlett Bay Park, NY – 2001-02 National Team Winners

Abstract: In complex mechanical systems, lubricants reduce friction and protect moving parts against wear. Ultra-thin film lubricants are prevalent in today’s technological world in all areas where tolerances are tight. In order for lubricants to work properly, their viscosity must be suitable for the particular application. For example, high viscosity may be required in automobile engines whereas low viscosity is needed in biomedical applications. Numerous authors have demonstrated that the glass transition temperature can be altered by interactions with specific surfaces when the lubricant film is thin. Since the viscosity is an exponential function of temperature¹, we therefore postulate that these interactions may also affect the viscosity of thin films. To our knowledge, no commercial viscometer exists that can provide the very high shear required to measure films thinner than one micron. Hence, we proposed a new method for measuring viscosity of films in-situ near a surface. This method is based on the theory of Brochard² for a liquid/liquid bi-layer.

When two liquid films are in contact, the energy of the bi-layer is minimized when the layer with the lower surface tension is exposed. Hence, if the surface tension of the upper layer is higher than the lower one it will dewet by forming holes. Brochard² calculates the velocity, V , with which these holes will grow and obtains the following equation: $V = |S| / \eta$ where S is the spreading parameter, or absolute value of the difference in surface energies and η is the viscosity of the least viscous of the two layers. Hence, one can measure the viscosity of a lubricant on a surface by covering it with a more viscous, high surface energy polymer, and observing the dewetting velocity. We tested this concept by constructing bi-layers where a low viscosity (?) poly- (methyl methacrylate) (PMMA) film is spun cast on a silicon wafer and covered by a high viscosity polystyrene (PS)

Mentor: Dr. Miriam Rafailovich