

Nanocomposites

Metal & Ceramic Filled Polymers for Dielectrics

...suspended nanoparticles

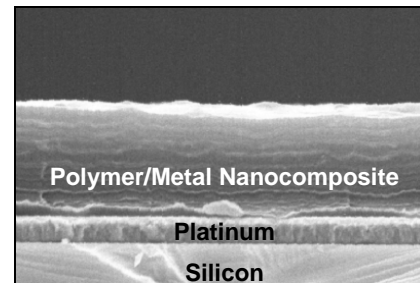
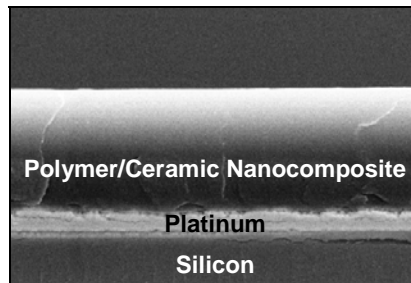
Nanocomposites are a subset of composites that take advantage of unique materials properties on the small scale. At *nGimat*TM, we use our proprietary NanoSpraySM and Combustion Chemical Vapor Condensation (CCVC) processes to produce polymer matrix / metal or ceramic nanoparticle nanocomposite coatings.

The Embedded Passive Advantage

Electronic technologies that allow for a reduction in size, weight, and cost while improving functionality and performance are highly desired for military and commercial applications, including telecommunications, network systems, automotive, and computer electronic devices. The architecture of passive components is one area with room for improvement due to the large and growing number of passive components in today's increasingly functional devices. Discrete passives, especially capacitors, have already become the major barrier of the electronic systems miniaturization. Therefore, the development of embedded passives is desired, if not required. Among passive components, the development of embedded capacitors has been an area of significant activity because of capacitor use in multiple functions, such as decoupling, by-passing, filtering, and timing capacitors.

Integral Passives Advantages over Discrete Passives

- No separate interconnects to the substrate
- Reduced parasitic inductance
- Improved electrical performance
- Lower cost
- Easier processing



SEM cross-sectional images of *nGimat*'s typical polymer/ceramic (left) and polymer/metal (right) nanocomposites, shown on Pt/Si wafer although can be used on any conductive surface.

Nanoceramics and Nanometals

Polymer/ceramic nanocomposites (polymer matrices filled with ceramic nanopowders) are a promising material for embedded capacitors. They combine the high dielectric constant of ceramic powders and the processability and flexibility of polymers. In addition, advances in nanotechnology may enable polymer/metal nanocomposites (polymer matrices dispersed with metal nanopowders) to compete favorably with more traditional ceramic-filled polymer composites. Like ceramic-filled polymers, metal-filled polymer nanocomposites have the potential to combine both performance and processability. However, metal-filled polymer composites ("artificial dielectrics") have shown the potential for exceptional dielectric constants. Artificial dielectrics are created when isolated metal particles become polarized due to the presence of an applied electric field. This polarization simulates the dipoles of a true dielectric ceramic. To capitalize on this effect, the properties of the conducting nanoparticle (such as size and composition) must be optimized.

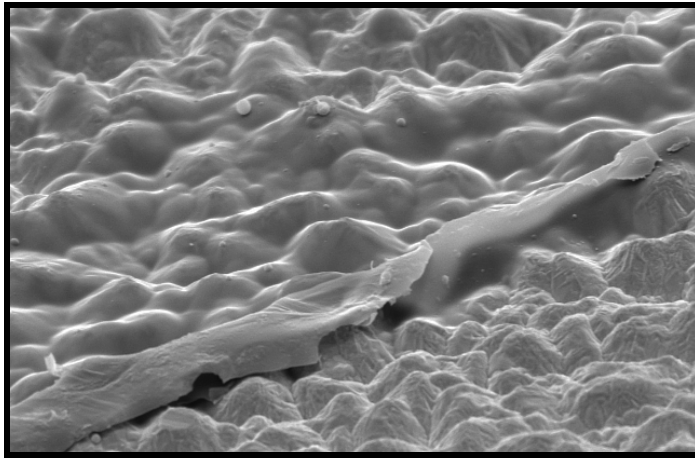
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nanoEngineered MaterialsTM

Metal-filled polymer composites (“artificial dielectrics”) have the potential to address the needs of emerging dielectric technologies, such as embedded capacitors with high capacitive densities (20-200 nF/cm²). In an applied field, dipoles form in each of the metal particles, resulting in polarization that simulates a true dielectric. For high frequency applications, engineering small particles with high electron mobilities is essential since only these properties will enable the rapid field response necessary for high dielectric constant and low loss. These new nanocomposite artificial dielectrics have the potential to have high dielectric constants (> 100) at high frequencies and to enable the low temperature processing associated with polymers. This combination of properties is not found in other capacitor materials.

Size and cost of electronic components is expected to decrease by an order of magnitude in this decade. To accomplish these goals, it is necessary to integrate many of the passive components. By incorporating capacitors within the board structure, significant miniaturization of the electronic device can be achieved. Embedding capacitors within the board also has the potential to increase performance by shortening conductive paths, improve reliability by decreasing the number of solder joints, and lower cost. However, the embedded capacitor concept does not come without challenges. To obtain the necessary values, a relative dielectric constant of greater than 100 is required for many dielectric applications. The magnitude of these values is easily achievable with various dense oxides, but high temperature processing is problematic since it is not compatible with conventional PWB technology. Thus, polymer composites have received a great deal of attention because of their adhesion, toughness, and ability to be processed at low temperatures. However, the dielectric constant of polymer composites is generally limited by the low dielectric constant of the polymer matrix ($\epsilon_r < 5$). Since the volume fraction of ferroelectric ceramic must be limited to less than 50% in order to maintain mechanical properties, achieving dielectric values greater than 100 is difficult. Experimentally, relative dielectric constants of 70 are considered excellent polymer/ferroelectric composites.



SEM image of *nGimat's* typical nanocomposite thin film coating on copper foil for printed wiring board applications.

The concept of artificial dielectrics has potential to produce polymer composites that overcome dielectric limitations of polymer/ferroelectric composites. As early as 1952, scientists reported dielectric constants an order of magnitude higher than the pure matrix when dispersing small metal particles in an organic matrix. The metal particles were theorized to become polarized in an applied electric field to simulate the dipoles of a true dielectric. To capitalize on this effect, properties of the conducting particle must be optimized. Specifically, the particles must be significantly smaller than the wavelength of the applied field to prevent anomalous dispersion. The artificial dielectric nanocomposite concept and *nGimat's* experience in producing and characterizing metal nanoparticles and polymer composite films combine to create significant potential for this technology.

nGimat offers its customers product sales, license arrangements, and R&D services, including research and development services for emerging technologies; sale of CCVD coating equipment in association with customer alliances; and licensing under strategic alliances and joint ventures of CCVD process and advanced material technology.

The Company. *nGimat*, located inside the perimeter of Atlanta, is an intellectual property and manufacturing company that engineers nanopowders, thin films, and devices. Our facilities are equipped with instrumentation to perform cutting edge materials research, development, and manufacturing. The scientists and engineers at *nGimat* bring backgrounds in materials science, chemistry, physics, mechanical/chemical/electrical engineering, and biochemistry to the challenges of engineering nanomaterials. In addition, our analytical personnel provide rapid turn-around times and state-of-the-art materials analysis to support our materials development.

We at *nGimat Co.* would like to discuss with you your nanocomposite requirements.

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