Lubrication applications for Metal Rubber

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Rubber is a member of a class of polymeric materials known as elastomers. These substances can be stretched to many times their original length and then revert to their original shape without any change in structure.

A piece of Metal Rubber with an electrical resistivity of 10^sup -5^ ohm cm corresponding to an electrical conductivity of 10^sup 5^ Siemens/cm.

Examples of elastomers include chloroprene, isoprene (natural rubber) and polybutadiene. Elastomers are unique because they combine some of the properties of solids, liquids and gases. Besides displaying the dimensional stability characteristic of a solid, they display the thermal expansion and isothermal compressibility of a liquid and the deformation characteristics of a gas. In the latter case, an increase in temperature will increase the stress on deformed elastomers just as it will increase the pressure in compressed gases.

Nanotechnology is enabling researchers to control the structure of materials at the molecular level. This process can lead to the development of some unique compounds that can utilize the characteristics of elastomers to improve the lubricity of a specific material or a particular surface

STRUCTURE OF METAL RUBBER

One such material has just been recently developed by researchers at NanoSonic, located in Blacksburg, Va., and is known as Metal Rubber(TM). This material was developed during the past year and is based upon efforts (since NanoSonic was established in 1998) to improve upon the robust nature of self-assembled films, a technology licensed from Virginia Tech.

Dr. Jennifer LaIIi, vice president of business development for NanoSonic, says, "Metal Rubber is a freestanding, novel nanocomposite that combines the properties of an elastomer with a highly conductive material. This product is made with polymers with molecular weights between 100 and 100,000 g/mol and metal nanoclusters. The volume percentage of metal in our product is less than 1%."

Metal Rubber is prepared in a systematic process known as Electrostatic Self-Assembly (ESA). Lalli explains, "A substrate is immersed into alternating aqueous baths of anionic and cationically charged components, metal and elastomers. The substrate is then dissolved, resulting in Metal Rubber. Between steps, the developing Metal Rubber is rinsed off in deionized water to remove loosely bonded particles." This process is analogous to making a layer cake, according to Lalli.

Lalli says, "The unique feature of ESA is the ability to control the thickness and the systematic addition of one layer after another. The properties of the final material are dependent upon such factors as the different anionic and cationic components used, immersion time in each of the aqueous baths, pH and the rinse steps."

Metal Rubber is not a conductive polymer, nor a metal-coated polymer film. Using ESA to produce Metal Rubber results in a material where the conductive and elastomeric components do not separate under large mechanical deformation (> 250%).

Thin self-assembled films with thicknesses in the range of 10 to 100 nanometers (or one thousandth of the thickness of a human hair) have been prepared by the ESA procedure until recently. Lalli and her associates have now developed a procedure to both further scale up the process from both the standpoint of thickness and surface area, which has resulted in Metal Rubber. In addition, the process can be accelerated to add layers at the rate of millimeters of thickness per day of synthesis time.

Lalli says, "We are now able to manufacture 20 liters of metal nanoparticles for Metal Rubber that can result in products as large as a two-square foot panel." The thickness of Metal Rubber can now be extended up to 1 centimeter.

PROPERTIES OF METAL RUBBER

Metal Rubber can be stretched to between 200% and 300% of its original length without any change in structure. Lalli says, "We have produced variations of Metal Rubber with an elasticity of up to 1,000%."

From a chemical-resistance standpoint, Metal Rubber is resistant to such additives and solvents as acetone, water and jet fuel. High- and low-temperature properties are also quite good. Metal Rubber can be heated to at least 150 C without decomposing and maintains its physical characteristics down to a temperature of -70 C. Variations with controlled thermal range are available upon special request. The material also maintains its properties after being subjected to boiling water for 24 hours.

The key physical properties of Metal Rubber are the combination of low modulus (less than 20 MPa) with high electrical conductivity. Figure 3 shows a picture of a piece of Metal Rubber that exhibits an electrical resistivity (the inverse of conductivity) of 10"5 ohm cm, which represents an electrical conductivity of 10^sup 5^ Siemens/cm.

POTENTIAL LUBRICANT APPLICATIONS

Lalli foresees that Metal Rubber could be used in two potential applications: "Metal Rubber could act as a sensor in a specific substrate so that changes in conductivity could be used to evaluate the impact of wear on the particular material." This feature would provide the user with significant information about where damage may be occurring in the substrate.

One example could be the use of Metal Rubber in a tool coating such as aluminum nitride (AlN). Lalli indicated that aluminum nitride is one of the components that can be self-assembled into Metal Rubber. As an AlN-coated cutting tool is being used, Metal Rubber could theoretically provide information about the rate at which wear is occurring.

Such a sensor could be of use in determining the operational status of bearings and gears. Seals could be a particularly useful application because the main component used is itself an elastomer. The inclusion of Metal Rubber could theoretically help the user understand where the seal might be wearing out and, as a consequence, prevent undesired leakage.

The second application is to incorporate Metal Rubber into a material that needs to be somewhat flexible while in use. An example is the body of an aircraft.

Lalli says, "NanoSonic has entered into an Alliance Agreement with Lockheed Martin to explore how nanotechnology can be used in large-scale structures. One application that NanoSonic is investigating is the use of Metal Rubber sensors to monitor the shape of aircraft wings while in flight."

"This effect would combine the ability of Metal Rubber to be flexible with its good electrical conductivity properties," Lalli adds. "The latter would be needed to house sensors and electrical conductors to enable the wing to understand its specific environment and change its shape as warranted."

Potentially, Metal Rubber can be incorporated into any kind of a material that has contact with a lubricant system or into a solid lubricant. The lubricity of Metal Rubber can be changed by including specific components such as ceramics, silicon and polyhedral oligomeric silsesquioxane. These additives build abrasion resistance into Metal Rubber that can improve its lubricity.

NanoSonic has applied for a patent on Metal Rubber that should be issued shortly. Other potential applications for the material include artificial muscles for robots, biomedical products (such as stents) and microelectronics (cell phones, personal digital assistants, etc.).

Lalli is open to exploring other uses for Metal Rubber. This material has an interesting combination of properties that should make it attractive for use in lubricant applications.

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