STUDY OF SMART MATERIALS USED IN THE DEVELOPMENT OF NEW TYPES OF ELECTRO AND THERMOMECHANICAL ACTUATORS

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Abstract: *The paper presents some of the most used intelligent materials used in the development of electro and thermomechanical actuators. Smart materials incorporate adaptability and versatility characteristics, being able to process information using only the intrinsic characteristics of the materials. These features provide many possible applications for these materials and structures in the industrial environment, civilian infrastructure systems and biomechanisms.*

Keywords: *smart material, Nitinol, polymers, actuator, piezoelectric*

Introduction

Smart materials are part of the cutting edge of discoveries in materials science, engineering applications, biomechanical systems as well as infrastructure, and more.

Smart materials incorporate adaptability and versatility characteristics, being able to process information using only the intrinsic characteristics of the materials.

These features provide many possible applications for these materials and structures in the industrial environment, civilian infrastructure systems and biomechanisms. System integration, power and mass reduction, moving parts from the drive system, the expression between the drive and the touch system are some of the benefits of using smart materials [1], [2].

1. Alloys with shape memory based on Nickel - titanium

The Ni-Ti alloy has the shape memory capability but also has a high damping and super-plasticity capability, these properties being based on the composition of the two metals as well as the mechanical and thermal treatments to which it is subjected.

Superelastic behavior occurs when it is deformed at a temperature slightly higher than the transformation temperature, the elasticity being 10 to 30 times higher than at the usual material [3], [4], [5].

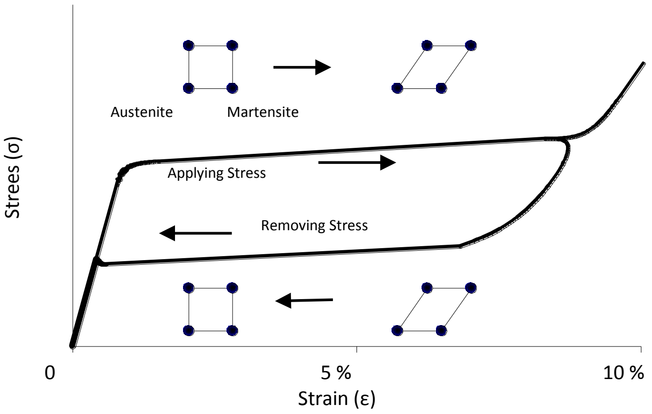

Figure 1. Superelastic Ni-Ti transformation [1]

At different temperatures a series of transformations occur on the alloy, which is a molecular transformation called martensite, corresponding to low and austenitic temperatures, at high temperatures. Between the two phases, the transformation is accompanied by thermal hysteresis, this being done in a temperature range. After the cooling process, martensitic transformation begins at M_s (martensite start) and complete transformation of the material structure takes place at A_f (austenite finite) [1], [2].

Aplicațiile ce utilizează materialele din Ni-Ti au exclusiv funcția de a produce mișcare de deformație si se pot regăsi într-o serie de domenii de aplicabilitate practică precum: medicină (filtre sangvine ce depărtează pereții venelor, oprind formarea unor cheaguri de sânge, proteze pentru membre superioare și inferioare, plăgi osoase, ramele ochelarilor de vedere), artă (statui compuse din părți mișcătoare, flori artificiale ce se deschid sau se închid la radiația solară sau la căldură, sculpturi mișcătoare), obiecte de uz casnic (scrumiere care ridică marginile si sting tigarile care ard până la capăt), jucării (roboți în miniatură, jucări acvatice), aplicații tehnice (actuatoare cu mișcări circulare sau liniare, supape hidraulice de sens, motoare solare și acvatice) [5], [6]. Applications that use Ni-Ti materials have the function of producing deformation and can be found in a number of areas of practical applicability such as medicine (blood filters that eloign the veins walls, stoping the blood clots, upper and lower limbs, bone wounds, eyeglasses frames), art (statues composed of moving parts, artificial flowers that open or close to sunlight or heat, moving sculptures), household objects (ashtrays that raise the edges and quench the cigarettes that burn to the end), toys (miniature robots, aquatic toys), technical applications (actuators with circular or linear movements, sensing hydraulic valves, solar and aquatic motors)[7].

2. Non-metallic shape memory materials

Conductive polymers

Conductive polymers are also called organic composites. They have an orbital p extended system through which the electrons have freedom of movement from one end to the other of the polymer

The most commonly used are polyaniline (PAni) and polypyrrole (PPY). From a constructive point of view, thin films of polyaniline are used, between which is placed a conductive ionic layer

Passing a current causes the reduction to one side and the oxidation to the other, the ions are transferred, so one part expands, the other contracts, causing the whole structure to bend.

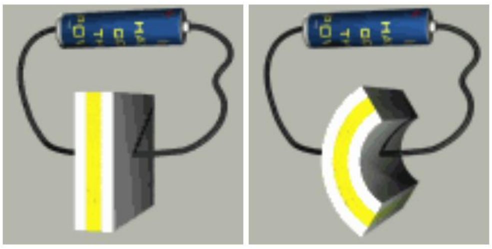

Figure2. Explanatory to the operating principle of conductors based on conductive polymers

In this way, both electric and chemical energy are transformed into mechanical energy. Conductive polymers are simpler to obtain than the polymeric gels shown above. The most used active elements of this type are laminated, unimorphic structures.

Polimeri electrostrictivi

Electrostatic polymers are also called dielectric elastomers. When placed in an electric field, it undergoes a mechanical deformation. Their striction capacity is much higher than piezoelectric materials (10-30% versus 0.1-0.3%).

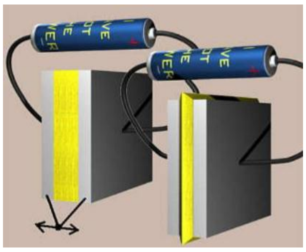

Figure 3. Explanatory to the principle of operation of actuators based on electrostrictive polymers

The most commonly used materials in this category are polymers based on polymethylmethacrylate (PMMA). Due to their electrostrictive deformation, they can be placed between two electrodes, thus reproducing the operation of the muscles. The expansion takes place in the plane of the electrodes, the developed force being proportional to the electric charge from the electrodes (Figure 3).

When applying voltage across electrodes, the different charges on each electrode are attracted, while the tasks of the same sign are rejected. The resulting forces compress the polymer and increase its area. They can be used as linear actuators without additional amplifiers. In addition to the film-like active elements, electrostatic polymers actuators are used stacked elements, recessed, bimorph shaped, tubular and / or cylindrical, generally like piezoelectric actuators.

Polimeri ionici

Ionic polymers (with ions exchange), if are introduced into wet environments, act as polyelectrolytes. Polyelectrolytes contain, on their main chains, ionic groups capable of developing electric fields with intensities of up to 1010V / m. When an external electric field is applied, it interacts with the electric field of the polymer, producing electromechanical deformation.

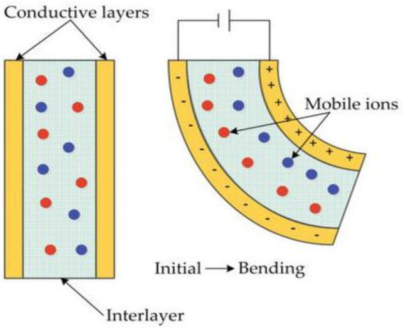

Figure 4. Explanatory to the operating principle of actuators based in ionic polymers

3. Piezoelectric materials

The discovery of the piezoelectric effect was preceded and even favored by the piroelectric effect, known since the seventeenth century, on the tourmaline crystal. The pyroelectric effect is manifested in 10 classes of crystals which - because of the asymmetric mode in which electric loads are distributed - show the phenomenon of spontaneous polarization. In a normal atmosphere, spontaneous polarization goes unnoticed, because the environment contains enough free ions to neutralize superficial tasks. With the rise in temperature, the free neutralizing ions in the atmosphere are removed and the crystal "seems" to have been electrically charged during heating [1].

Piezoelectricity occurs only in certain insulating materials and is manifested by the occurrence of electrical charges on the surfaces of a monocrystal which is mechanically deformed. By applying the mechanical tension, a separation of the weight centers of the electric, negative and positive loads is produced, which gives rise to an electrical dipole, characterized by a dipole electric moment. So the direct piezoelectric effect consists of producing the electric current through deformation and is determined by the asymmetric distribution of electrical loads (there is no center of symmetry). Electric voltage, generated by direct piezoelectric effect, is directly proportional to the applied mechanical stress and to each other (in the case of the piezoelectric inverse effect) [5], [6].

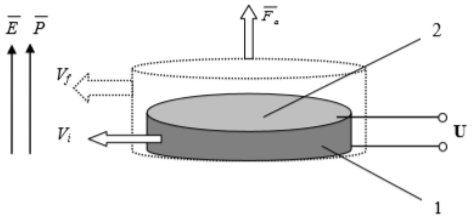

Figure 5. Deformation of a piezoceramic pill in c.c.: 1 - piezoceramic pill; 2 - disc electrode

Piezoelectric actuators exert mechanical forces as the effect of the applied electrical voltage, by piezoelectric effect. Typical deformation is in the order of 2 - 3 ‰ but current research is directed to obtaining a 1% deformation. For these materials, the energy converted to the volume unit is in the order of $(0.18 - 120) \cdot 10^3$ J/m^3. The main qualities of piezoceramic actuators are reduced reaction times and elevated piezoelectric coupling coefficients. They are divided into three classes: monocrystals, polarized ceramic materials and piezoelectric composites.

Quartz is, historically, the first piezoelectric material. It is naturally in the form of large monocrystals. The silica is melted at 1710 ° C and, if it is cooled very slowly, crystalline symmetry of high crystalline symmetry is formed. At crystallization rates higher than $2.2 \cdot 10^{-7}$cm / s, vitreous (amorphous) quartz is obtained. Under T_C = 573 ° C, quartz α is obtained with less crystalline symmetry due to a triple helical crystal lattice. Artificial quartz monocrystals obtained by guided solidification are used in electronic oscillators. If it is cut into thin plates, according to certain directions and very accurate thicknesses, the quartz acquires highly resonant frequency, depending on the dimensions of the plate. Under the effect of an alternating current, an electronic oscillator with a very high frequency (about 20 GHz) and precise, able to provide clock pulsing in quartz computers or clocks or to control the frequencies of radio transmitters is obtained. The most widespread piezoelectric actuators are ceramic. They are able to generate large forces at very low times, being used for: vibration control, matrix printer heads and piezoelectric motors.

Lead Titanate Zirconate (PZT), with the stoichiometric formula PbTi1-zZrzO3 ($z \approx 0.52$), was discovered in 1954 and now holds the largest percentage of the world market for electromechanical transducers. The direct piezoelectric effect of PZT can be more accurately appreciated if one bar of this material with a cross-section of 1 mm^2 and 1 cm length is hit by an ordinary hammer (a mass of 1 kg develops a force of about 10 N) generates a potential difference of 1550 V at its ends [2], [3].Another piezoceramic material, used as actuator, is obtained from PZT by "doping" it with lanthanum. It results in titanate zirconate of lanthanum and lead (PLZT), "an extraordinary electrooptic material", with a piezoelectric coupling coefficient greater than three times the PZT. The above-mentioned material, commonly noted 8/65/35 PLZT, has a typical 5 μm granulation and exhibits a martensite transformation of the trapezoidal type which promotes electromechanical coupling. The threshold voltage over which the depolarization can occur is 5 MPa although the material has a modulus of longitudinal elasticity of 80 GPa at the combined load consisting of mechanical and electrical loading produces a nonlinear behavior closer to the electrostrictive materials than of piezoelectric ones [2], [3].

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