Development of Electroplated Magnetic Materials for MEMS

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INTRODUCTION

Micro/Nano Electro Mechanical Systems (MEMS/NEMS) technologies are uniquely suited for space applications since they offer the advantages of low mass, low power consumption and reliability, with novel capabilities. Given the prohibitive costs of launching any payload into space (between $10,000 - $1000,000 per kg, depending on the type of mission), NASA's goal has been towards "smaller, faster and cheaper" space missions. Such missions are necessarily of the "micro-spacecraft" (under 100 kg mass) with integrated microdevices including inertial guidance devices, micro-propulsion devices, adaptive optics, micro-instruments and nano-mechanical resonator devices.

There are many different ways to deposit and integrate magnetic materials into MEMS/NEMS. Electrochemical processes including electrodeposition and electroless deposition are competitively well-suited to provide requirements of high yield and cost effective processes. Electrochemical processes have many advantages, including precisely controlled room temperature operation, lower energy requirements, faster deposition rates, deposition over complicated shapes, less costly, and simple scale-up with easily maintained equipment. In addition, the properties of materials can be "tailored" by controlling solution compositions and deposition parameters. Due to these advantages, electroplated soft magnetic materials such as $Ni_{80}Fe_{20}$, $Ni_{50}Fe_{50}$, and CoNiFe have been widely used as recording head materials for computer hard drive industries. (1).

In the case of magnetic-MEMS/NEMS, the magnetic layer thickness can be range from a few nanometers to a few mm depending on the applications. Magnetic materials must also have a good adhesion, low-stress, corrosion resistance, thermally stable and excellent magnetic properties. Especially, stress can be a big issue for thicker, because stress in the deposit can cracks or bends MEMS structure.

This paper will review the currently available electroplating materials for magnetic-MEMS/NEMS and challenges associated with incorporation these materials. In addition, the relationship between electroplating parameters including pH, temperature, metal ions solution concentration, complexing agents, other additives, current density (CD), hydrodynamics, and current waveforms (direct current, pulse plating, and pulse-reverse plating) and their physical properties will be discussed. In addition, a few case studies on electroplated magnetic materials on magnetic-MEMS/NEMS devices will be discussed. For example, micro Force Detected Nuclear Magnetic Resonance (μFD-NMR), which is currently under development at JPL for *in-situ* planetary exploration, will be presented (figure 1). The primary focus of this device is to determine whether life exists or existed on other planets such as Mars. MEMS fabricated FD-NMR (a conventional NMR spectrometer is typically room-sized) could be a powerful tool for astrobiology missions.

Figure 2 shows a LIGA fabricated two-dimensional quadrupole mass filter with 3 mm thick electroplated materials for miniature Gas Chromatograph/Mass Spectrometer (GC/MS).

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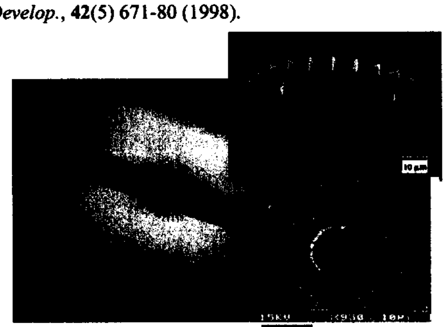

100μm 171X

Figure 1. Microfabricated FDNMR with 8 micron thick 40Co60Ni electrodeposit as detector and annular magnets: "Sunshine" gap is to minimize eddy current effect on the device

Figure 2. LIGA fabricated two-dimensional quadrupole mass filter with 3 mm thick electroplated materials for miniature Gas Chromatograph/Mass Spectrometer (GC/MS).