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Pulse Reversal PermAlloy Plating Process for MEMS Applications
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We present a stable permalloy plating bath suitable for MEMS applications. Furthermore, we have established a process control method utilizing spectrophotometry and pH-measurements. We also demonstrate a MEMS device, where the permalloy of this bath is an integral part.

A plating recipe with pulse-reversal (PR) plating has been developed. Fig. 1 shows the spectrophotometric response of the different components of the bath.

Fig. 2 shows spectrophotometric data for the bath over time. It is seen that the peak at 470 nm grows steadily. The pH-value of the solution was maintained in the range between 3.5-4.5. The growth of the 470 nm peak is expected to be due to oxidation of Fe\textsuperscript{2+} to Fe\textsuperscript{3+}, which is known to have much higher absorbance. It is also seen that after the bath has been used for electroplating, using a 3 cm by 4 cm copper plate for one hour at an average current density of 10 mA/cm\textsuperscript{2}, the absorbance at 470 nm is decreased. This indicates that some of the current is used to reduce the Fe\textsuperscript{3+} ions to Fe\textsuperscript{2+}, resulting in a reduced current efficiency.

The above measurements were made on a freshly mixed 1 l bath, but a bath with the same formulation was mixed in a 25 l tank, and it has been running stably for approximately one year.

Magnetic separation is a well-known technique for extraction of (bio)chemical species. Magnetic beads with targeted surface chemistries are introduced into a solution, and the bound target molecules are thus extracted magnetically along with the beads. Within the last five years, there has been growing interest in integrating this functionality in MEMS/Lab-on-a-chip devices.

Fig. 3 shows a MEMS device fabricated using the plating bath. It is a passive magnetic separator, where long (yellow vertical) permalloy bars are magnetized by an external magnetic field. The magnetized bars create strong magnetic fields and gradients near the ends of these bars. When magnetic beads flow through the \( \mu \)-fluidic channel, they are attracted to places with large magnetic fields, and thus they will gather at the ends of the long magnetic elements. Fig. 4 shows a close-up of the \( \mu \)-fluidic channel, where both beads and permalloy elements can be seen. It is shown how magnetic beads (green) are captured near the ends of the (orange) magnetic permalloy elements.

The electroplated permalloy is a soft magnetic material with a coercive field of approximately 0.5 mT, and the fabricated magnetic bars are easily magnetized. 20 mT is sufficient to saturate the bars. This enables easy capture of beads with only small applied external fields and, fast release, when the external field is turned off.