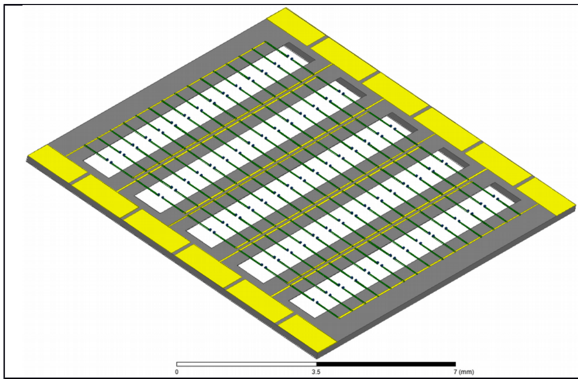
3.3 Microfabrication Process

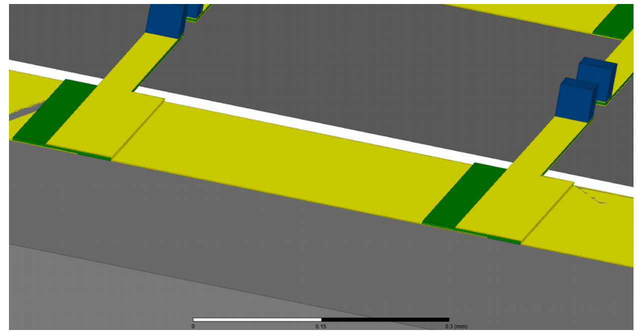
Microfabrication processes are capable of constructing the above-described sensor. The process consists of two main fabrication tasks: piezoelectric cantilever construction and magnetic material integration. Zinc oxide (ZnO) has a high strain-to-voltage coefficient in both the 31 and 33 directions and is highly suitable for piezoelectric sensors [22]. It is also bio compatible, and environmentally friendly. ZnO is typically deposited with sputtering or solution-based deposition techniques [*1*] and patterned with chemical or ion etching.

Rare-earth magnetic materials, such as alloys of Sm-Co, offer high magnetic energy products at room temperature and can be integrated into MEMS using sputtering or pulsed lased deposition (PLD) [2]. However, patterning of these materials is slow, using wet etching or ion-beam milling. Additionally, thick films or high aspect ratio structures composed of these materials become difficult, mainly due to the lack of a suitable electroplating process. To solve this problem, it is possible to embed a rare earth transition metal magnetic material, such as NdFeB, in a resin, then use a mold to pattern the magnetic resin composite [27]. Additionally, transition metal magnetic materials, such as FePt or CoPt, can be electroplated and also show relatively high magnetic energy products at room temperature [2,*2*].

Our proposed fabrication procedure is similar to others in MEMS [20]. The process involves six masks with one being a backside mask. The process will require double sided polished wafers, but the p+ etch stop removes the need for SOI wafers. However, if the doping process does not give the needed uniformity, SOI wafers may be used as well. Alternatively, if the KOH etching is too rough or if smaller spacing between columns is needed, reactive ion etching (RIE) may be used for the backside etch. The electrode area is patterned separately from the cantilevers since the accuracy of both the alignment and etching is not nearly as high. The detail fabrication steps are as follows:

1. Deposit silicon oxide using plasma enhanced chemical vapor deposition (PECVD) and pattern bottom electrode materials (titanium and platinum: Ti/Pt) with RIE etching according to the first mask in the electrode area (Fig. 4(a))
2. Deposit the piezoelectric material (ZnO) and pattern with wet etching according to the second mask in the electrode area (Fig. 4(a))
3. Deposit the top electrode material (Ti/Pt) and pattern with liftoff according to the third mask in the electrode area (Fig. 4(a))
4. Use RIE to etch the layers deposited in the preceding steps to define the cantilever with the forth mask (Fig. 4(b))
5. Deposit the magnetic proof mass using the mold approach (NdFeB) or electroplating (FePt or CoPt) with the fifth mask (Fig. 4(c))
6. Use backside exposure to pattern the backside of the silicon according to the sixth mask (Fig. 4(d))
7. Etch the backside of the silicon using KOH with a p+ epilayer as an etch stop (Fig. 4(e))
8. Release the cantilevers with a selective frontside RIE (Fig. 4(f))





Silicon | Piezoelectric cantilever | Magnetic proof mass | Metal interconnects

Figure 3: (Left) 3D view of the entire sensor array (15 x 5). The columns, left facing and right facing cantilevers, are individually addressed and the unconnected terminals (top and bottom corners) are ground. The ground interconnects are not shown to not simplify the image. (Right) 3D close up view of the cantilevers, which are connected in series on each column.

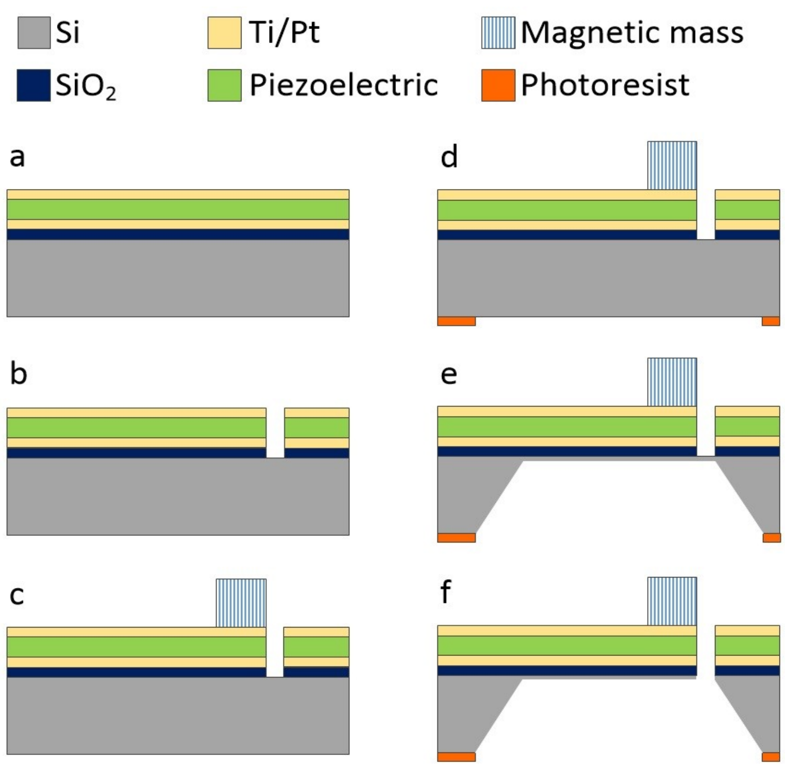


Figure 4: Magnetic cantilever fabrication. The patterning associated with steps 1-3 of the process described in the text are not shown due to image complexity and are represented by (a)

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Dr. Yoon has direct experience in the development of MEMS resonator based magnetic sensors [1-3], and strong expertise in microfabrication [25], piezoelectric [4], ferroelectric [5-7], ferromagnetic [8,9], and multiferroic devices [10,11].

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