

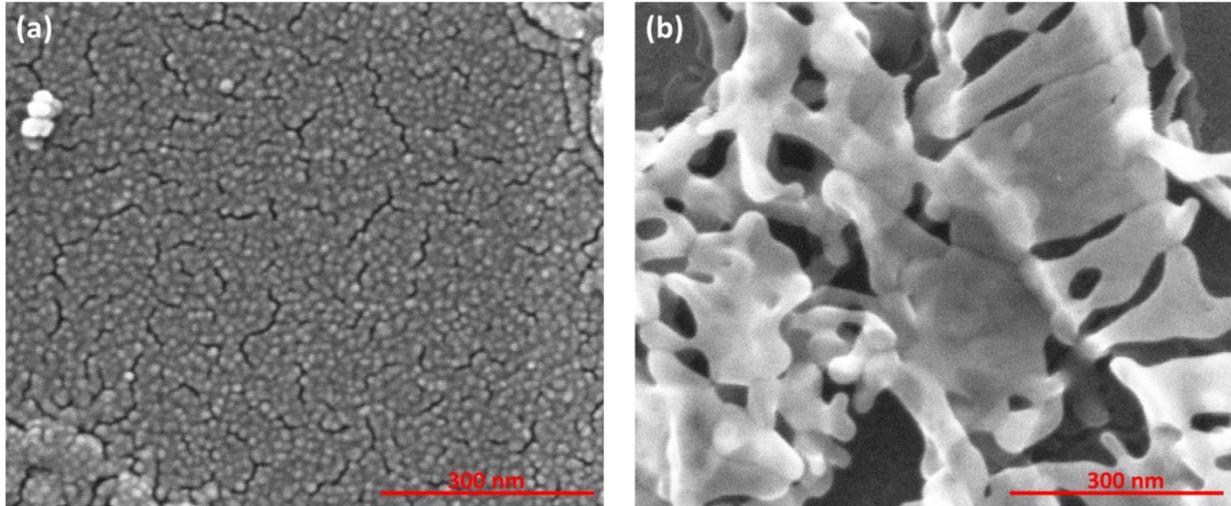
## Supplemental Materials

### 1. Materials characterizations

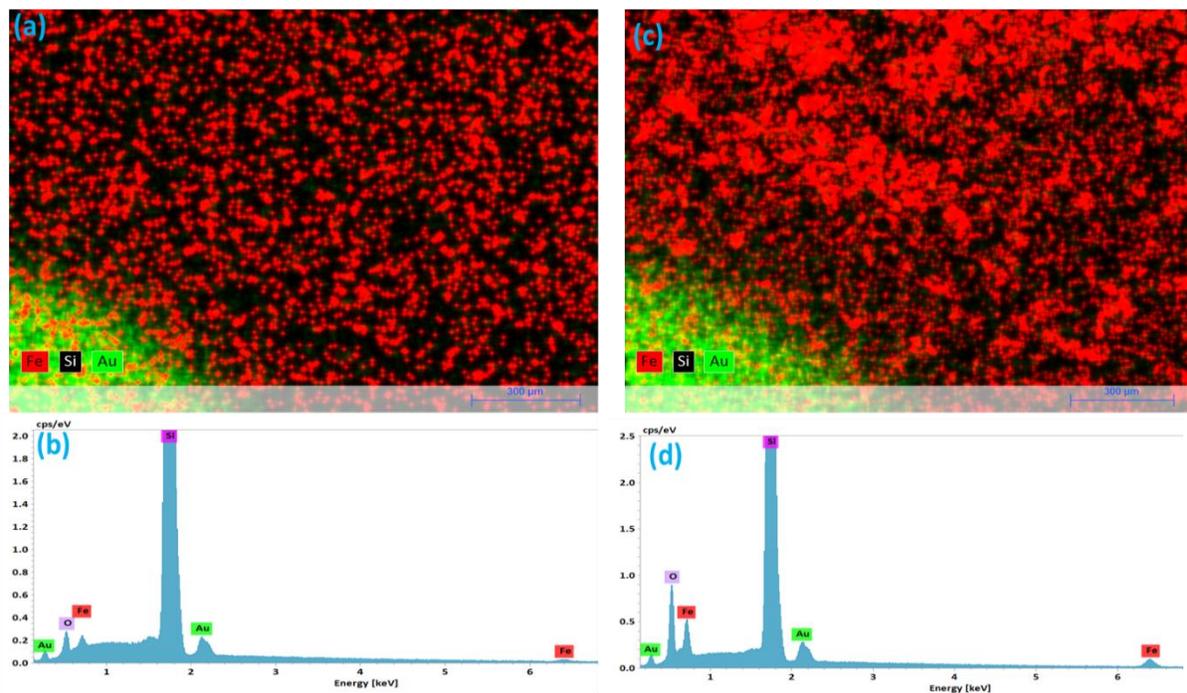
The morphology of the Fe<sub>2</sub>O<sub>3</sub> thin films are studied using FEI Scanning Electron Microscopy (SEM). The overall distribution of  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> in the samples and the concentrations of Fe, Au, Si are mapped on the sample by using Energy Dispersive X-ray Spectroscopy (EDX) (Bruker Nano Berlin, Germany) with primary energy of 10 keV, take off and azimuth angles of 35° and 45° respectively. To characterize the phase of  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> thin film, Raman spectroscopy was done with a WITec alpha 300R Raman microscope, equipped with a 532 nm laser. Raman spectrum was collected using a 100× objective lens of 0.9 numerical aperture, 600 lines/mm grating, and 100  $\mu$ m confocal aperture (fiber) diameter.

### 2. Results and Discussions

SEM micrographs show overall morphology of the two samples prepared using 28 mM and 141 mM solutions in fig. 1(a) and 1(b) respectively. In the sample prepared from 28 mM solution, the thin film has uniform distribution of materials with average void size of <15nm whereas the sample from 141 mM solution has non uniform and bulk crystals with size averaging 175 nm. The sample consists of gold spots as an electrical contact, Si as substrate, and  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> microcrystalline particles in green, black and red colors respectively in fig. 2. Fig. 2 (a) shows the elemental mapping of the sample prepared by using a 28 mM solution and fig. 2(b) for sample from 140 mM solutions. Samples prepared using 28 mM solutions have thinner  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> thin film distributed on the Si substrate whereas the samples prepared using 141 mM solutions have a thicker distribution of  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> thin film.



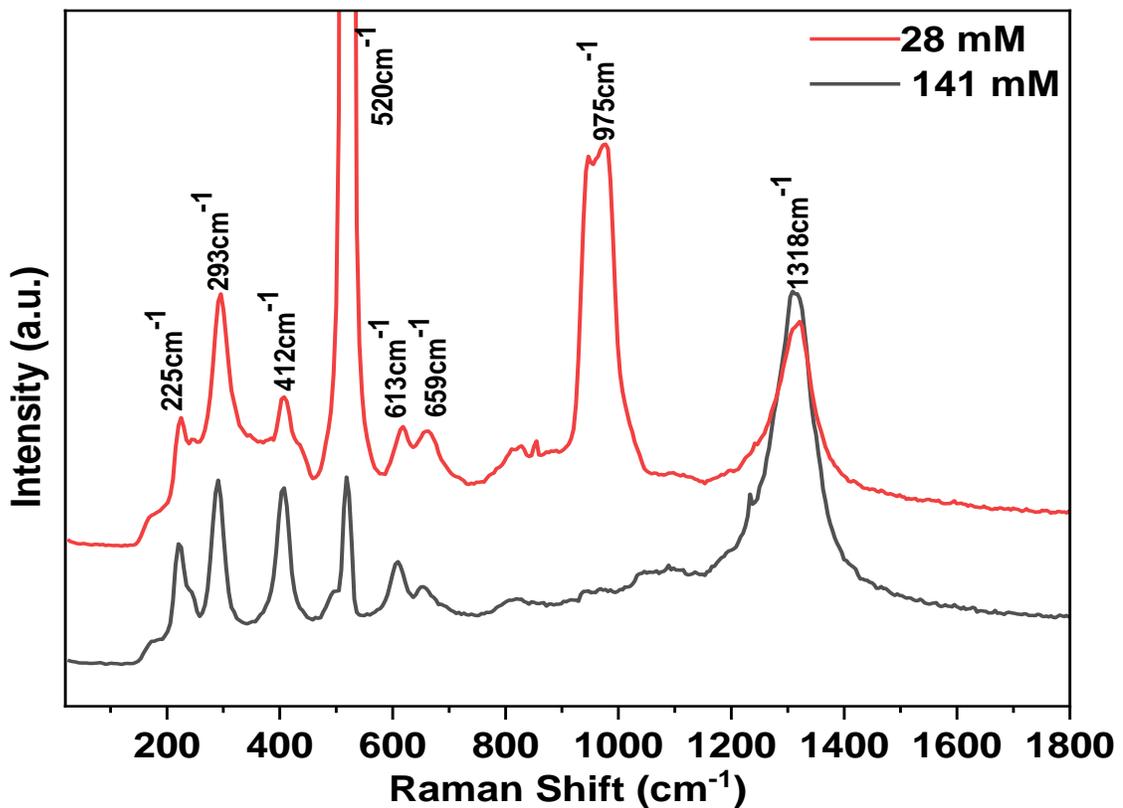
**Figure S1:** SEM micrographs for sample prepared using (a) 28 mM and (b) 141 mM solutions shows variation of the bulk size.



**Figure S2:** (a) EDX mapping of elements and (b) EDX spectra for sample prepared using 28 mM. (c) EDX mapping of elements and (d) EDX spectra for samples prepared using 141 mM solutions. Higher intensity of Fe peak in (d) shows the increased bulk size in the samples.

Raman spectroscopy of the samples in Fig. 3 confirms the presence of  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> on the p-Si substrate. The signature peaks for the  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> A<sub>1g</sub> mode (225 cm<sup>-1</sup>) and E<sub>g</sub> modes ( 293

$\text{cm}^{-1}$ ,  $412 \text{ cm}^{-1}$ ,  $613 \text{ cm}^{-1}$ ) are observed [1], [2] whereas the peak at  $659 \text{ cm}^{-1}$  may possibly be due to the disorder [3]. The prominent peak at  $1318 \text{ cm}^{-1}$  corresponds to an  $\alpha\text{-Fe}_2\text{O}_3$  (Hematite) two magnon scattering which is not expected in other forms of iron oxides (Magnetite, Maghemite, etc.) [4]. The peaks at  $520 \text{ cm}^{-1}$  and  $975 \text{ cm}^{-1}$  correspond to the scattering of first-order optical phonon and two transverse optical phonons in c-Si [5]. In Fig. 3, the intensity of Si peaks in the case of concentrated samples are reduced due to the higher thickness of  $\alpha\text{-Fe}_2\text{O}_3$  thin film on the p-Si substrate which is expected for the samples prepared using 141 mM solution. For the study of synaptic potentiation, the samples prepared from 141 mM solution was used.



**Figure S3:** Raman Spectroscopy of the samples prepared using the 28 mM and 141 mM solutions. Peaks that are the signatures of  $\alpha\text{-Fe}_2\text{O}_3$  and Si were observed.

## References

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