Magnetic and structural properties of the Fe$_{5-x}$Si$_x$Ge$_x$B$_2$ system

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Materials with magnetic properties are already known to have numerous applications including perhaps most notably, energy conversion. Many of the currently used materials utilise rare earth elements which pose some concerns for both their sustainability and cost. Rare earth free magnets could provide a solution to these issues, but further research is needed to develop and gain a full understanding of these materials. One example of a rare earth free magnetic material is Fe$_5$SiB$_2$ which adopts a tetragonal I$4/mcm$ space group (Figure 1) and is ferromagnetic below 760 K. The compound has a saturation magnetisation $M_S$ larger than 1 MA/m, a magnetocrystalline anisotropy (MAE) of 0.30 MJ/m$^3$ at 300 K and undergoes a spin reorientation at 172 K.[1] Whilst the compound has the high Curie temperature $T_C$ and saturation magnetisation $M_S$ required, the magnetocrystalline anisotropy (MAE) is too low for most applications. Research has aimed to increase the MAE whilst maintaining the high $T_C$ and $M_S$ required. There are several existing studies on the effects of P, S, and Co doping with varying results, whilst Fe$_{5-x}$Si$_{0.75}$Ge$_{0.25}$B$_2$ has been previously reported, the Fe$_{5-x}$Si$_x$Ge$_x$B$_2$ system has yet to be fully explored.[2,3] In this study, the Fe$_{5-x}$Si$_x$Ge$_x$B$_2$ system is explored and the structure and properties of the first 4 compounds where $X = 0.05, 0.10, 0.15$ and 0.20 have been investigated in detail using a combination of powder X-ray diffraction and magnetometry (Figure 1).[4]

![Figure 1](image-url)  
**Figure 1.** a) crystal structure of Fe$_{5-x}$Si$_x$Ge$_x$B$_2$ b) unit cell parameters of Fe$_{5-x}$Si$_x$Ge$_x$B$_2$ c) magnetisation versus Ge content of Fe$_{5-x}$Si$_x$Ge$_x$B$_2$.


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