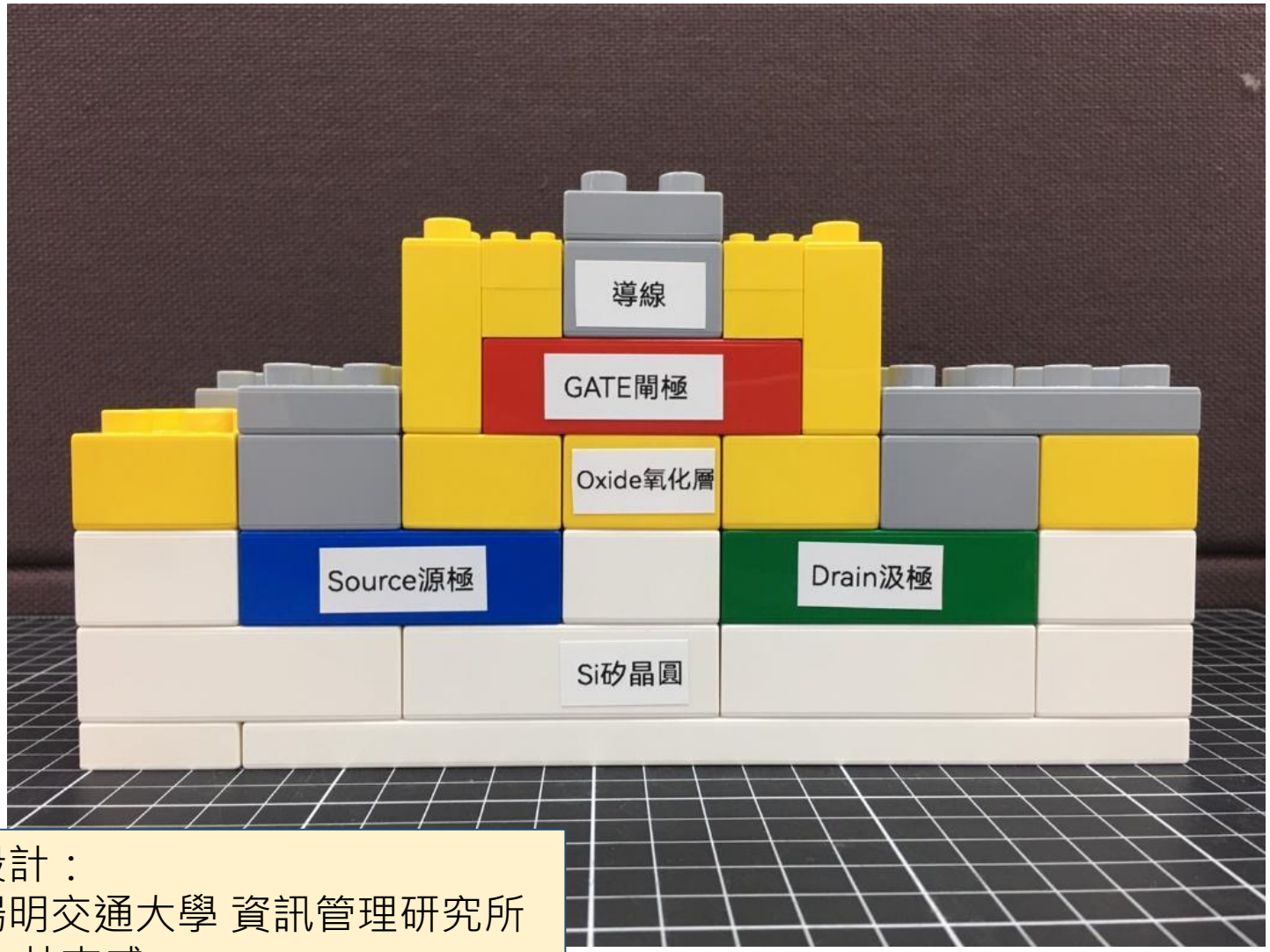
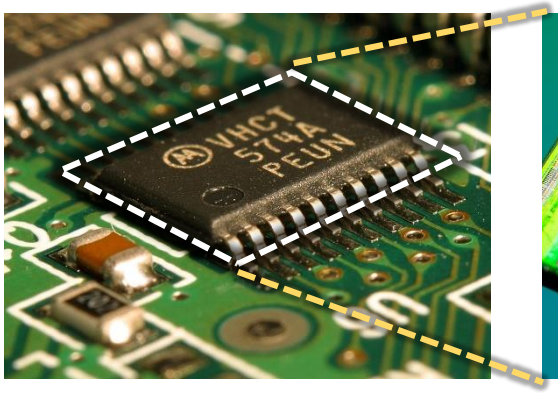
用樂高積木介紹半導體製程



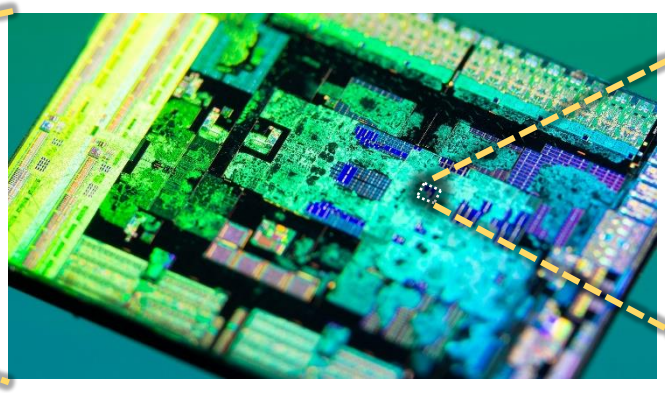
教材設計：
國立陽明交通大學 資訊管理研究所
研究生 林志威

電晶體簡介

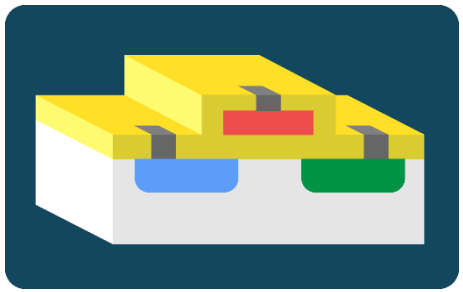
- 電晶體是積體電路(IC)等器件的基本組成單元。
- 電晶體有兩種最主要的作用，可以用來當作開關，也可以用來放大信號。
- 電晶體是用半導體材料(矽等)作出來的電子元件。
- 此講義以場效電晶體作為解說。



積體電路



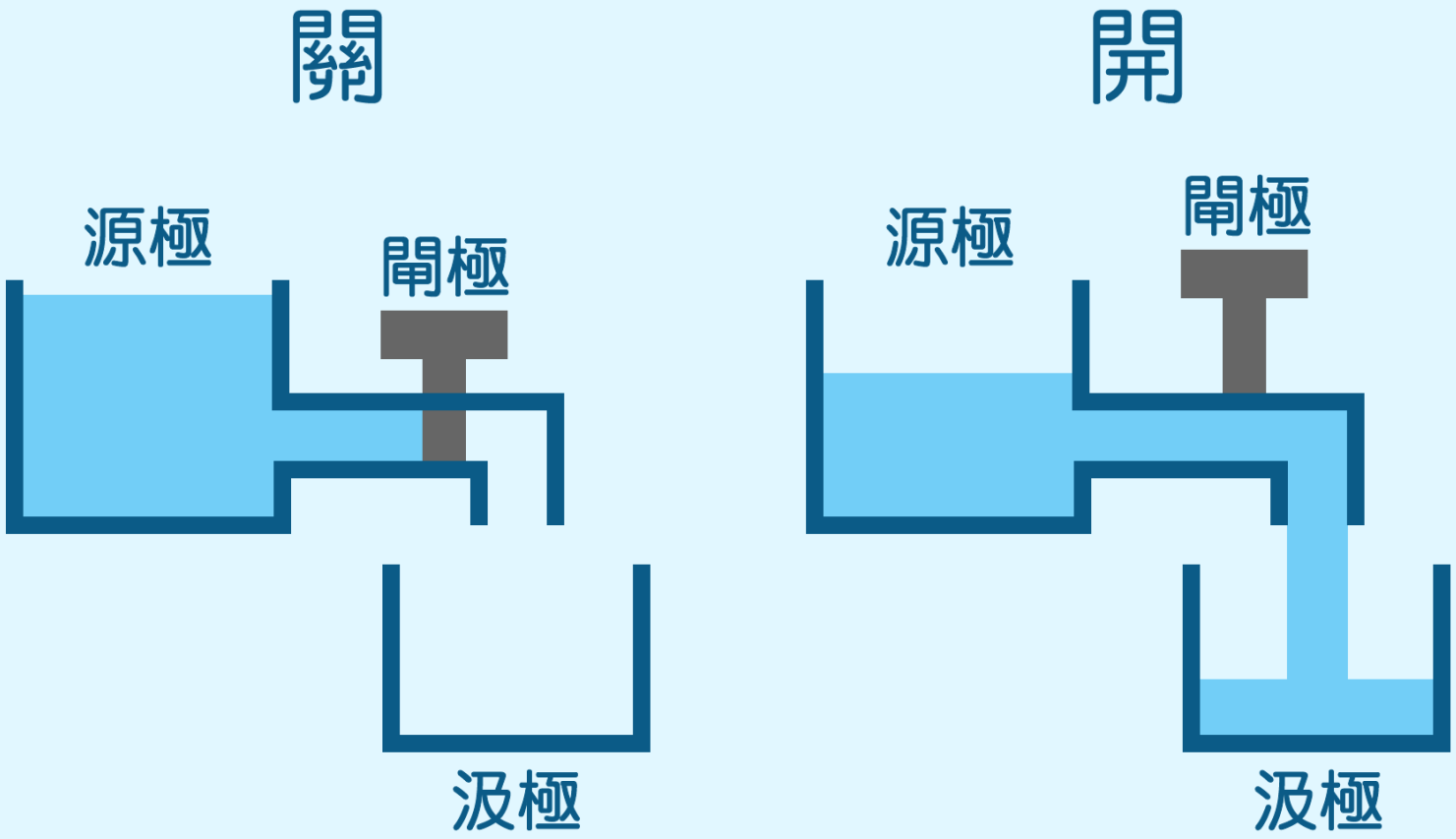
晶片



電晶體

圖片來源：Wikipedia
資料來源：科學研習月刊第50卷

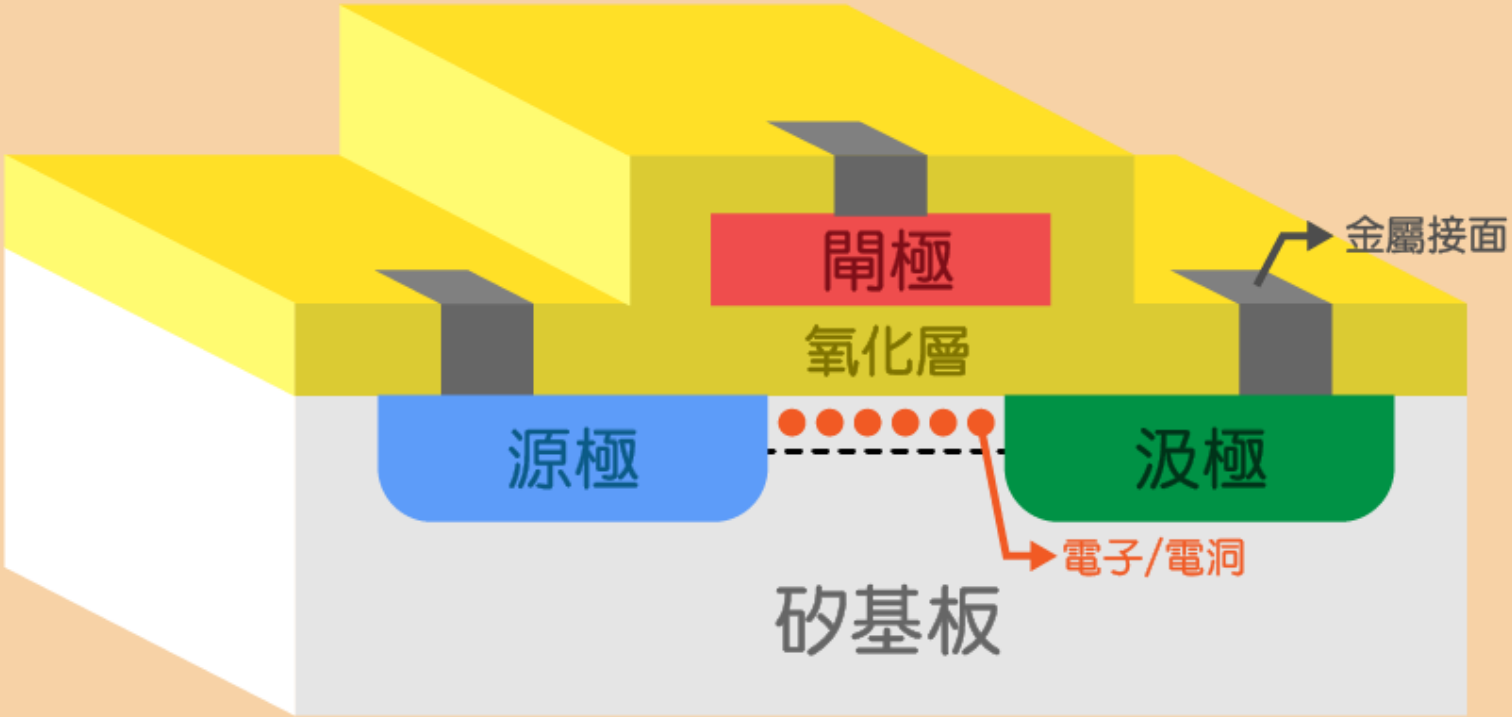
場效電晶體開關原理



製圖：林志威

資料來源：科學研習月刊第50卷

場效電晶體
(Field-Effect Transistor, FET)

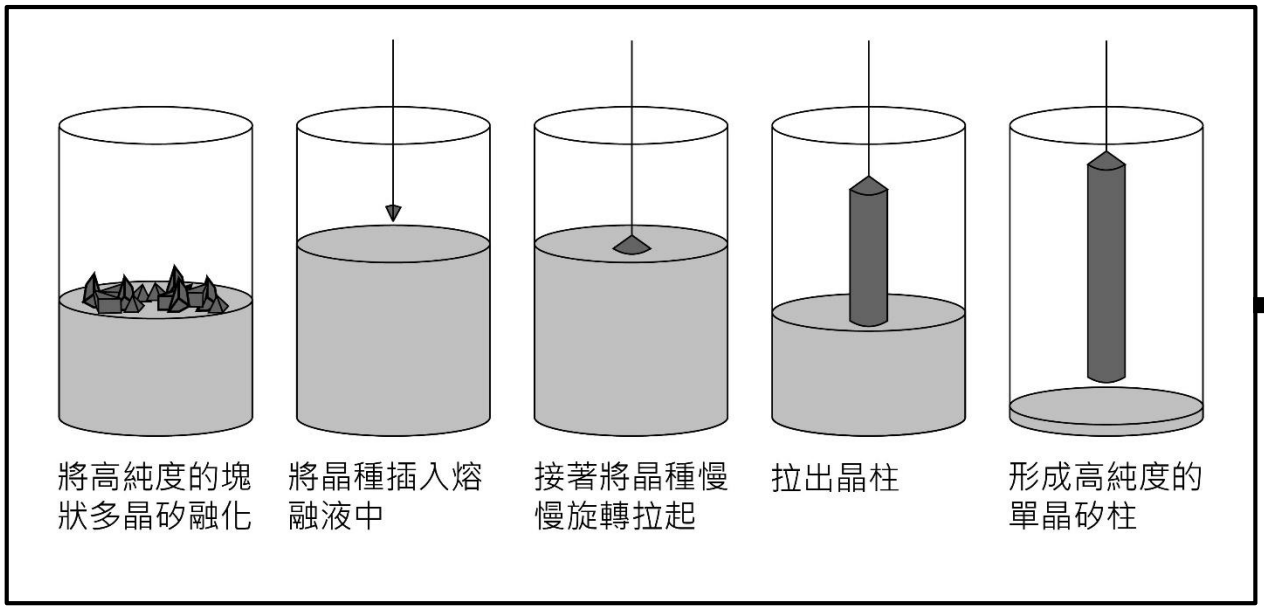


*註：此為簡易版，省略基極

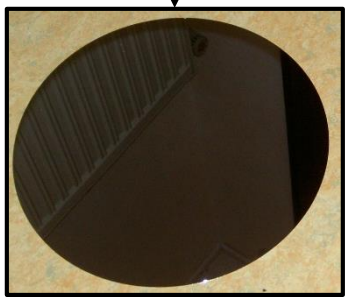
製圖：林志威

資料來源：科學研習月刊第50卷

關於晶圓片的製作

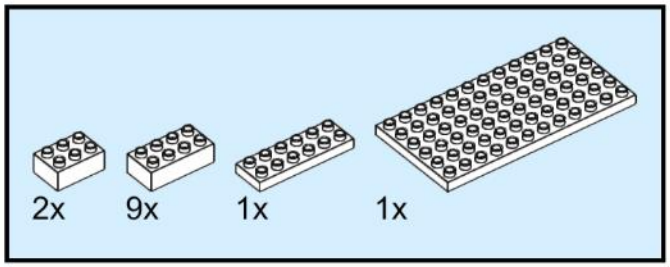


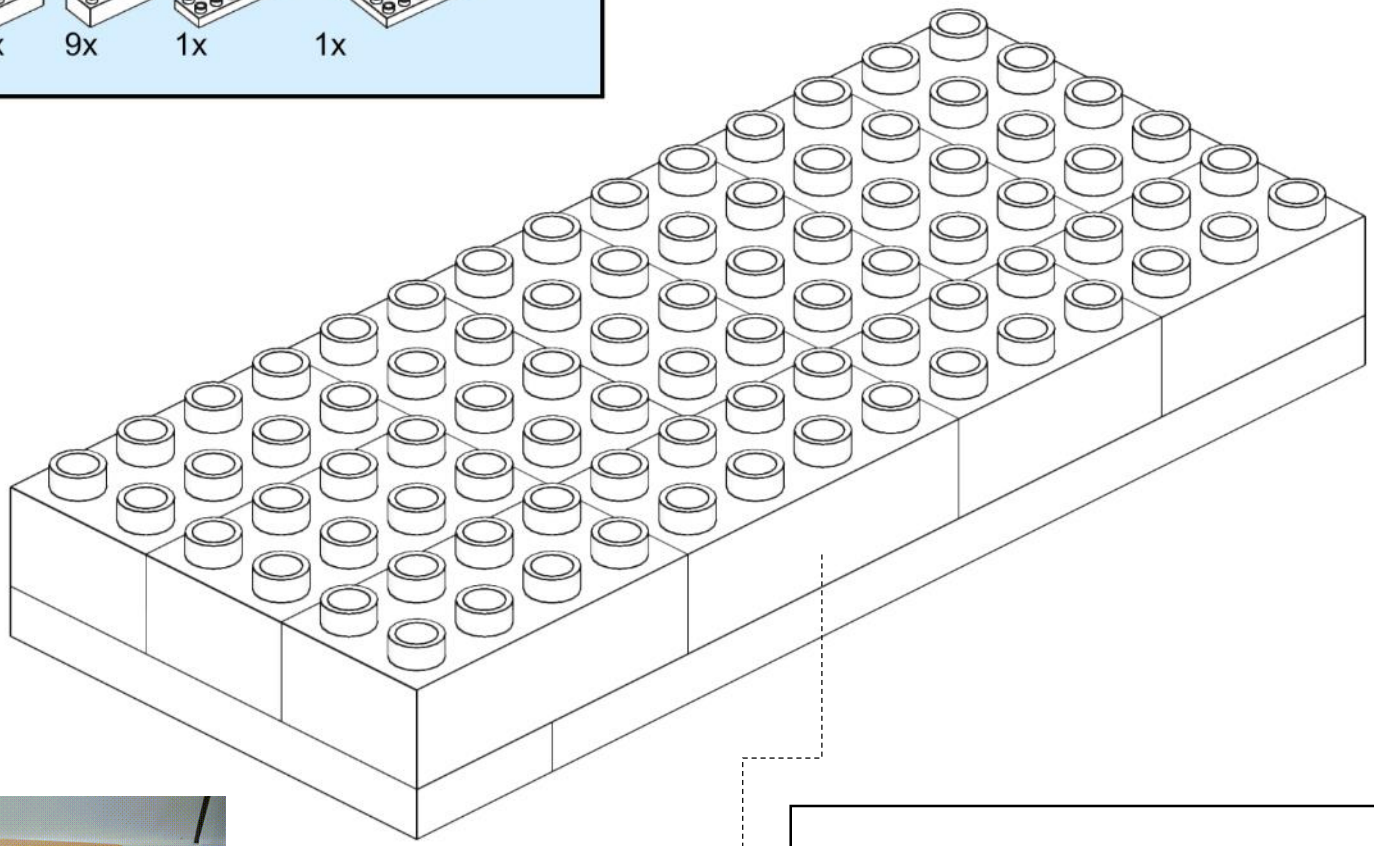
切割、拋光

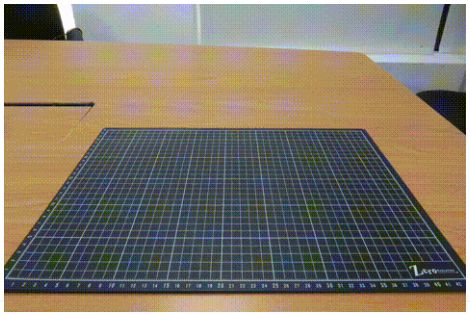


晶圓片

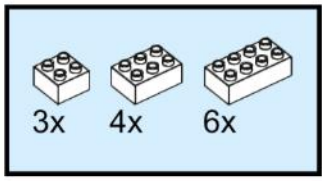
圖片來源：[Wikipedia]

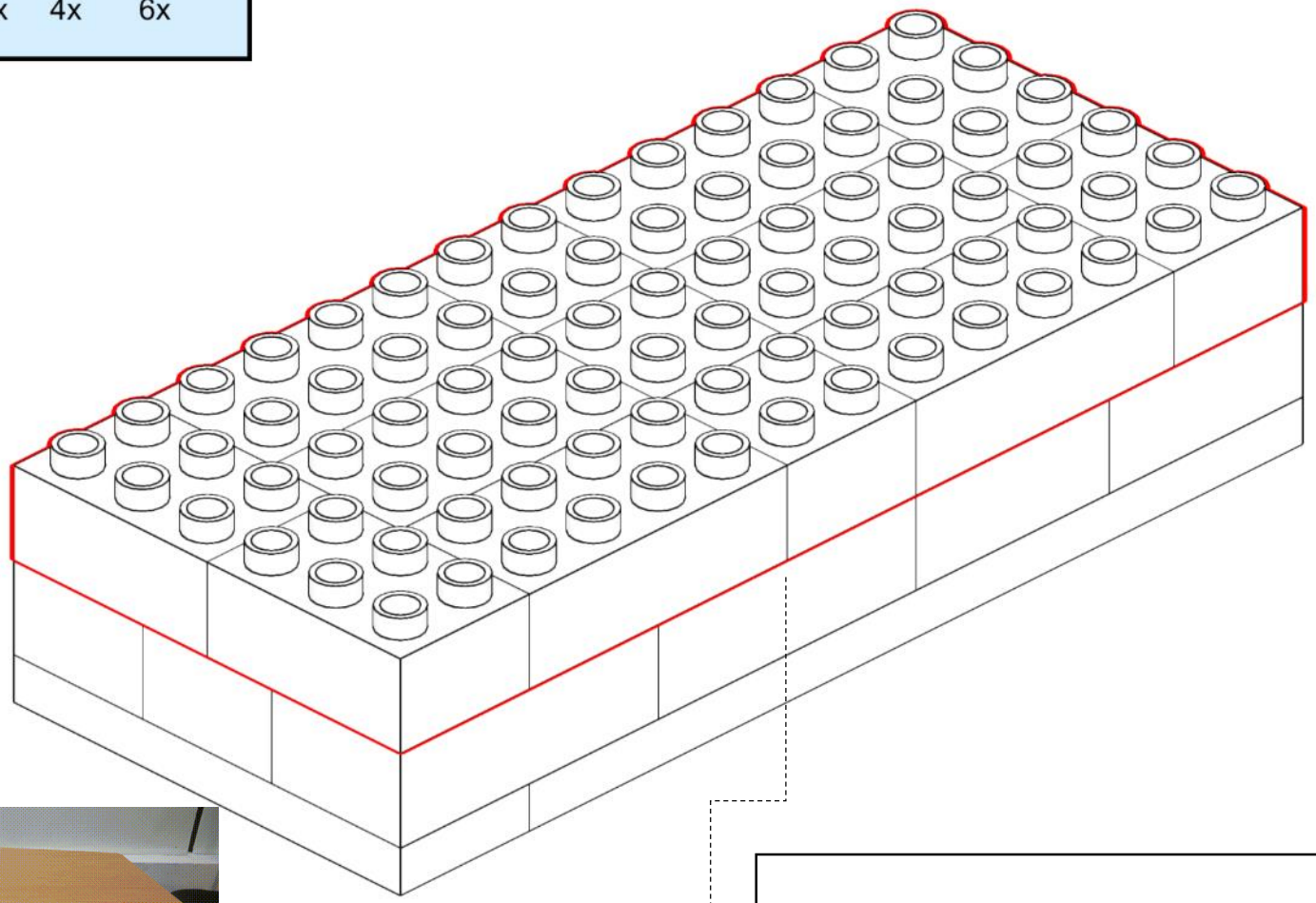


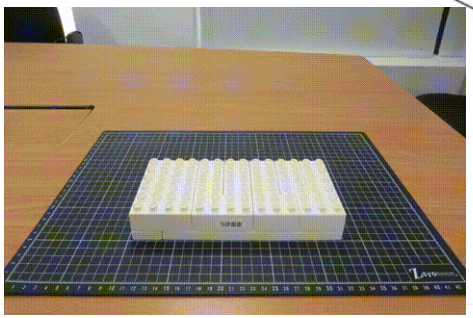




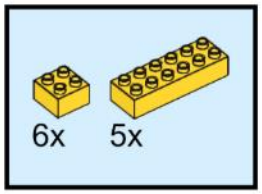
先拼一層白色積木

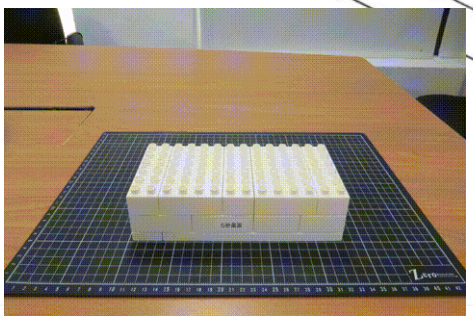




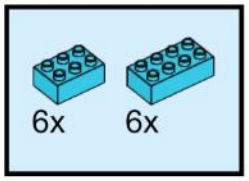


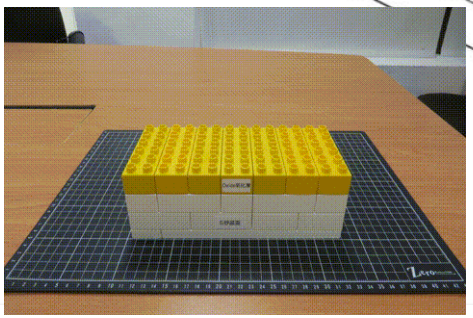
接著再一層白色積木。
白色積木部分為矽晶圓。



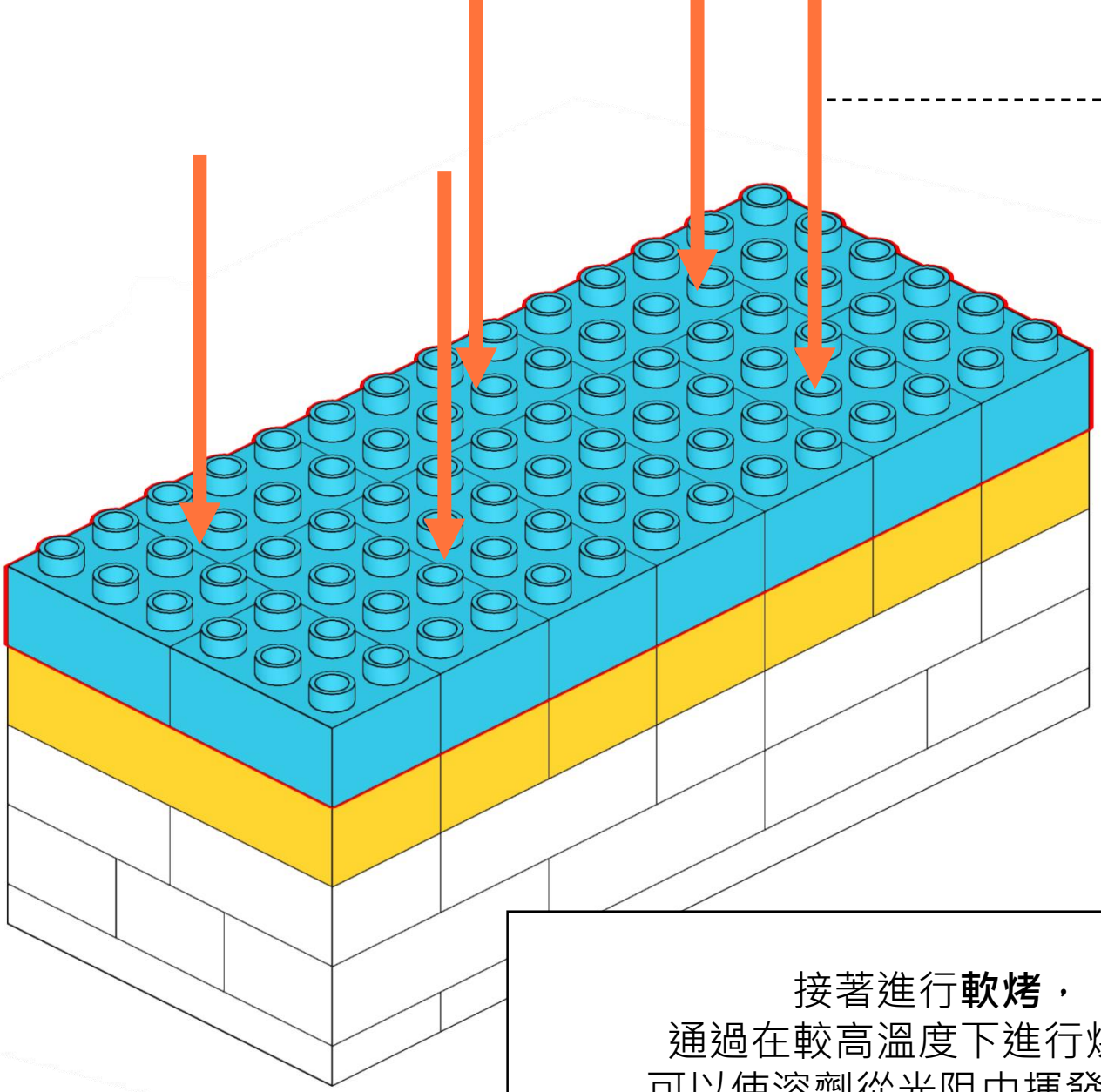


首先，會以高溫烘烤方式，
在表面形成一層絕緣的氧化層(黃色積木)。





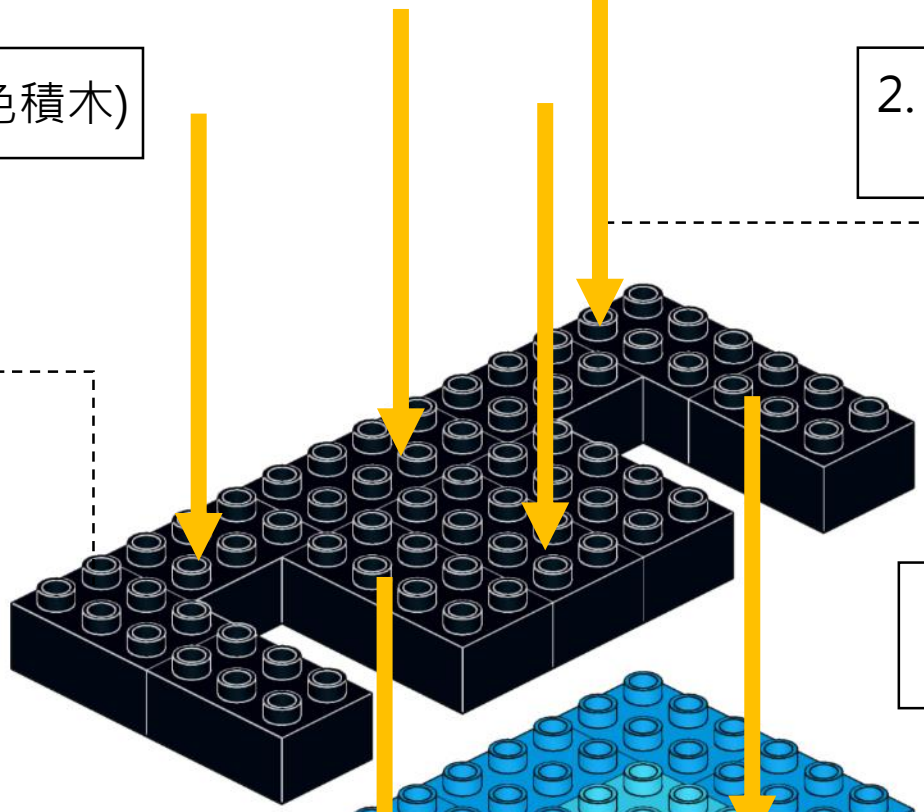
接著我們想將氧化層部分區域去除掉，
先在氧化層上塗抹光阻劑(天藍色積木)。



接著進行**軟烤**，
通過在較高溫度下進行烘烤，
可以使溶劑從光阻中揮發出來，
從而**降低灰塵的沾污**及**提高光阻的附著性**。

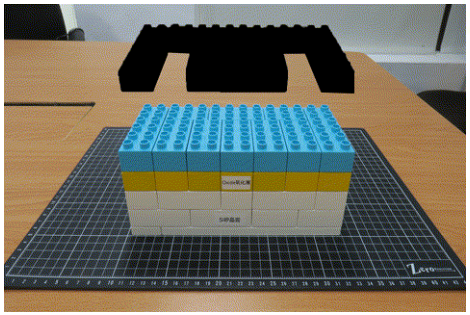
1. 然後放上光罩(黑色積木)

2. 進行曝光(黃色箭頭)
通常為紫外光

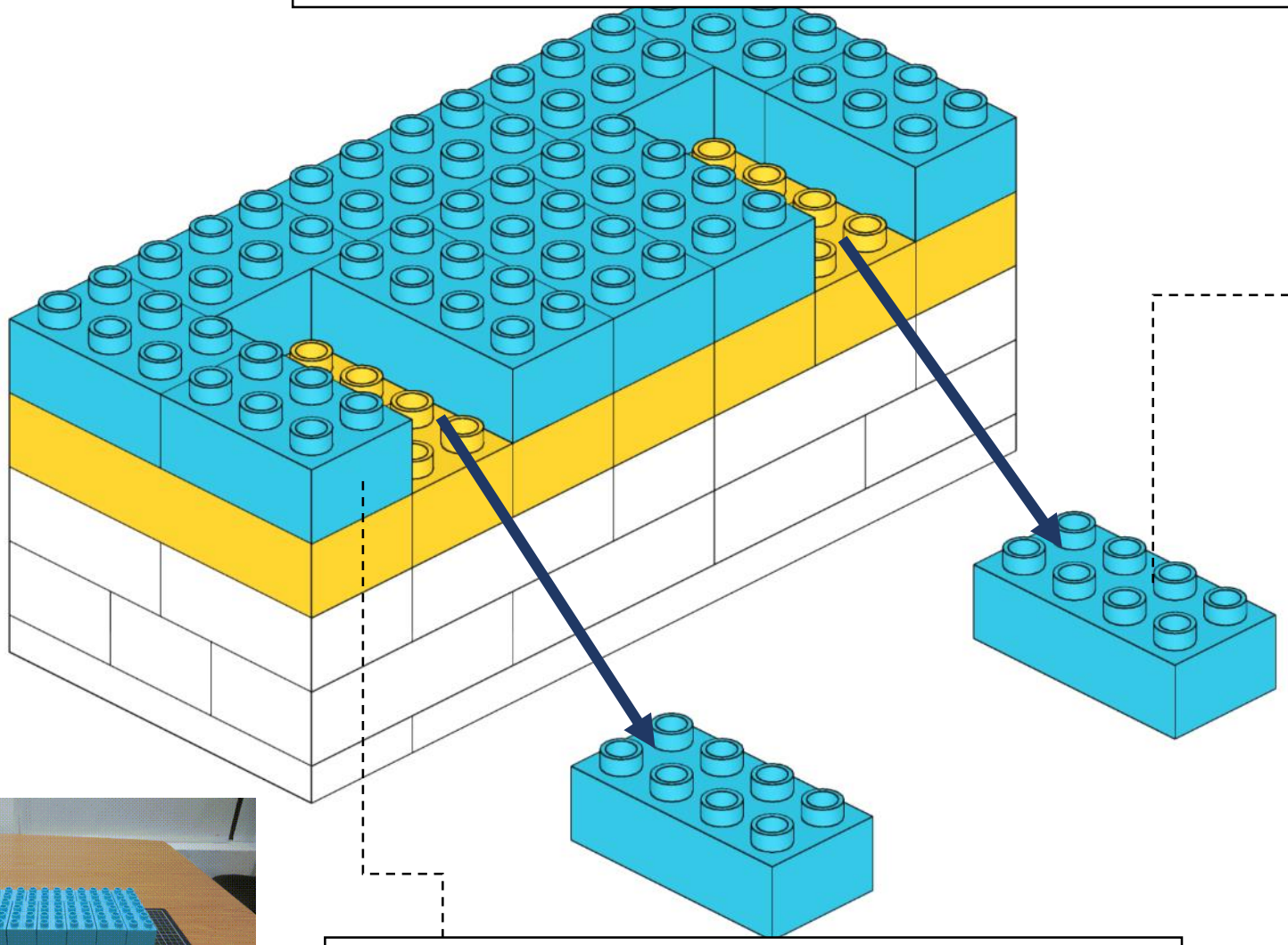


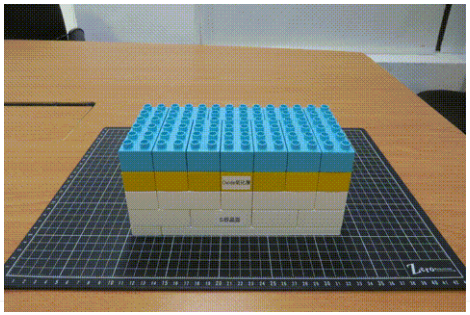
沒被照射到的地方
(深天藍色積木)

被照射到的地方
(藍色積木)

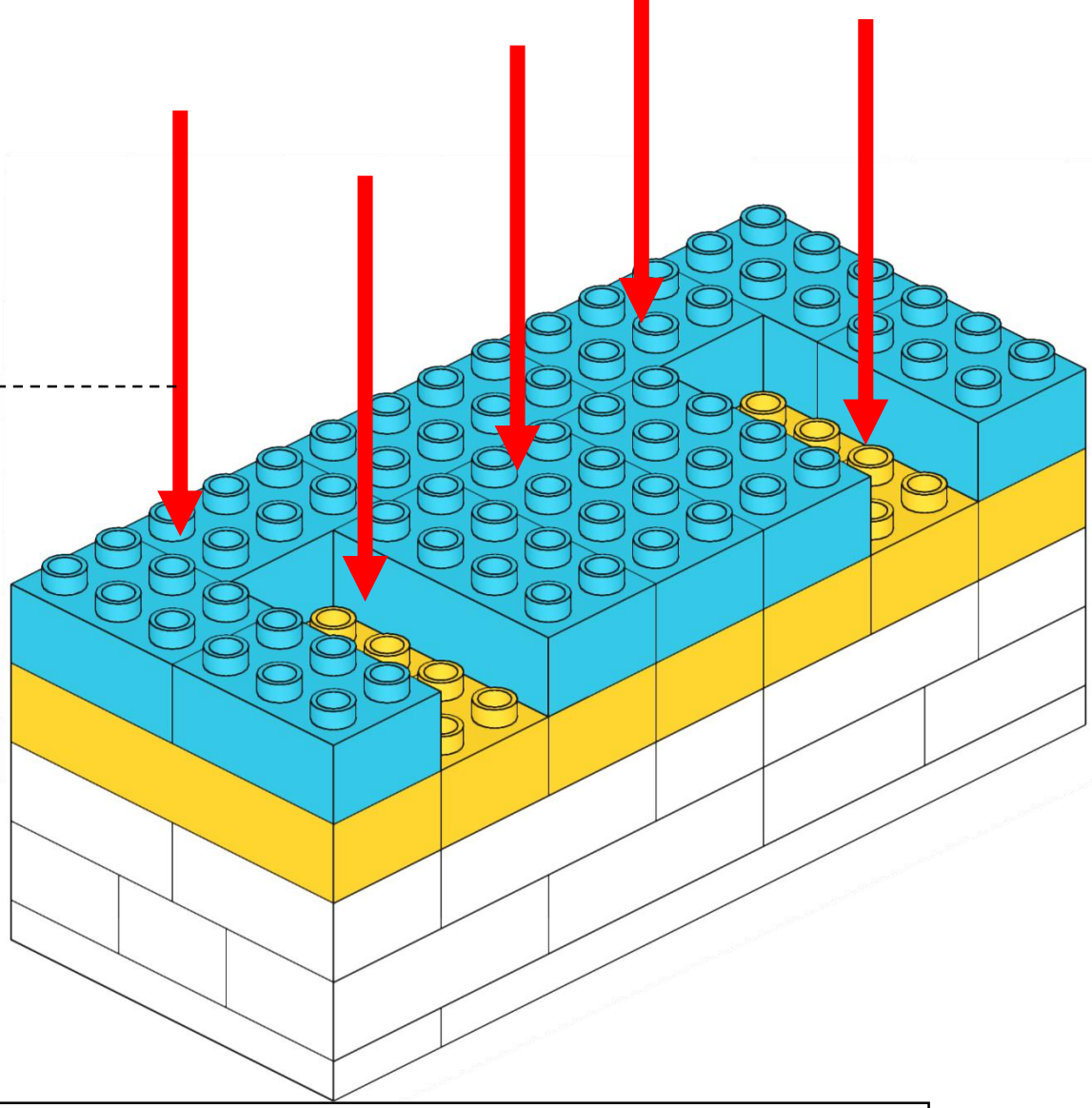


接著是**顯影**，
剛剛被照射到的光阻劑，會因為當中的感光劑發生**光化學反應**，
使光阻劑產生**化學成分變化**，並**溶解於特定的顯影液**。



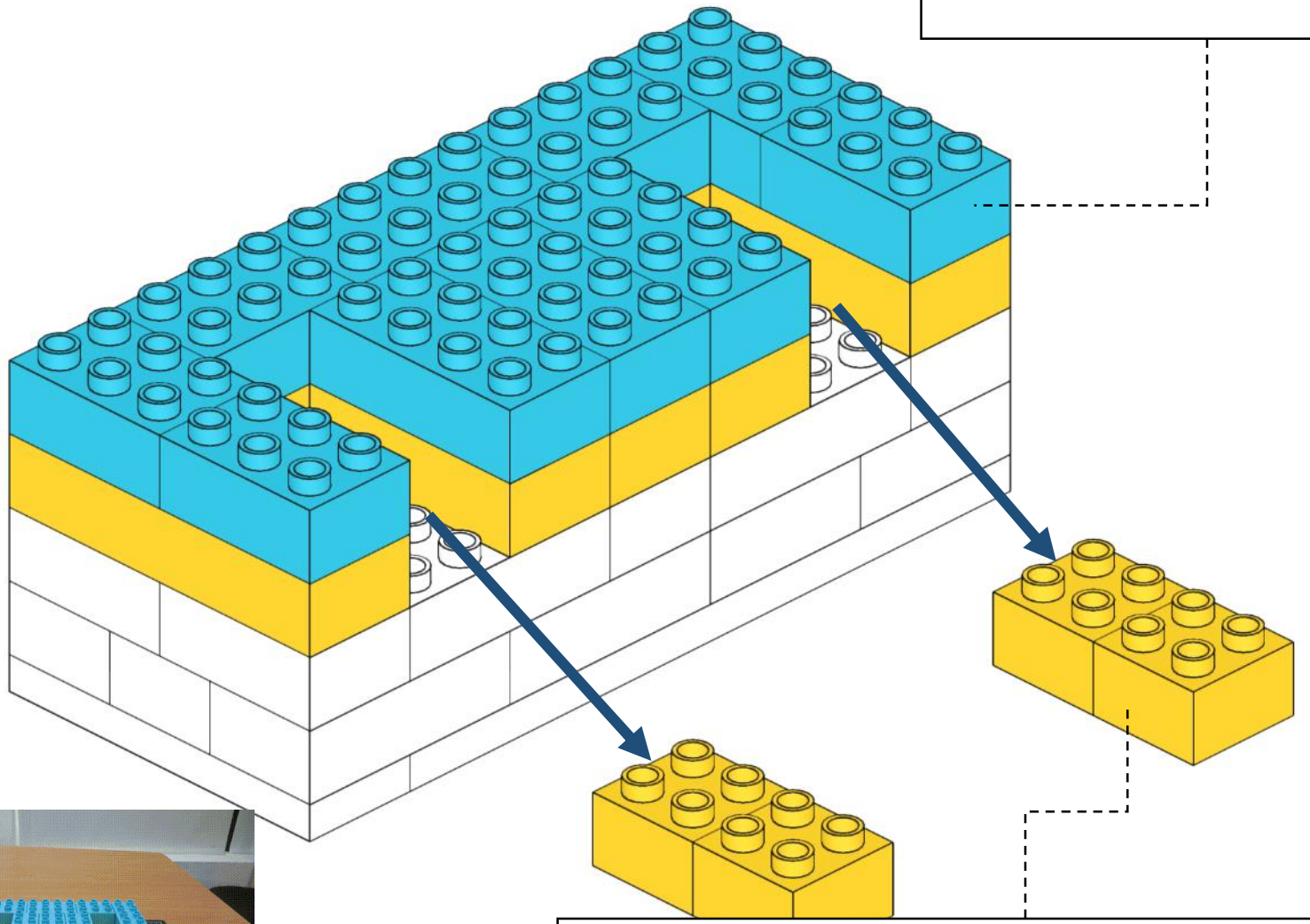


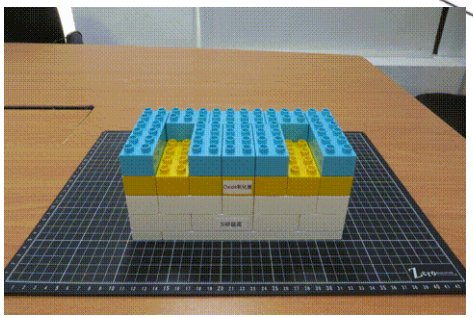
沒被照射到的光阻劑區域，
則不會被顯影液溶解，所以會被保留下來。



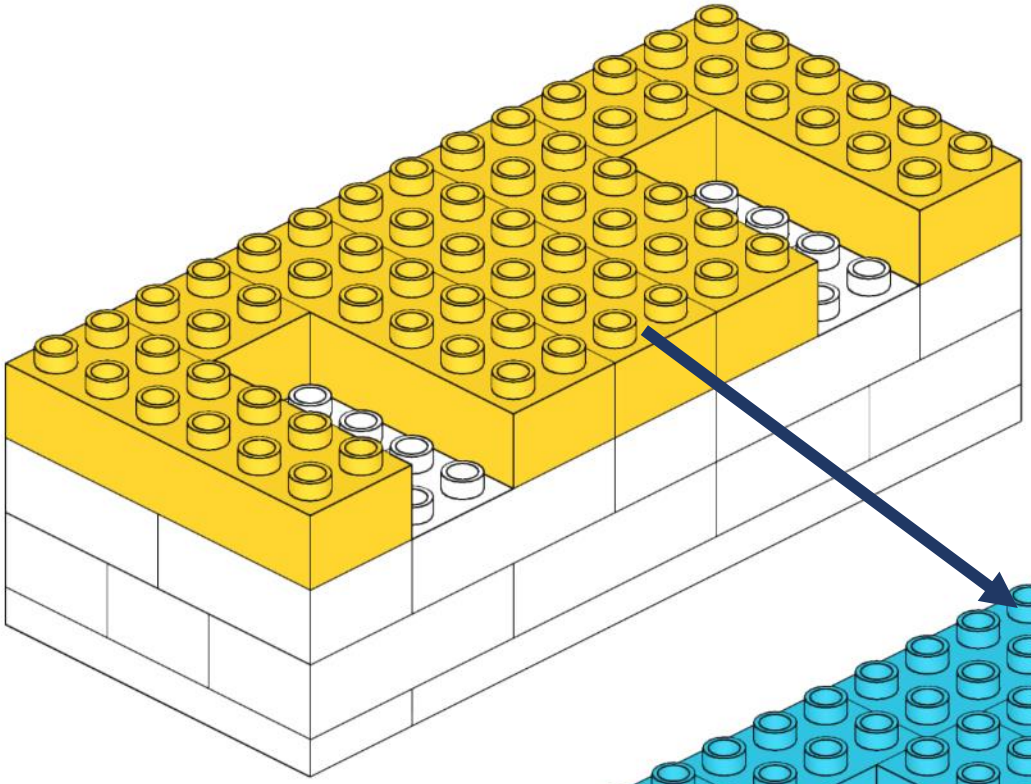
顯影後會進行**硬烤**，使光阻的性質更為穩定。
在這過程中，利用高溫處理，
提高光阻在隨後**蝕刻**和**摻雜**過程中的**抗蝕性能力**。

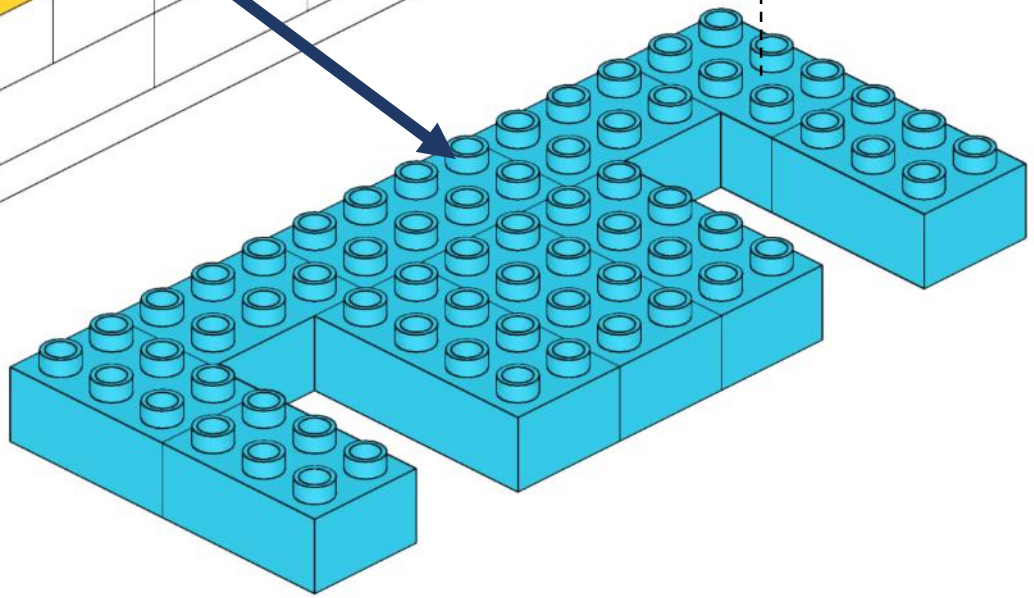
上層還有光阻的
氧化層不會被蝕刻到。



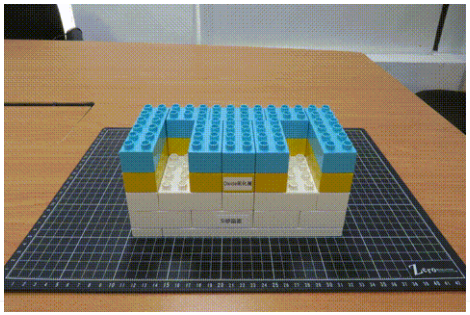


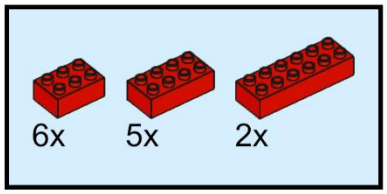
接著是**蝕刻**，
蝕刻有分濕式蝕刻及乾式(電漿)蝕刻，
都是**利用化學反應的方式來削除下方的氧化層。**

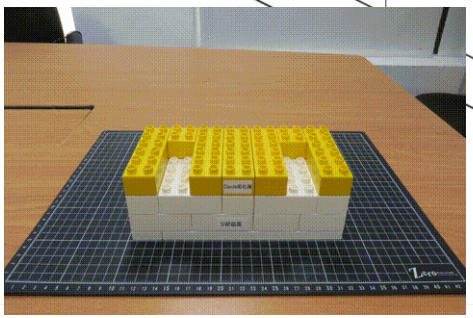




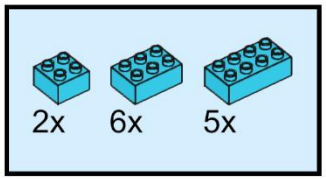
接著透過溶劑或是電漿，
去除(剝離)剩餘的光阻

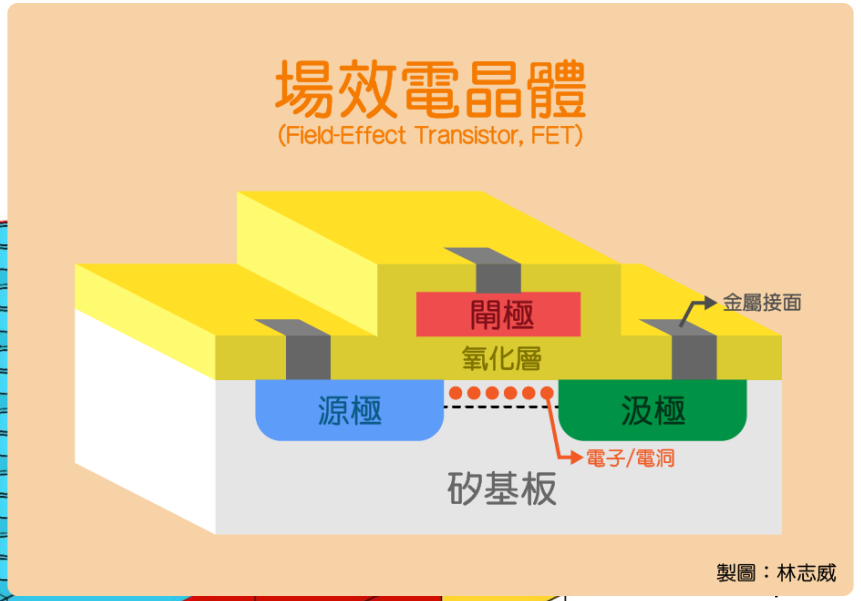


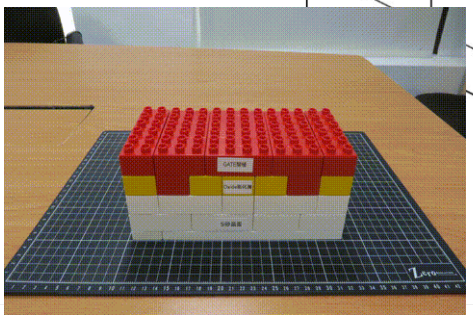




接著是**沉積**，
將導電多晶矽(紅色積木)，
沉積在表面。

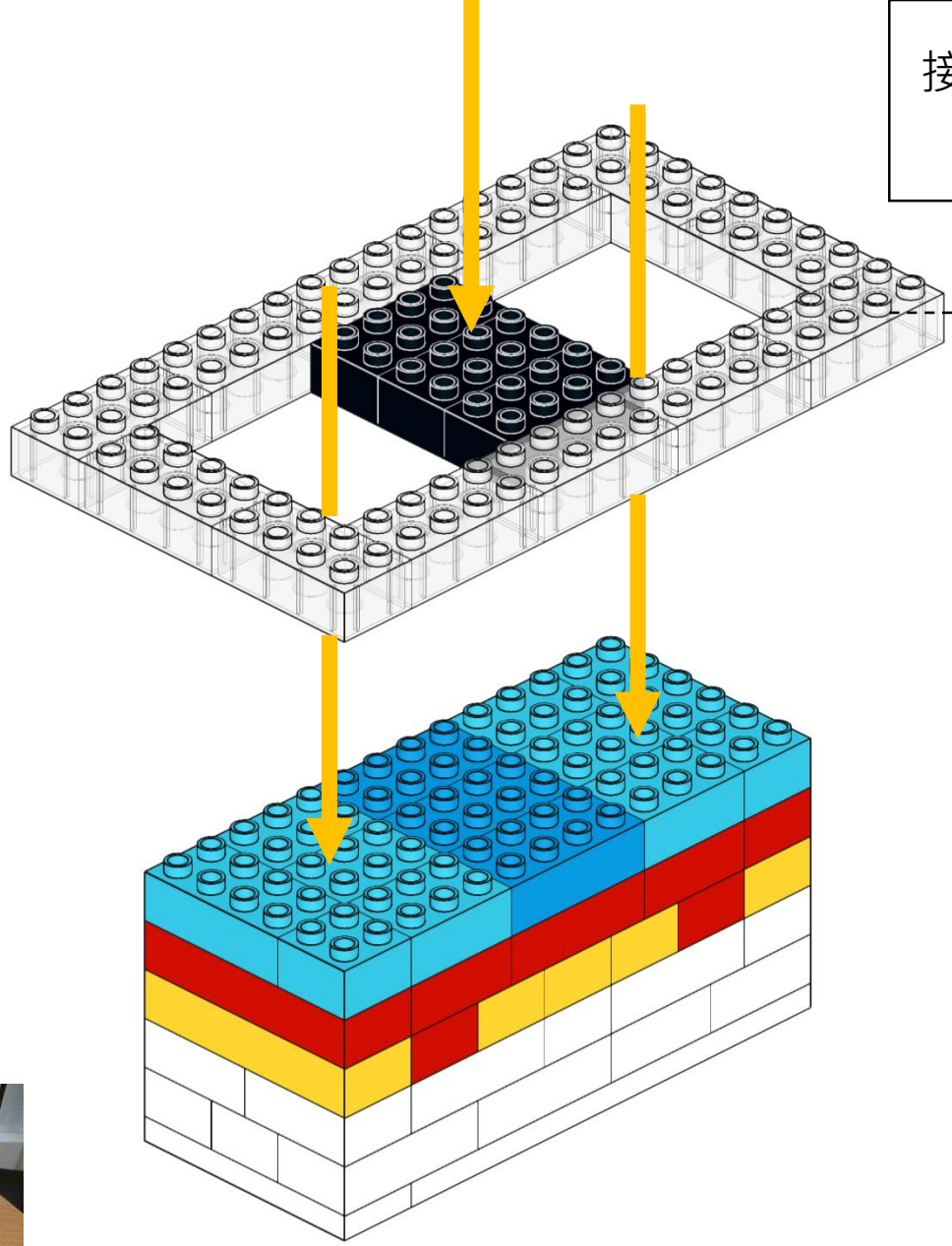


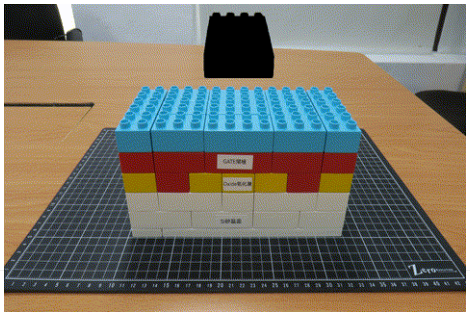


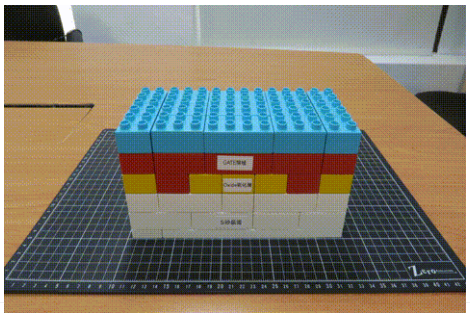


一樣塗抹光阻劑(天藍色積木)，並進**軟烤**。
而我們只需要中間部分的導電多晶矽來做為閘極(Gate)，
所以需要將旁邊多餘的部分去除。

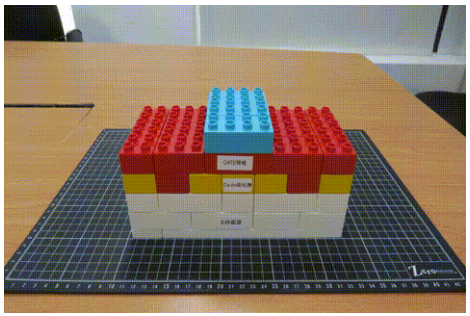
接著一樣裝上光罩後，
進行**曝光**。



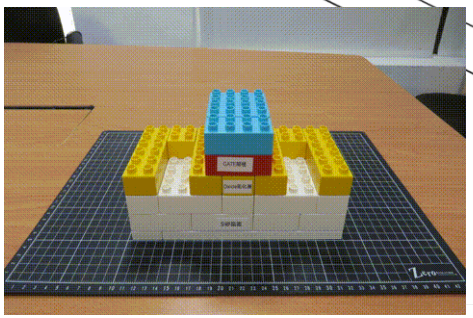




曝光到的光阻會被顯影液沖洗掉，
並進行**硬烤**。

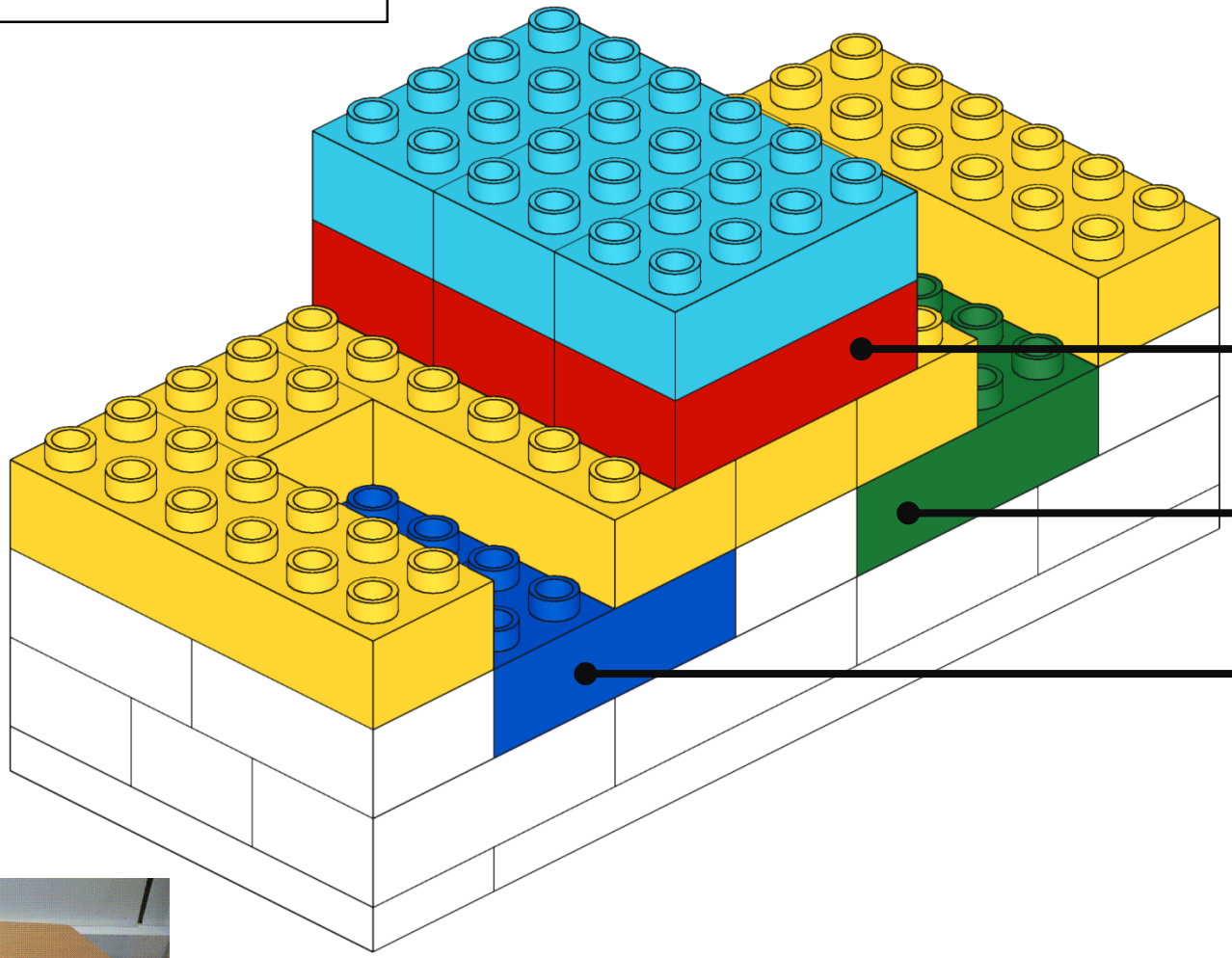


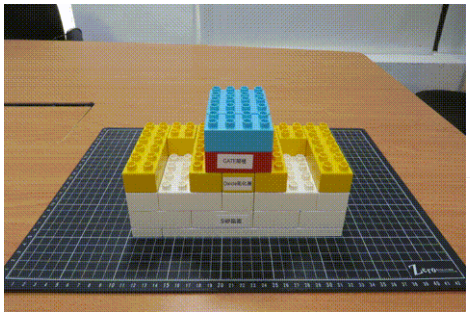
將旁邊的導電多晶矽**蝕刻**掉。
而上層有光阻的會被保留下來。



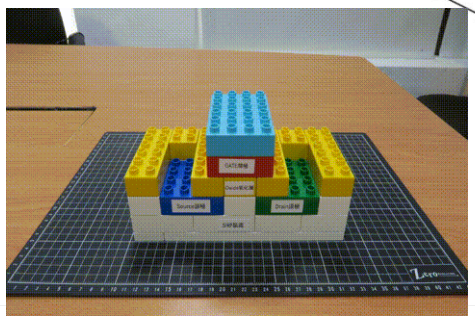
接著是**摻雜**，
將硼或磷離子(電活性雜質原子，藍色箭頭)植入基底，
使被植入的部分形成半導體元件。
有離子植入法跟擴散法。

完成**摻雜(擴散法)**後的示意圖

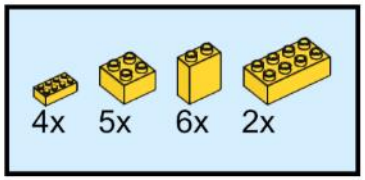


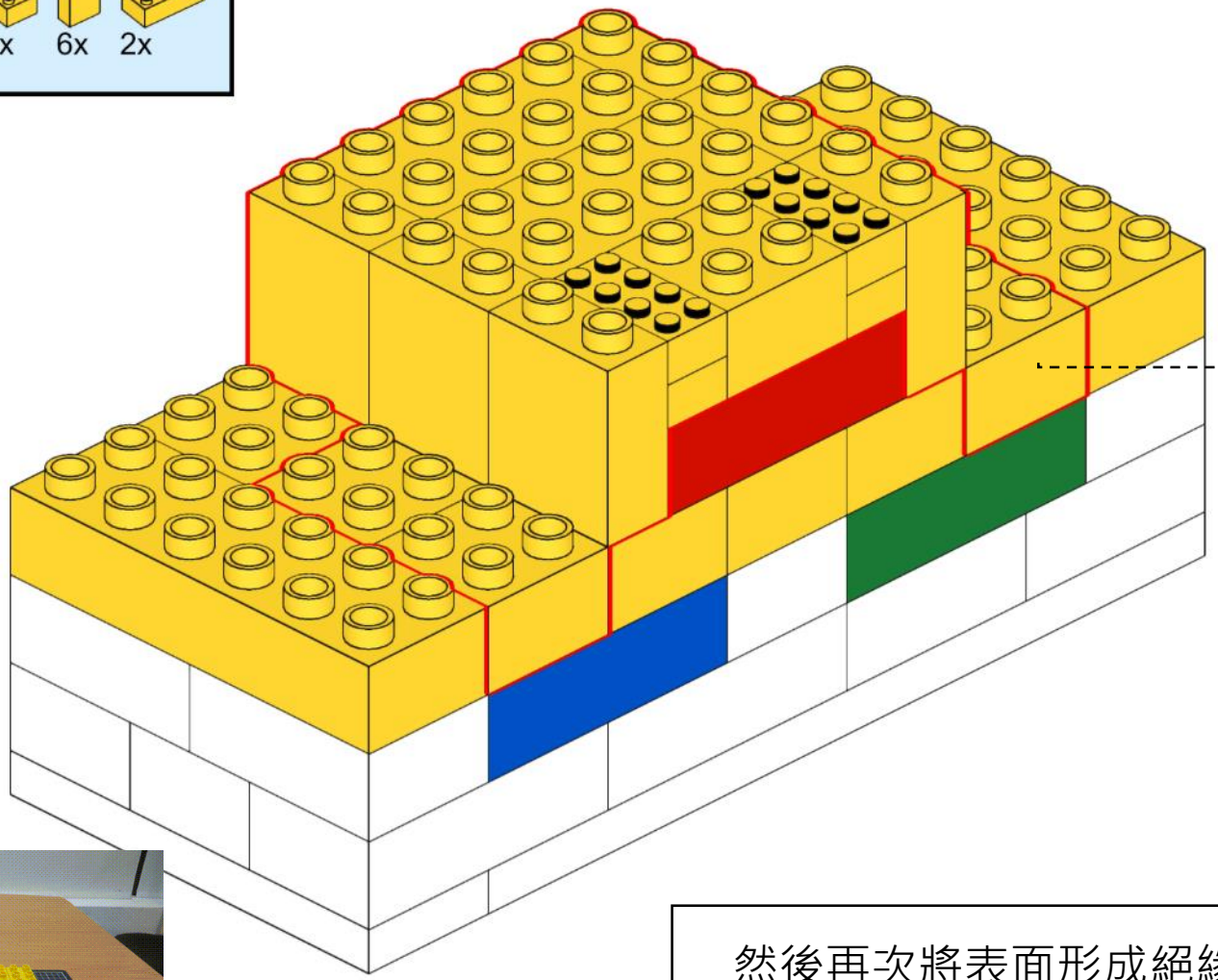


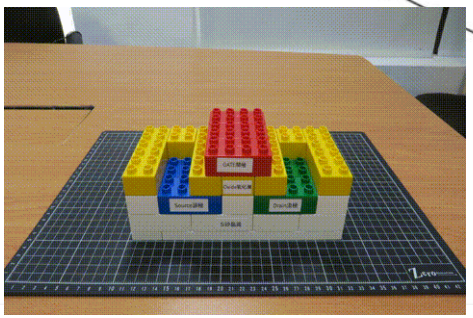
完成後會有三個極性：
閘極（Gate）、汲極（Drain）、源極（Source）。



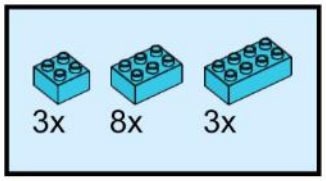
接著一樣把剩餘的光阻劑去除。

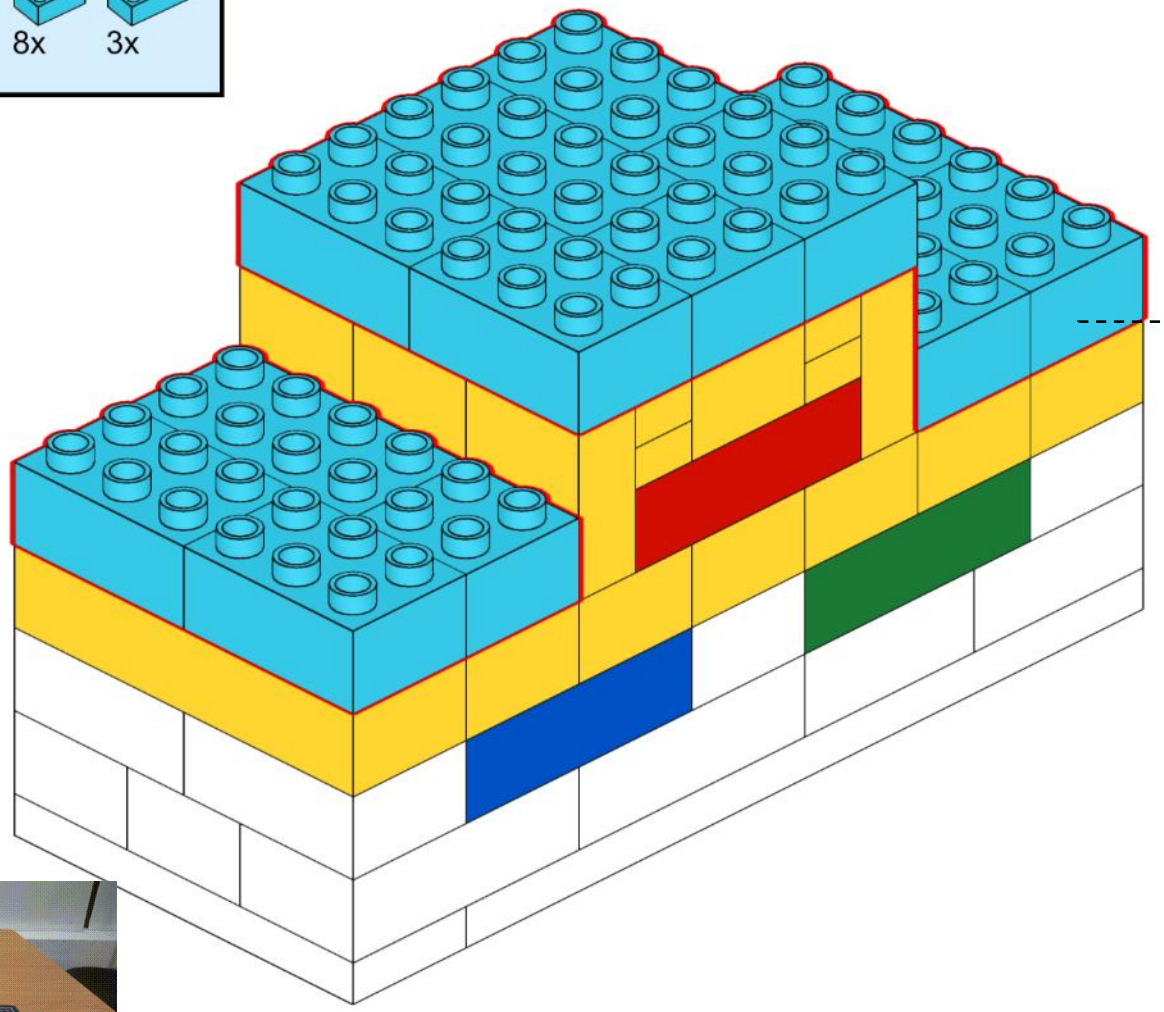


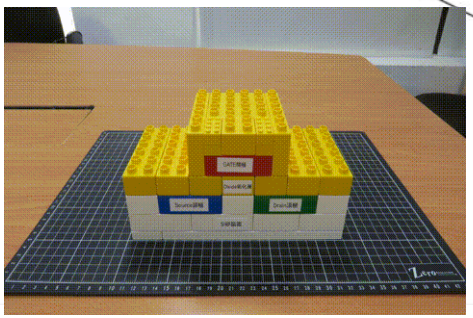




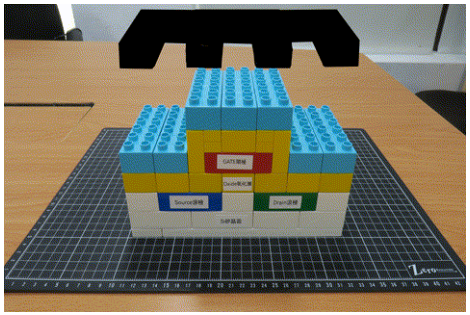
然後再次將表面形成絕緣氧化層。
接著要在三個極上面開井窗，
讓金屬導線可以接入。

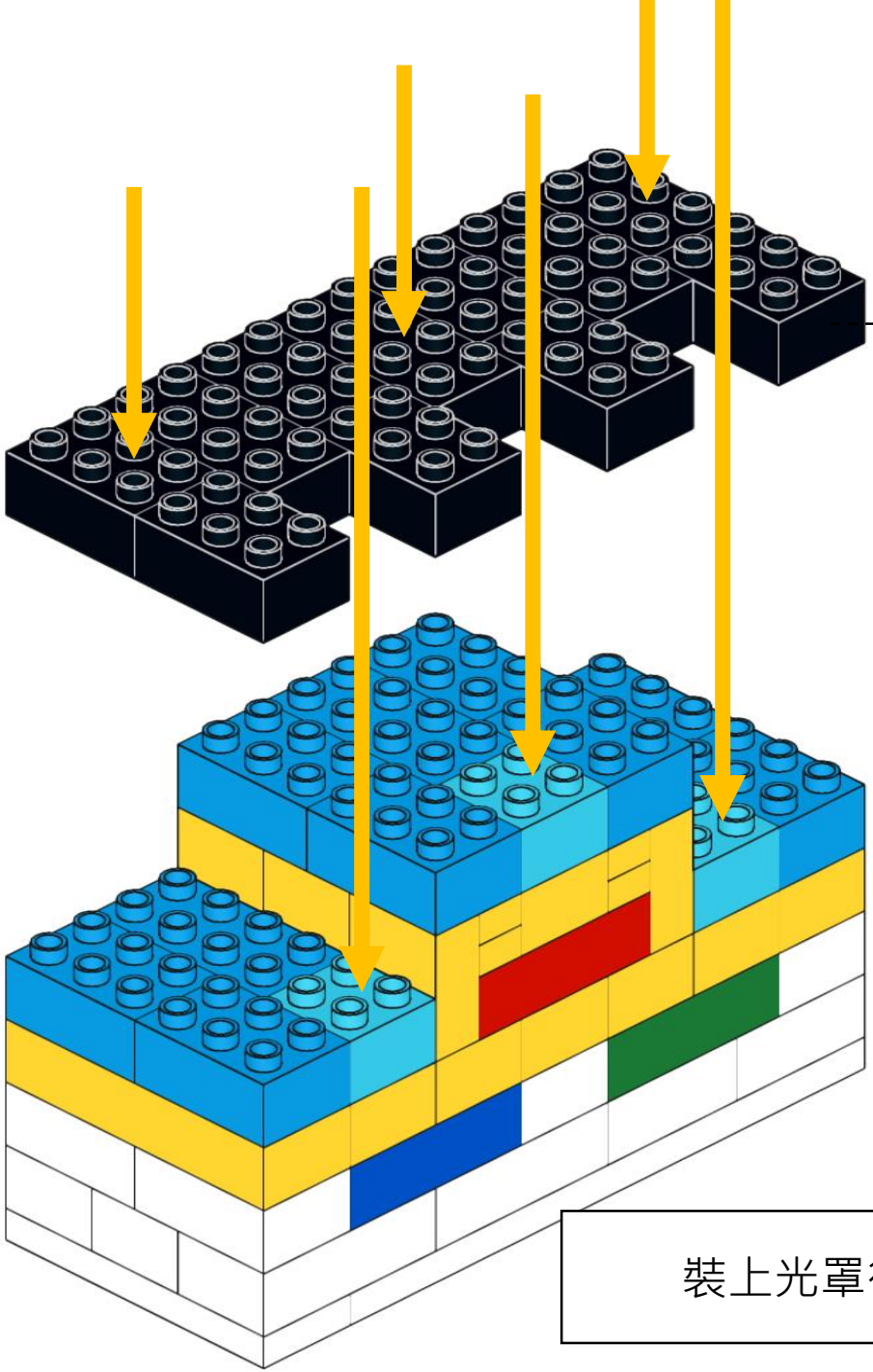




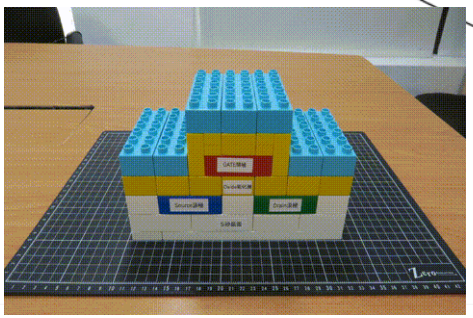


一樣塗抹光阻劑，並**軟烤**。
以利在這三個極上各開一個洞(通道)，

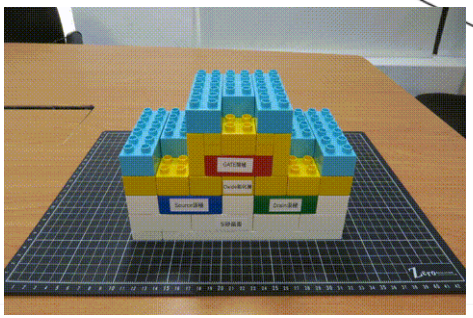




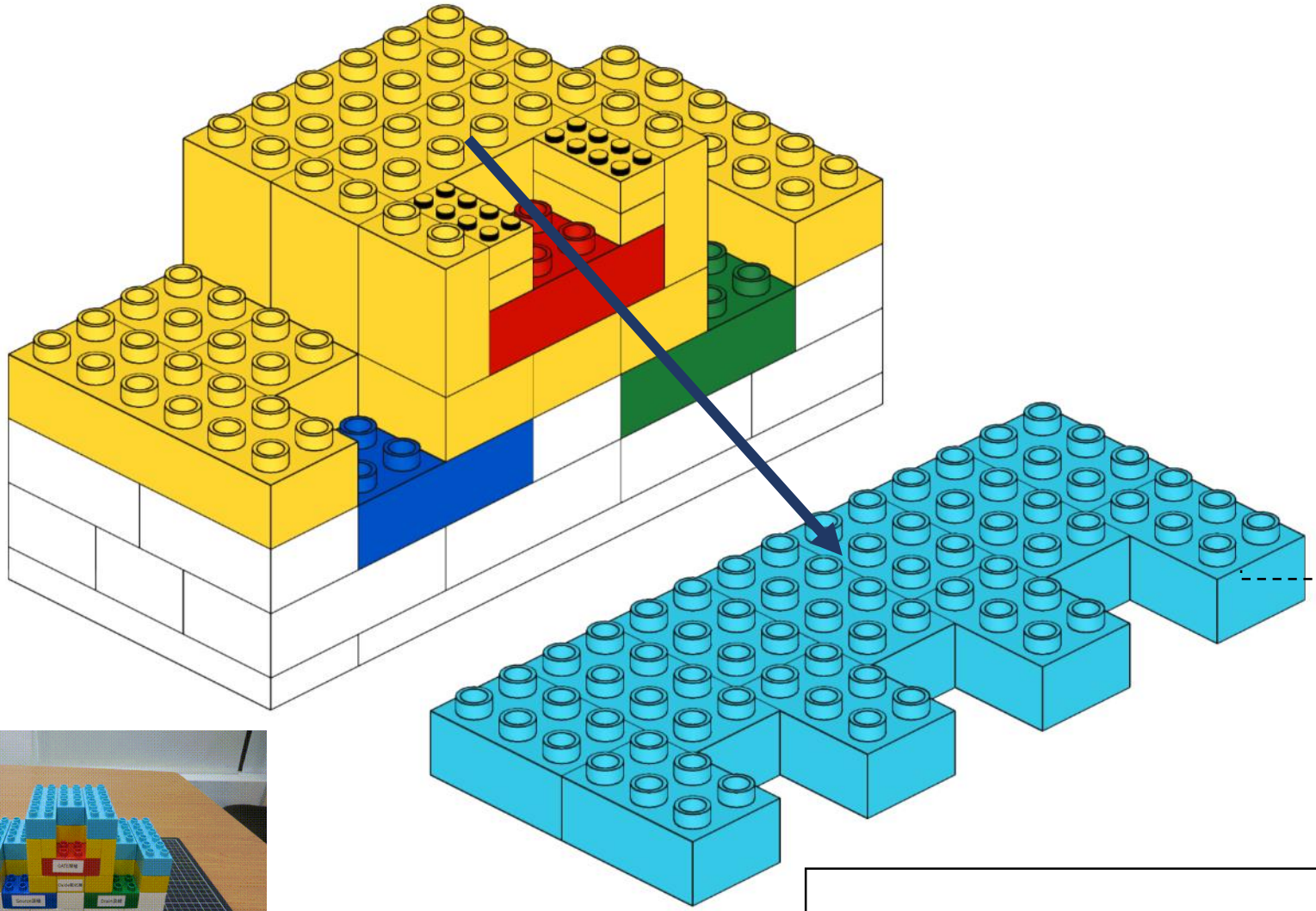
裝上光罩後，進行**曝光**。

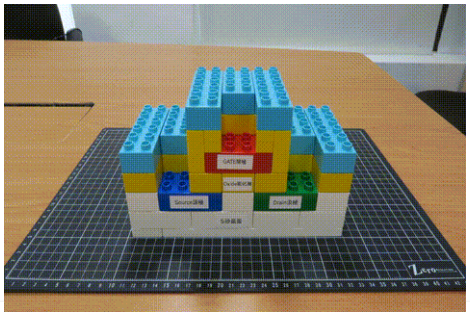


被曝光到的光阻劑會被沖洗掉，
並進行**硬烤**。

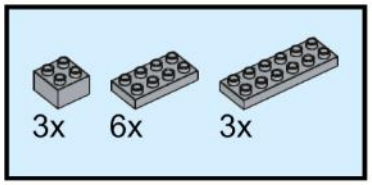


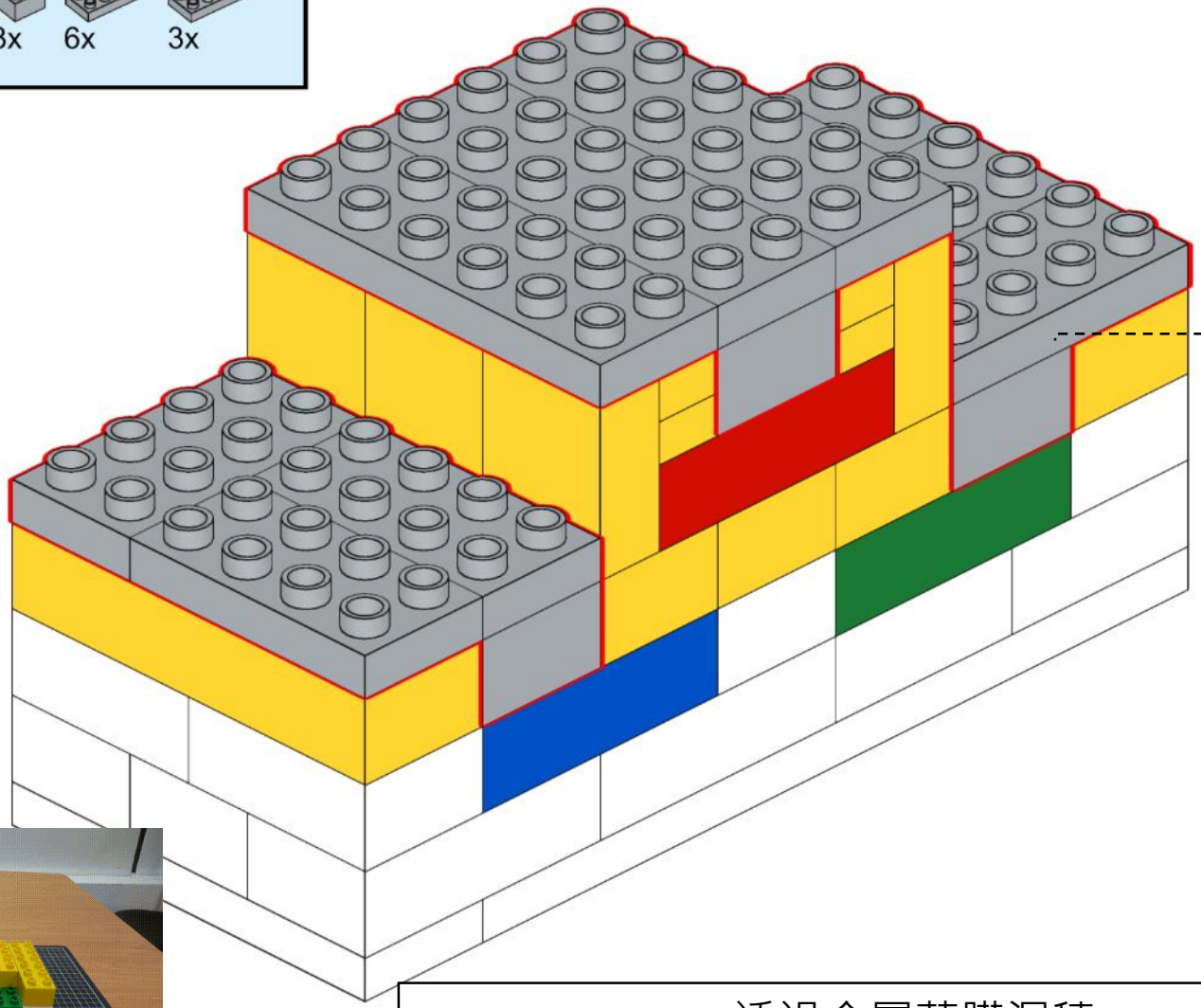
接著進行**蝕刻**，
將下方的氧化層去除，
如此就可以開出井窗。

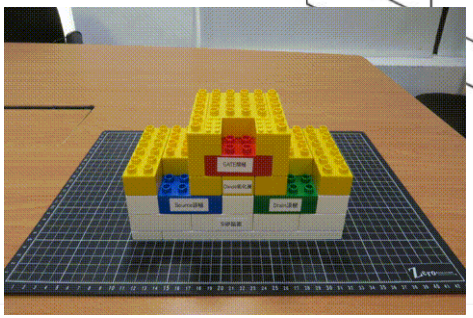




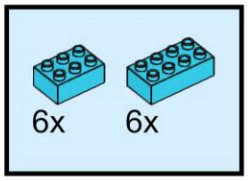
剩餘的光阻一樣去除掉。

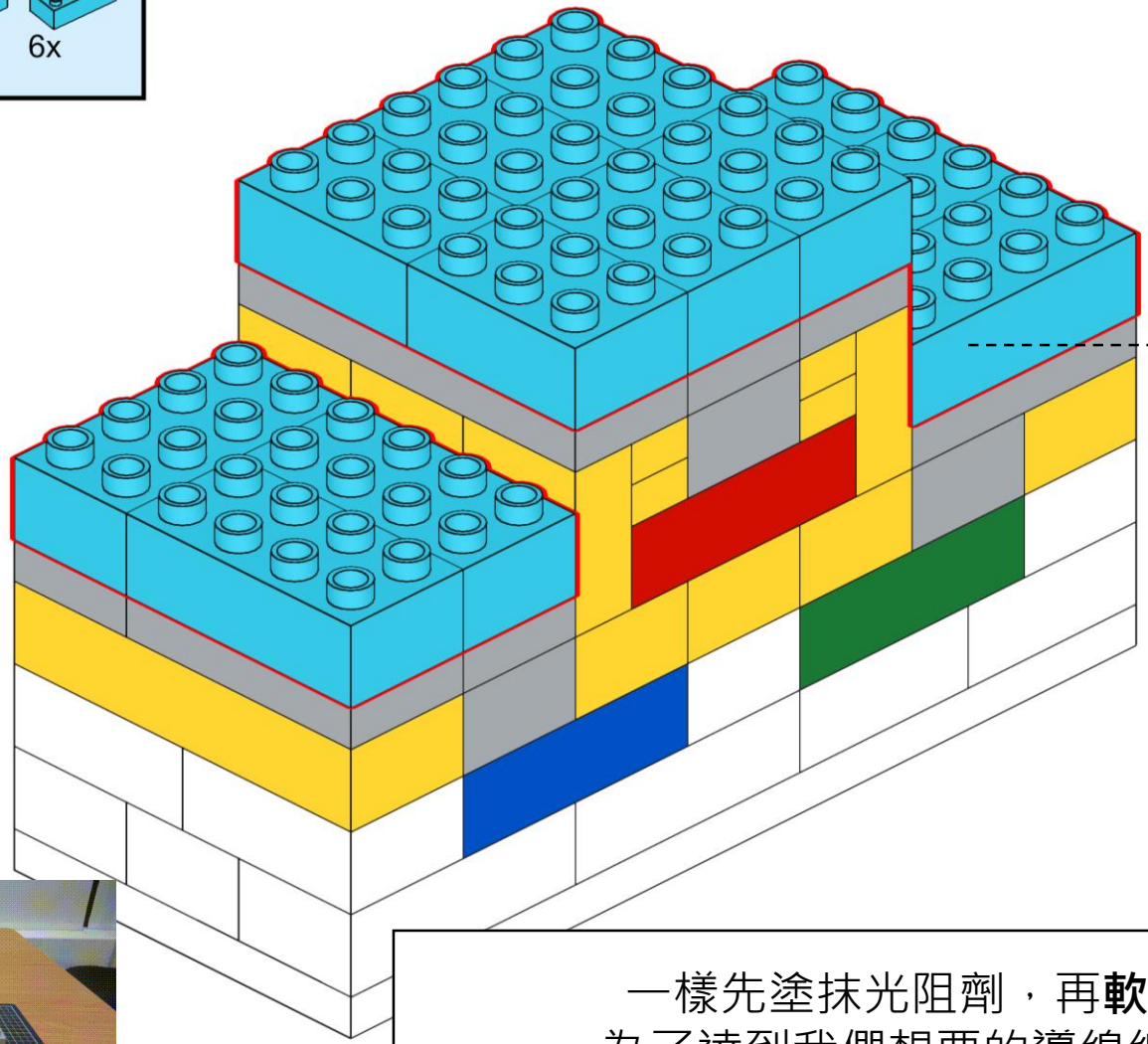


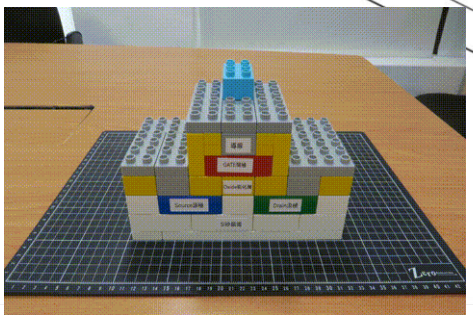




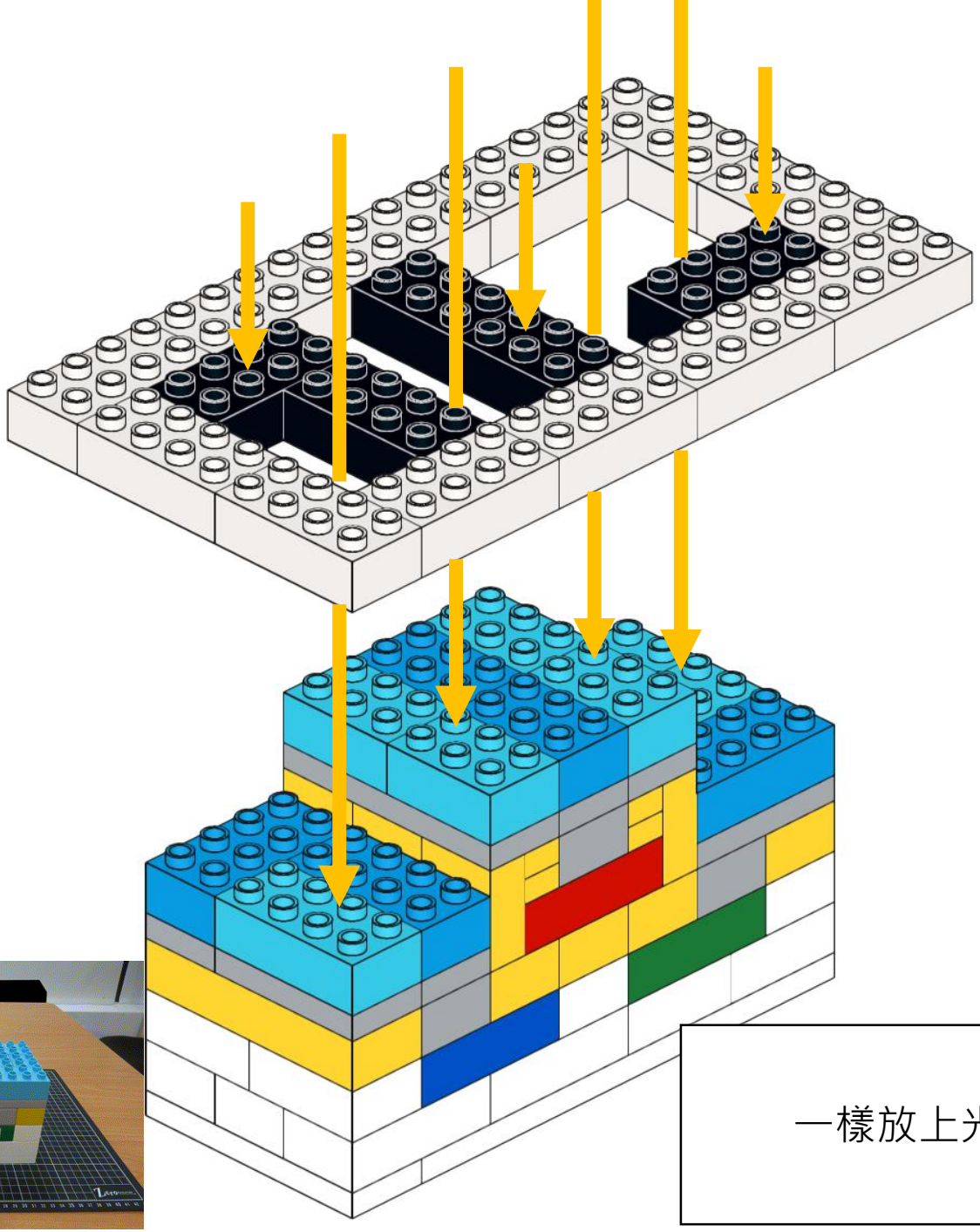
透過金屬薄膜沉積，
在表面形成金屬薄膜(像是鋁) 。

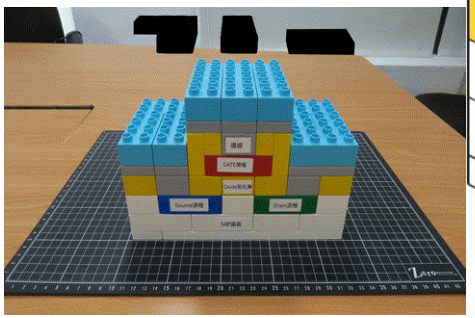




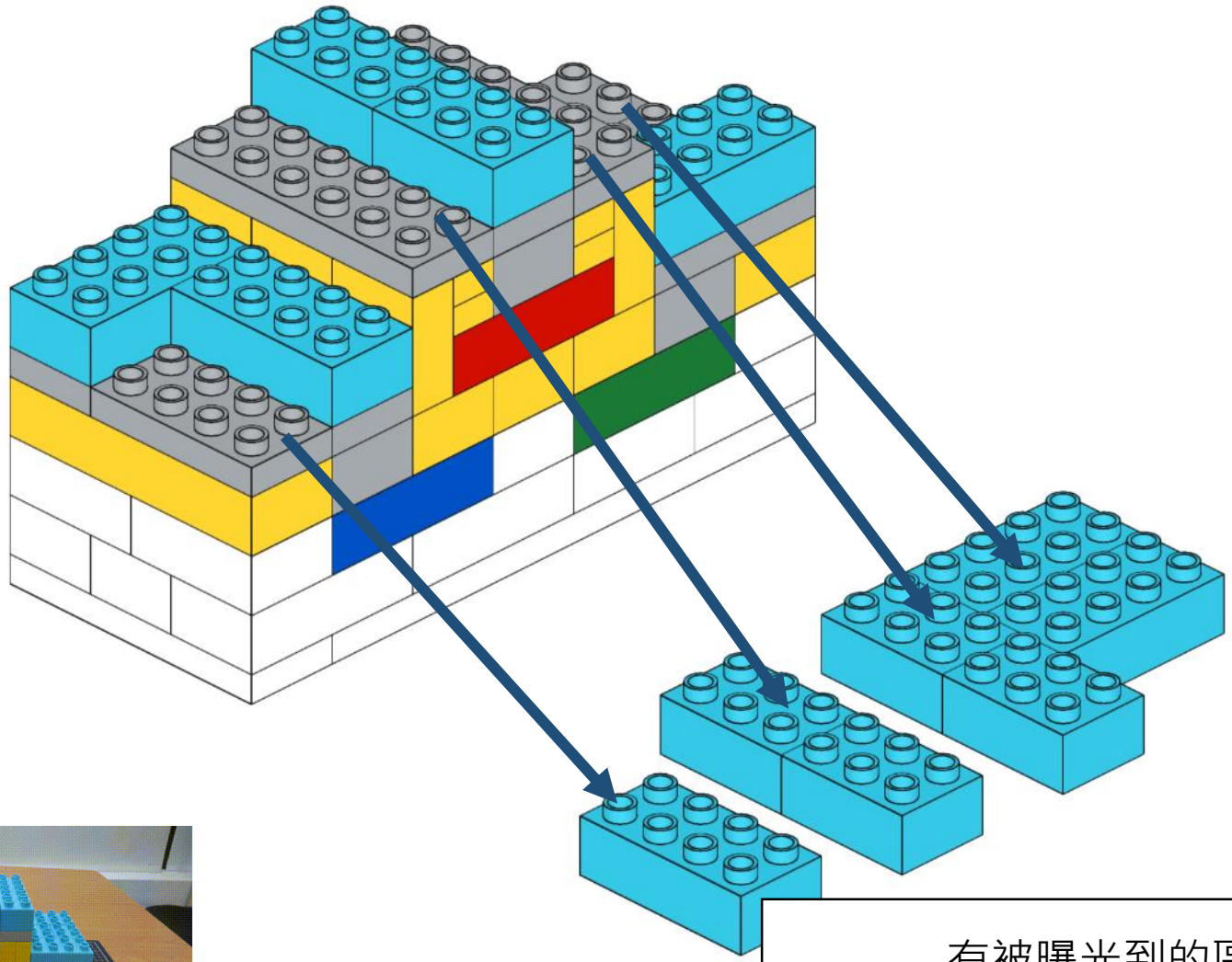


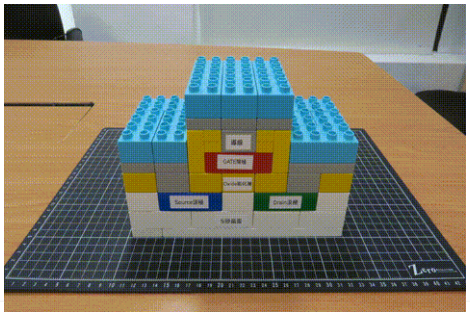
一樣先塗抹光阻劑，再**軟烤**。
為了達到我們想要的導線線路，
所以也需要利用蝕刻來達到我們想要得圖案(線路)。



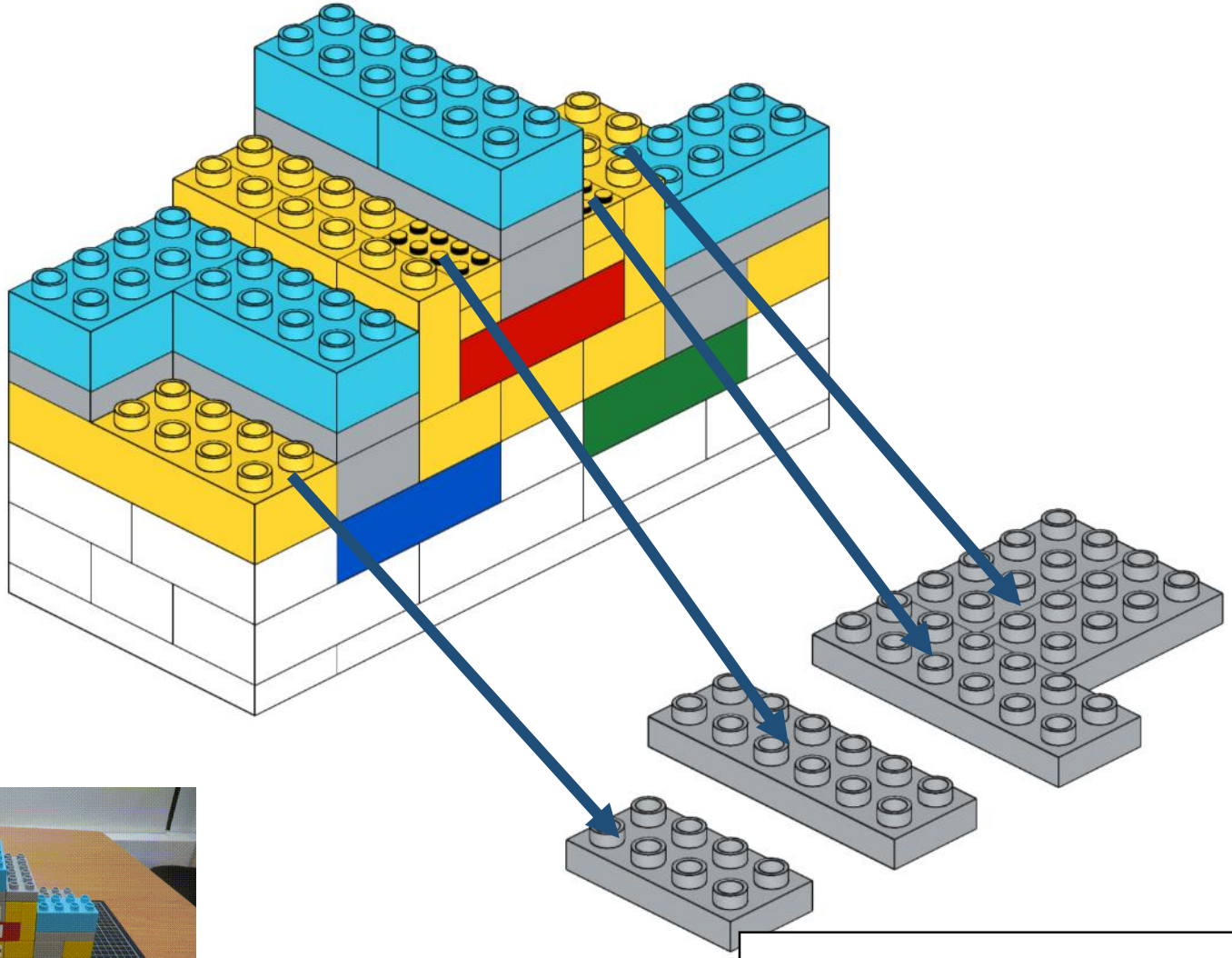


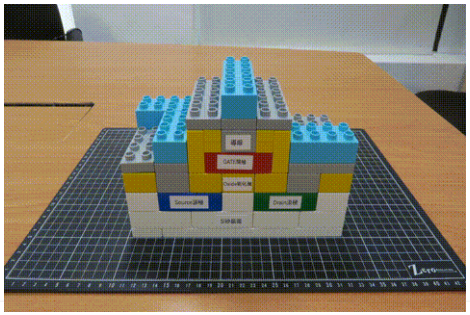
一樣放上光罩後並曝光。



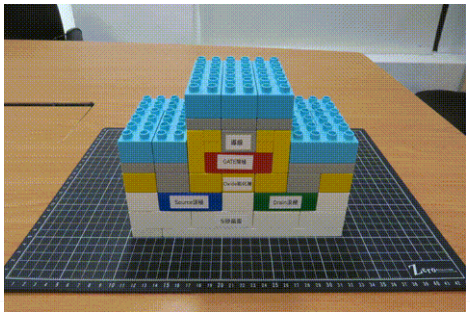


有被曝光到的區域
可以被顯影劑沖洗掉。
並進行**硬烤**。

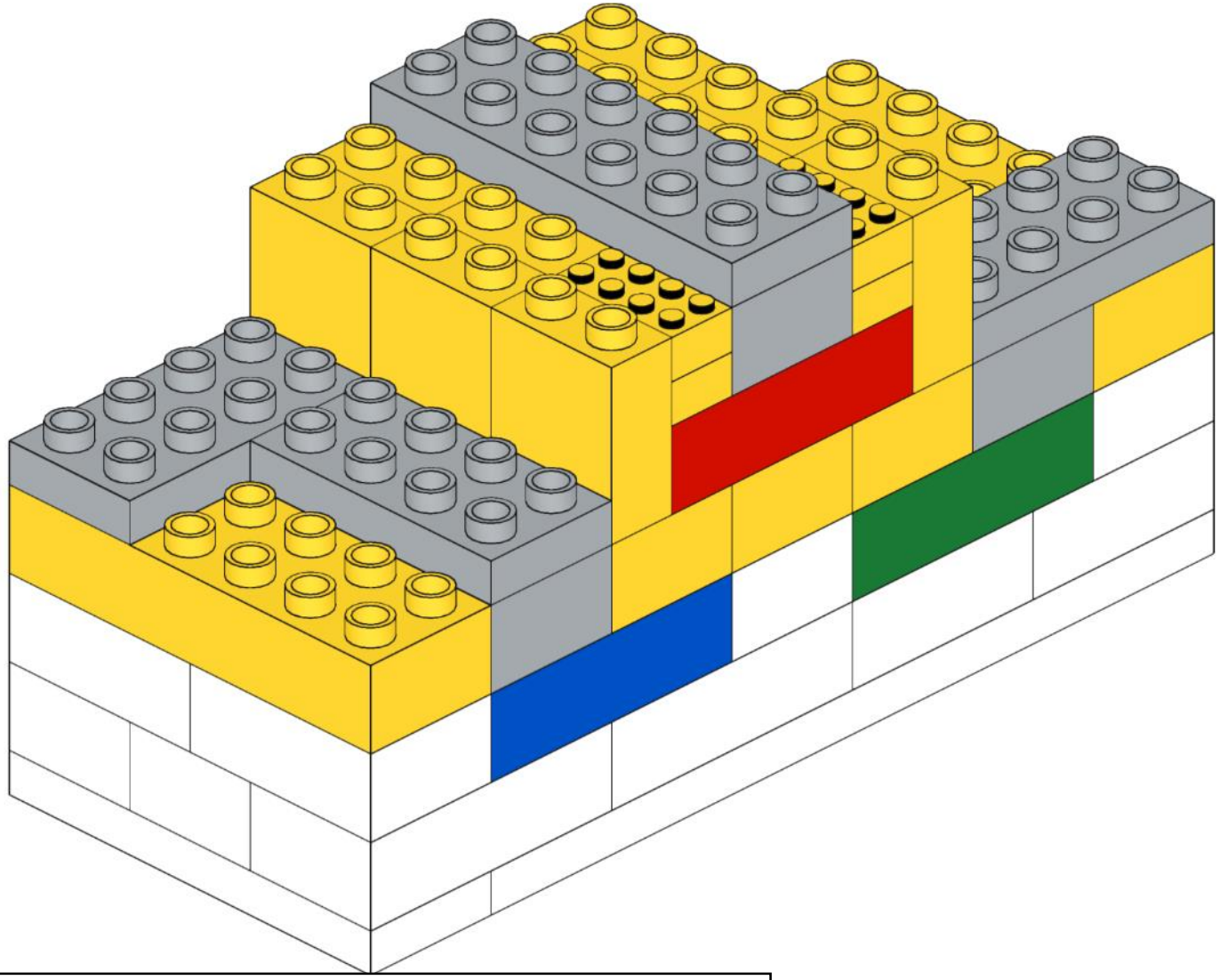




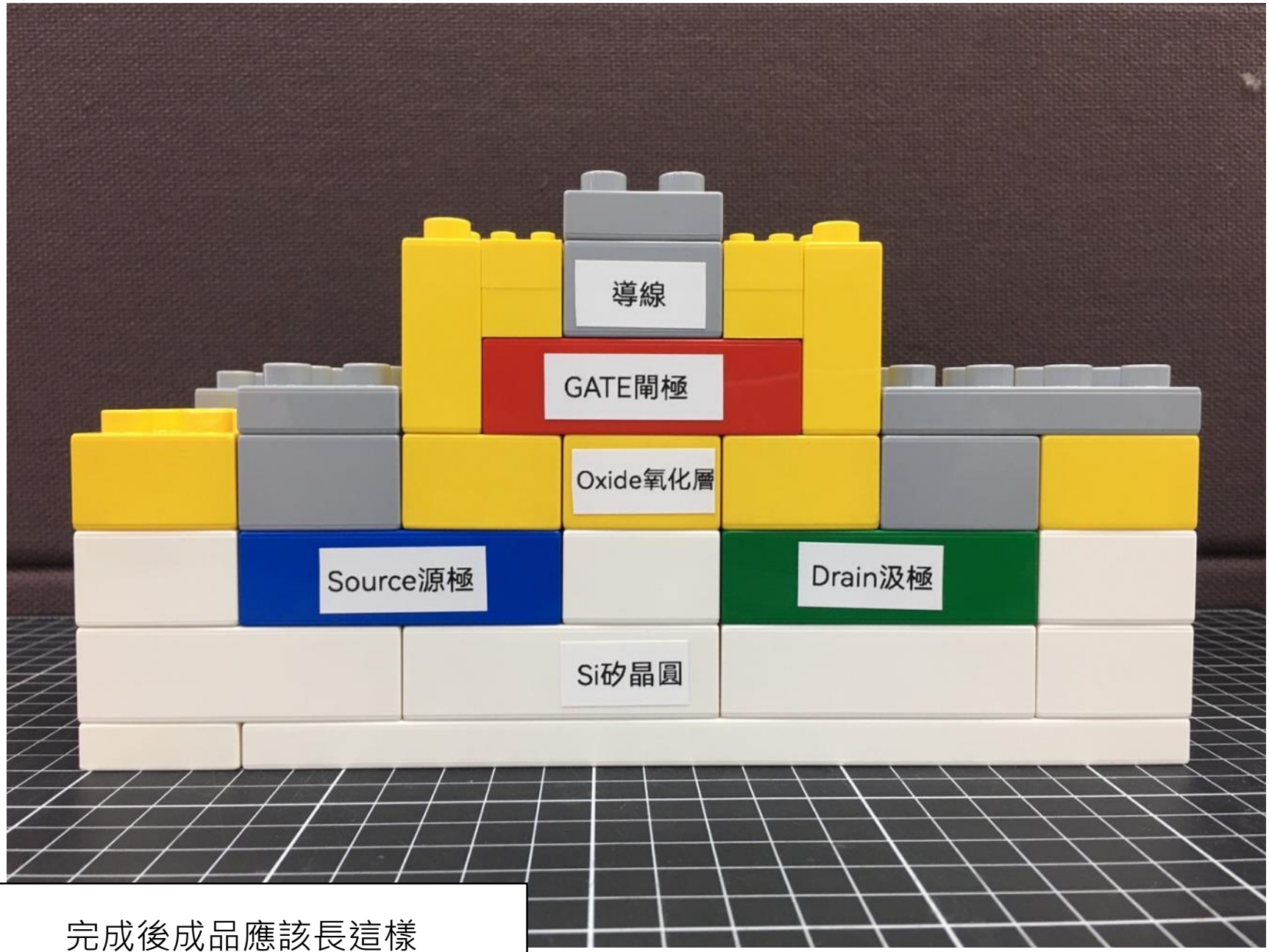
接著**蝕刻**掉不需要的金屬薄膜。



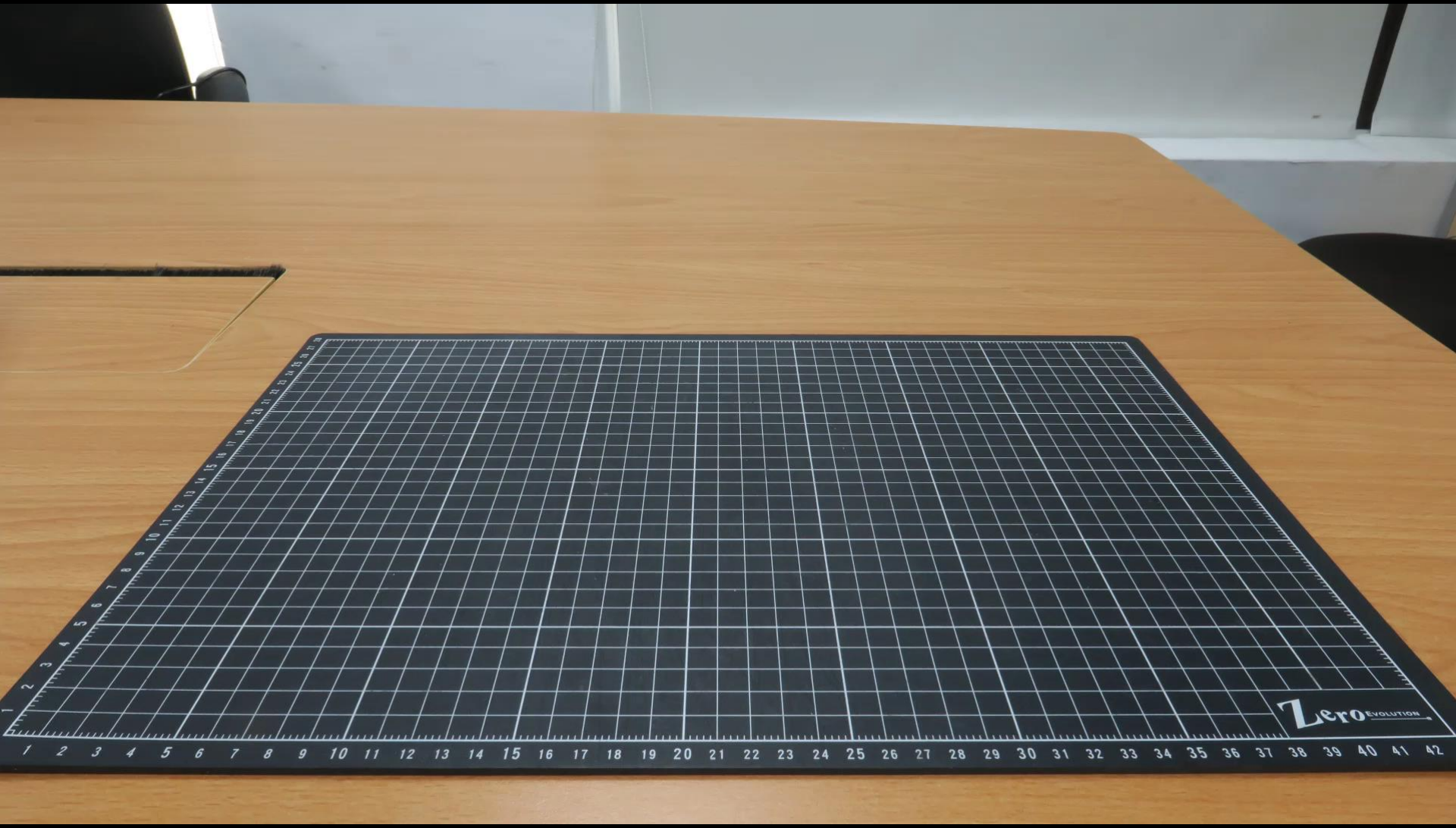
剩餘的光阻劑一樣去除掉。



這樣就完成了一個半導體元件 – 場效電晶體了！



完成後成品應該長這樣



YT link: https://youtu.be/gnieAZq_-Gc

Thank you for your attention.